Soil Brief CN 7

# PEOPLE'S REPUBLIC OF CHINA

## Reference soils of tropical China (Hainan Island)

J.H. Kauffman
Wang Minzhu
Zhang Bin

ISRIC

Institute of Soil Science - Academia Sinica

International Soil Reference and Information Centre

ISSAS

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# Reference soils of tropical China (Hainan Island)

ISRIC Soil Monoliths:

| *Number* | *FAO (1988)* | *Soil Taxonomy (1992)* |
|---|---|---|
| CN 17 | Haplic Acrisol | Typic Kandiudult |
| CN 18 | Geric Ferralsol | Anionic Acrudox |
| CN 19 | Haplic Acrisol | Typic Kandiudult |
| CN 20 | Haplic Acrisol | Typic Hapludox |

J.H. Kauffman
Wang Minzhu
Zhang Bin

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ISRIC
P.O. Box 353
6700 AJ Wageningen
The Netherlands

ISSAS
P.O. Box 821
Nanjing
P.R. of China

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PHOTOGRAPHS

# ABSTRACT

Four representative soils, located on Hainan Island, were studied for the establishment of a Chinese soil reference collection and pedon database. Description and sampling were carried out within the framework of a programme of co-operation between the "Institute of Soil Science, Academia Sinica", People's Republic of China and the "International Soil Reference and Information Centre", Wageningen, The Netherlands. A short environmental inventory of Hainan Island, comprising a general description of the landscape, geology, vegetation and land-use, including a study of water-balances, variability of precipitation and temperature diagrams of three meteorological stations, precede the soil descriptions and analyses.

According to the Köppen climate classification, Hainan island belongs to a tropical rainforest climate (Af), except for part of West Hainan which is drier and belongs to a tropical deciduous forest or savanna climate (Aw). Its main characteristics are a high temperature with small diurnal range and in comparison to the rest of China, a small annual variation. Precipitation occurs in a long monsoon rainy season and there is a relative short dry season.

Of the four soils studied, three are from low altitude zones and one from a high altitude zone in the Central Mountain region of Hainan.

The first soil (West Hainan, CN 17) is a very deep, well drained, reddish brown sandy clay loam derived from granite. It is a well rooted, highly porous soil. The soil is classified as Haplic Acrisol.

The second soil (West Hainan, CN 18) is a very deep, well drained, dark reddish brown clay derived from basalt. The soil has a very uniform morphology, has many roots and has a very high porosity. The soil is classified as Geric Ferralsol.

The third soil (Central Mountains, CN 19) is a shallow to very deep, well drained, yellowish brown sandy clay derived from granite. It has a distinct black topsoil over a bright yellowish subsoil and the soil depth ranges from shallow to very deep, depending on slope gradient and position in the landscape. The soil is classified as Haplic Acrisol.

The fourth soil (East Hainan, CN 20) is very deep, well drained, bright reddish brown coarse sandy loam derived from acid igneous rock. The deeper subsoil is strongly mottled. The soil is classified as Haplic Acrisol.

All three lowland sites are suitable for tree crops such as rubber, coffee and various tropical fruits. The potential for the sustainable growing of annual crops is limited, mainly, because of the (very) poor plant nutrient status of the soils. Tree crops and agroforestry techniques are recommended. An assessment of major land qualities has been made, and the major constraints for agriculture at the three lowland soils are:

- the occurrence of typhoons
- the occurrence of temperatures below 0°C (although rare and restricted to northern Hainan,
- a (very) low availability of plant nutrients, a (very) low capacity for nutrient retention, strong soil acidity and the moderate to high level of toxic exchangeable aluminium.

The potential of the high altitude soil is restricted mainly to forestry, because of the very steep slopes on which it occurs.

# 摘 要

为建立中国土壤样品参比库和土壤剖面数据库，四个典型土壤剖面采自海南岛地区。该项目在欧共体STD2项目资助下，由中国科学院南京土壤所和荷兰国际土壤信息参比中心合作实施。本册中除了提供有详细的土壤描述和分析资料外，还有概略的环境背景材料，包括地形景观，地质，植被和土地利用以及三个气象站的水分平衡、降雨和温度图示。

按照柯蓬气候分类体系，海南岛除西部较干旱属于热带稀树草原气候（Aw）外，其他的属于热带雨林气候（Af）。其主要特征表现在高温短昼，同其他地方相比，年变异小。降水出现在长季风雨季而干燥期短。

四个土壤剖面中，三个采自低海拔地区，另一个采自海南中部山区高海拔地。处于海南西部的第一个剖面，土层非常深厚，排水良好，红棕色砂粘壤土发育于花岗岩。土壤中根系和孔隙密布。该土壤分类为普通强酸土（FAO，1990）。海南西部的第二个剖面，土层非常深厚，排水良好，暗红棕色粘土发育于玄武岩。土壤形态全剖面均一。土壤中根系和孔隙密布。该土壤分类为强风化铁铝土（FAO，1990）。采自中部山区的土壤剖面，土层深浅不一，排水良好，黄棕色砂粘壤土发育于花岗岩。地表具有一明显的黑土层覆盖在亮黄色的亚土层上，而土层深浅取决于地形部位和坡度。该土壤分类为普通强酸土（FAO，1990）。

# FOREWORD

The objective of a Soil Brief is to provide a description of a reference soil for a specific agro-ecological zone. The Soil Brief is composed of a text with data annexes.

The text includes graphical presentations and provides a description and discussion of the major characteristics of the soil, its classification, an evaluation of its soil/land qualities, and attention is given to special topics such as erosion, and soil formation. Comprehensive data available from field, laboratory and office work are presented in annexes.

The Soil Brief is written both for soil scientists and other interested people. For the latter the comprehensive information in the annexes is often too detailed and therefore would require further explication in the text. For the soil scientist the text part can be helpful as it summarizes the important land and soil qualities, relevant aspects of soil management and processes of soil formation. Furthermore, it provides access to additional information about research and discussions which cannot be stored in the computerized database.

This report is result of the joint research programme of ISSAS and ISRIC in the framework of the Science and Technology for Development Programme (STD2) of the European Community, contract No. TS2* -CT91-0336. The "Establishment of a soil reference collection and pedon-database for the classification and assessment of soil/land" forms part of this project. In 1992 the Institute of Soil Science of the Academia Sinica (ISSAS) and the International Soil Reference and Information Centre (ISRIC) described and sampled four reference soils from Hainan Island for the establishment of a Chinese soil reference collection and pedon database at ISSAS. Duplicates of these soils were collected for ISRIC's world soil collection. In this Soil Brief the four reference soils are presented.

Support for the fieldwork was received from the Department of Tropical Crops, South China College (SCATC) in Baodao Xincun, Hainan. The ISSAS/ISRIC team was accompanied during the field study by Prof. Liang Jixing, soil scientist of SCATC. With his long experience of Hainan Island, he was able to contribute much to the final selection of the sites to be studied. Messrs. Zong Hai Hong and Liu Dong Zhen contributed to the laboratory work in the Ecological Experimental Station of Red Soils in Yingtan.

Valuable comments on draft versions of this report were received from ISSAS and ISRIC staff. Soil analytical work was carried out at the soil laboratories of ISSAS and ISRIC. The editing and final lay-out of the document was done at ISRIC with contributions of E.M. Bridges (editing), W.C.W.A. Bomer (cross-section), M.B. Clabaut (text processing) and J.W. Resink (map compilation) and R. Smaal (diagrams).

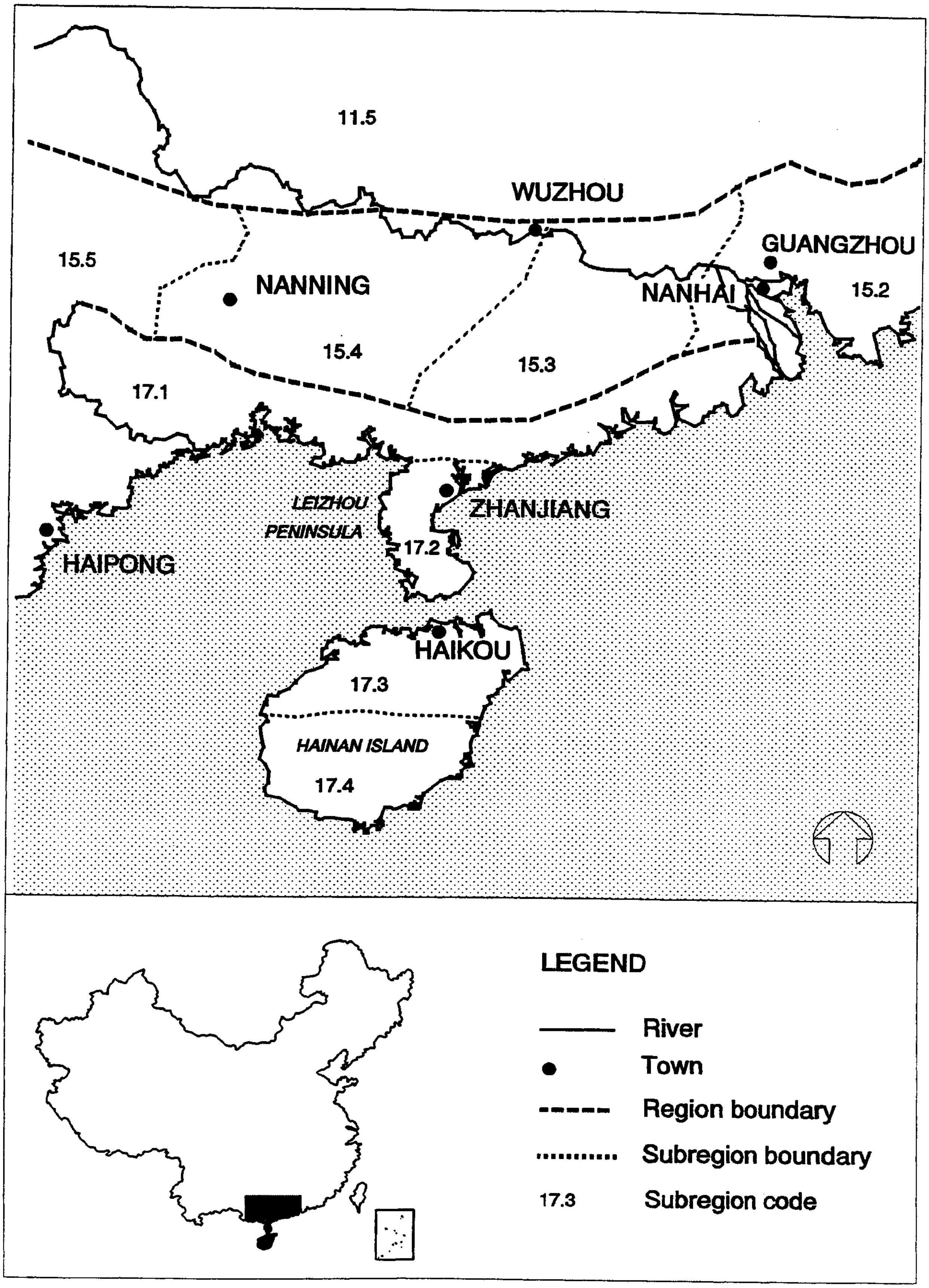



**Figure 1** Physiographic map of South-East China.

# 1 THE MAJOR ECOLOGICAL REGIONS OF HUMID TROPICAL SOUTH EAST CHINA

The climate of south-east China is described as humid tropical in the Physical Geography of China by Songqiao (1986). In this chapter a short characterization of the four main divisions of Humid Tropical South China is given. The sub-region designations 17.1 to 17.4 in figure 1 are also taken from Songqiao (1986).

- Coastal plain of Southwestern Guangdong and Southern Guangxi (17.1)
- The Leizhou Peninsula (17.2)
- Northern Hainan Island (17.3)
- Southern Hainan Island (17.4)

The coastal plain of Southwestern Guangdong and Southern Guangxi is mainly composed of plains and terraces with an altitude below 100 m, interspersed with low hills. It is located on the northern margin of the humid tropical zone. Natural limitations are: occurrence of frost (rare), spring drought, summer floods, typhoons and soil erosion caused by the removal of natural vegetation since ancient times.

The Leizhou Peninsula with an overall elevation below 100 m is mainly composed of basalt terraces (43%), marine terraces (27%) and alluvial plains (17%), while the rest consists of volcanic cones, sandy beaches and other unspecified plains. The natural limitations are similar to the coastal plain of Guangdong. However, irrigation has created already a larger potential for agriculture and extensive re-afforestation has occurred.

The sub-region of northern Hainan Island is composed of extensive basalt and granite platforms with an overall elevation below 300m. The low alluvial plain is mainly restricted to the middle and lower reaches of the Nandu river. Natural limitations are comparable to the Leizhou Peninsula.

The southern Hainan Island sub-region occupies about 55% of the total land area of the island. It is composed of medium to high mountains with elevation over 800m, low mountains (500-800m), hills (250-800m), inter-montane basins and coastal fringes with an elevation below 250m. Temperature and rainfall depend on elevation. The area's topography gives some protection, so the devastating results of typhoons are restricted. Extensive deforestation has taken place on the lower hills. Above 500 m, a montane forest prevails, although nature conservation practices are regarded as necessary to ensure its preservation.

# 2 HAINAN ISLAND

## 2.1 Climate

According to the Köppen climate classification, Hainan island belongs to a tropical rainforest climate (Af), except for a part of West Hainan which is drier and belongs to a tropical deciduous forest or savanna climate (Aw). Its main characteristics are a high temperature with small diurnal range and in comparison to the rest of China a small annual variation. There is a high precipitation in the long rainy season and a relative short dry season.

The meteorological stations Na-Da, Qiongzhong and Lingshui are representative of the sites of profiles CN 17, 18, 19 and 20 (for location, see fig. 1). From these stations, sufficient data are available to construct climatic diagrams showing average monthly precipitation, evaporation and temperatures. The data for these diagrams and of other climatic elements are given in Annex 1 - Soil and environmental data sheets. In addition data of Haikou meteorological station are given in annex 1, because site CN 18 has a climate which is intermediate between taht of Na-da and Haikou.

In addition to the measured (Chinese standard) pan evaporation data, the Potential Evapotranspiration (PET) is calculated according to Penman Monteith (FAO, 1991) and given in annex 1. The measured pan evaporation data are about 30 to 50 % higher in comparison to the PET Penman-Monteith data. For world-wide comparison, the PET Penman-Monteith data are used in the Precipitation - Evapotranspiration diagrams.

The Precipitation - Evapotranspiration diagrams of meteorological stations Na-Da, Qiongzhong and Lingshui (fig. 2, 3 and 4) show a rainy season from April to November. The dry season extends from December to March.

The total Leaching Rainfall (LR), the surplus of rainfall percolating through the soil, is high. The LR for the lowland sites CN 17, 18 and 20 is 500 to 600 mm. For site CN 19 in the mountainous region, the LR is 1400 mm. The high LR indicates the need for good soil drainage for upland (non-rice) crops.

The rainfall deficit during the dry season from December to March is 100 mm in the mountains (Qiongzhong) and in the lowland ranges from 200 mm at Nada to 400 mm at Lingshui. The seasonal shortage of rainfall indicates the need for supplementary irrigation.

Monthly and annual precipitation data over a period of about 30 years are plotted in two diagrams to show their variation.

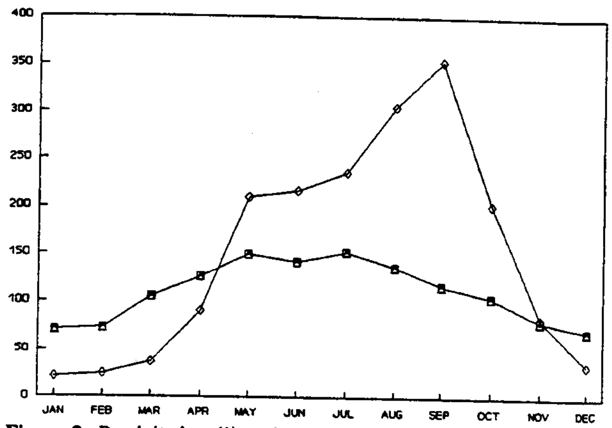



**Figure 2** Precipitation (◊) and evapotranspiration (□) in mm at Na-Da city, corresponding to sites CN 17 and CN 18.

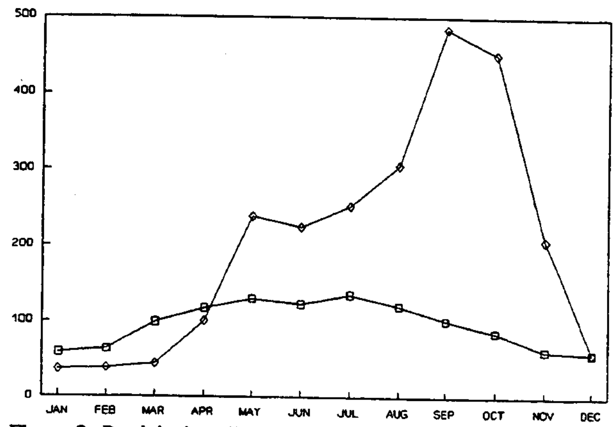



**Figure 3** Precipitation (◊) and evapotranspiration (□) in mm at Qiongzhong city, corresponding to site CN 19.

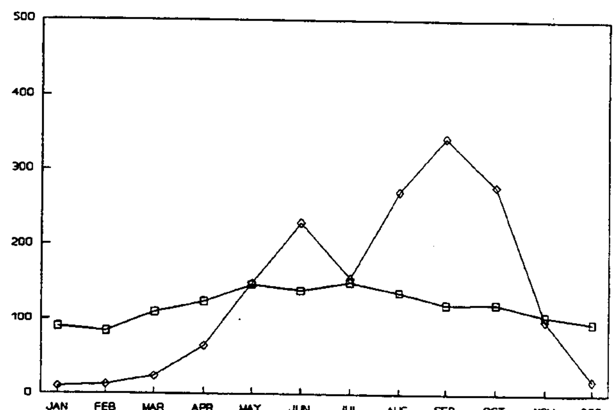



**Figure 4** Precipitation (◊) and evapotranspiration (□) in mm at Lingshui, corresponding to site CN 20.

The annual precipitation ranges in most years from 1400 - 2100 mm, with extreme values of 1150 and 2300 mm (see figure 5).

The diagram of montly precipitation, see figure 6, shows the large range during the rainy season. The maximum monthly rainfall can be as high as 500 mm and the minimum slightly below 100 mm. The diagram shows that rainfall is seldom less than the Potential Evapotranspiration (PET). In about 95 % of all plotted months, the rainfall exceeds PET.

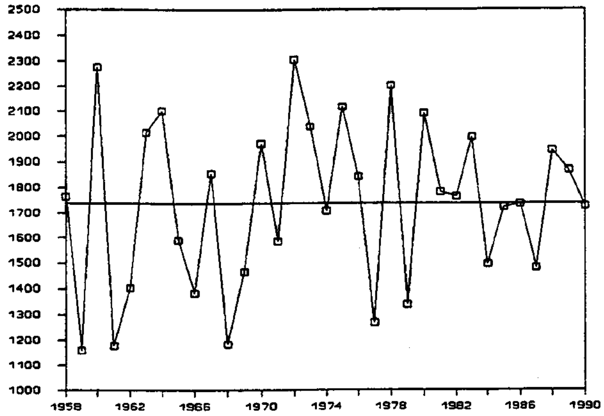



**Figure 5** Annual precipitation of Nada meteorological station over the period 1958 - 1990.

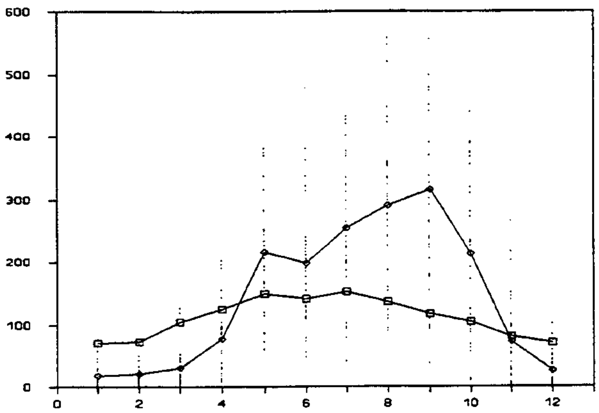



**Figure 6** The range of monthly precipitation data (.) in mm during the period 1958 - 1990. Average precipitation (◇) and evapotranspiration (□) are taken from figure 4.

Variations for annual and monthly precipitation are comparable for the other meteorological stations.

The variation of the maximum, average and minimum temperature over the year at three meteorological stations is given in figures 7, 8 and 9.

Although Hainan Island belongs to the tropical region of China, there is a still a minor risk of frost in the northern part of the island, which is not apparent from the average minimum temperatures shown in figures 7 to 9. Statistical details are given in ARC/TAST (1981), which gives information on the occurrence of other climatic limitations for agriculture such as typhoons and heavy storms. The highest risk is from typhoons, which generally occur in the summer and autumn seasons. Frequency of occurrence is 5.8 times/year, with the wind speed reaching a maximum level of 12 m/s. This has devastating consequences for agriculture. Therefore sites for rubber trees should be areas surrounded by protecting hills or mountains such as in Central Hainan.

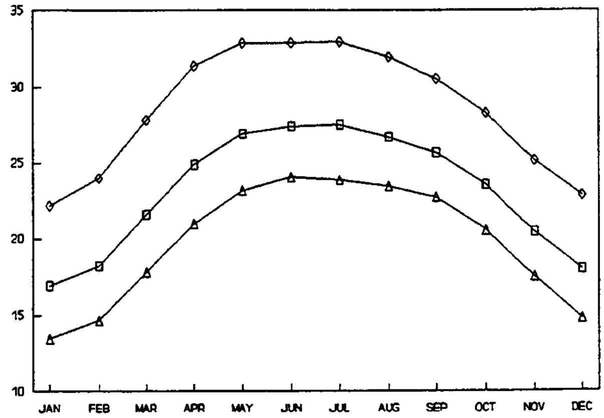



**Figure 7** Maximum (◇), average (□) and minimum (△) temperature in °C at Na-Da (site CN 17).

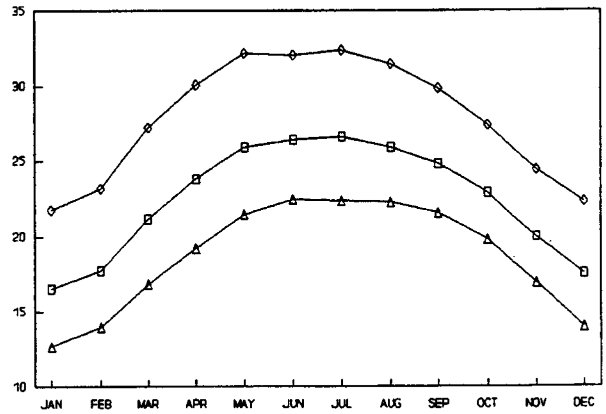



**Figure 8** Maximum (◇), average (□) and minimum (△) temperature in °C at Qiongzhong city (site CN 19).

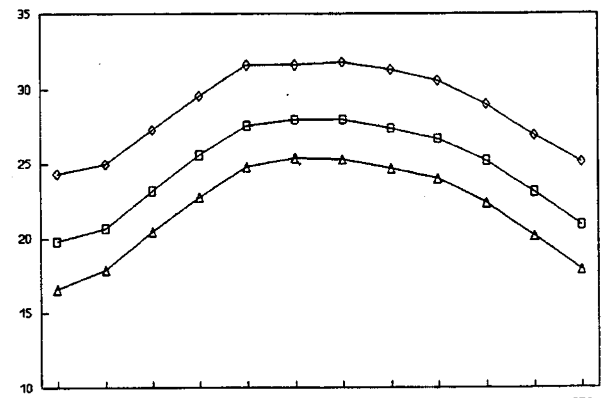



**Figure 9** Maximum (◇), average (□) and minimum (△) temperature in °C at Lingshui (site CN 20).

## 2.2 Physiography and Soils

Hainan Island can be sub-divided into a northern part (about 45 % of the Island) and a southern part (about 55%). The northern part is composed of extensive basalt and granite 'platforms' (planation surfaces) below 300m altitude. The profile CN 17 is located in the granite area and CN 18 in the basalt area.

The southern part of Hainan Island, located south of the line between Chanjiang and Qionghai, is composed of granite mountains with an elevation of more than 500 m, hills with an elevation between 250 and 500 m, and inter-montane basins and coastal areas below 250 m.

The Chinese Soil Classification System of 1978 is based on bio-climatic zones. Almost all low altitude soils in Hainan therefore are classified as Latosols. In the new Chinese Soil Taxonomy, based on soil properties (CSTC, 1992), only small areas belong to Latosols. The greater part belong to Latored soils and Red soils.

Parent material also determines the soil type. Latosols are often derived from basalt and Latored soils from granite, although there are exceptions.

The distribution of major soils of the Hainan Island is well known. A number of soil surveys have been completed by ISSAS in the 1950's and SCATC in the 1980's. The results of these surveys are summarized on the 1 : 500,000 soil map of Hainan (1985, compiled by SCATC).

The dominant soils and altitudinal zones shown on the 1:500,000 soil map are summarized according to the Chinese soil classification of 1986 and 1992, and of FAO (1988) in the following table.

| Altitude zone | CS (1978) | CSTC (1992) | FAO (1988) |
|---|---|---|---|
| High altitude | Mountain meadow | Shrubby meadow soil | Haplic Acrisol |
| Middle altitude | Yellow soil | Lato-yellow soil | |
| Low altitude | Latosol | Latosols, Latored | Geric Ferralsol, Haplic Acrisol |

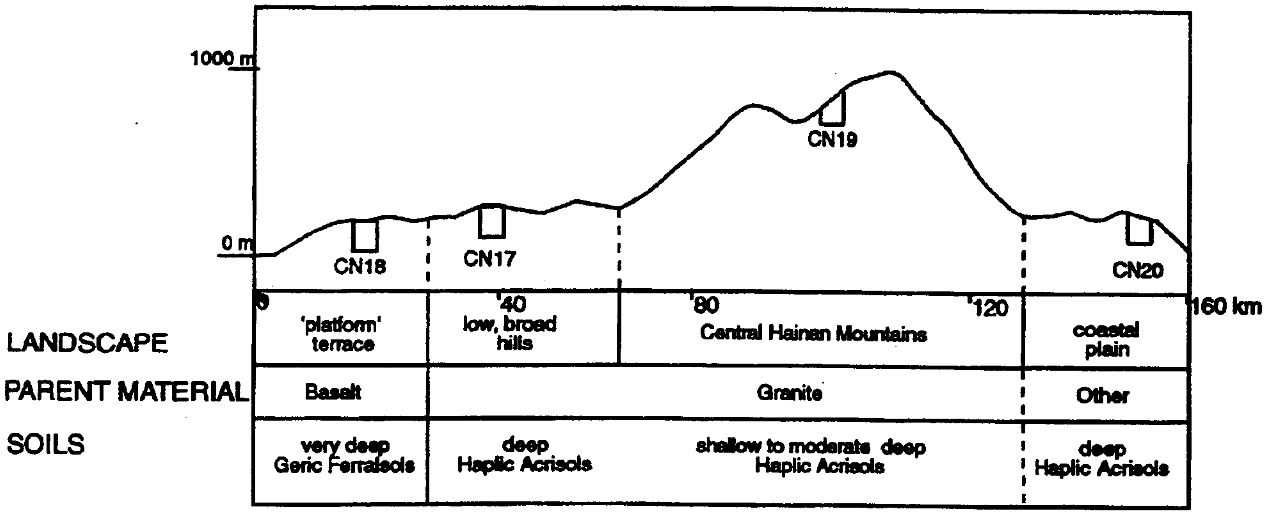



**Figure 10** Cross-section of Hainan Island with the location of sites CN 17 to CN 20.

# 3 REFERENCE SOILS CN 17, 18, 19 and 20

In this chapter, a selection of data and research information on reference soils CN 17, 18, 19 and 20 will be discussed. Comprehensive field and laboratory data are given in Annex 1 - Soil and environmental data-sheets, which were made with the ISRIC Soil Information System (ISIS, 1988). All diagrams presented in this Soil Brief have been made using SOLGRAPH (Brunt, 1994).

## 3.1 Location, landscape and land-use

In figure 10 an idealized cross-section (sketch) shows the geographic distribution and altitude range of the four sites.

The location of the sites CN 17 to CN 20 is given in figure 11 - Location map.

According to soil maps by SCATC (1985) and Liang Jixing (1988) the four selected sites are representative of the dominant soil types of Hainan island. CN 17, 18 and 20 are representative of the lower altitude planation surfaces. CN 20 is representative of the higher altitude Central Mountains of Hainan Island.

*Profile CN 17*
The 1:500.000 soil map by SCATC (1985) indicates that soil profile CN 17 is located in the largest map unit, i.e. a Latosol derived from granite, the dominant rock type of Hainan Island. CN 17 is a reddish-brown clayey soil, located on a Pleistocene erosion terrace. The altitude of the landscape is about 150 m. The landscape has a plain-like appearance and consists of very low broad hills. CN 17 is located on an upper slope of a such a hill. On the lower slope, where the transition towards the flat valley bottom occurs, soil colour becomes more yellow and the subsoil strongly mottled. The original deciduous tropical forest was cleared a long time ago and extensive interfluve areas have been planted with rubber trees (Hevea). In addition, sugar cane is grown and in the valleys, rice.

Besides the reddish-brown clayey soil of CN 17, other variations of soil colour and texture type exist, a light grey sandy loam to loamy sand soil was observed during the field trips. When this grey soil is located at the lower part of the soil toposequence (catena), the soil colour is caused by groundwater influence. However, the grey soil type may also occupy the upper slopes, in which case the soil colour and texture is probably mainly determined by the parent rock, a coarse acid granite type.

*Profile CN 18*
Site CN 18 is located on the basalt coastal plain a terrace-like 'platform' with an altitude of about 150m. The landscape has a flat topography. The soil of site CN 18 is a 'type locality' for the very deep dark red clay soils derived from the basalt plains with an extensive area in the northern part of Hainan island. The original tropical rainforest was cleared for rubber trees about 30 years ago.

*Profile CN 19*
Site CN 19 is located in a mountainous area, consisting of coarse-grained, acid igneous rock. The altitude is about 770 m. The soil of site CN 19 is representative of large areas in the Central Hainan mountain region. The soil studied is a deeply developed one. However, field observations indicate that there is a large variation in soil depth. The real soil depth (i.e. A and B horizons) down to the weathered granite may vary from very shallow to deep, depending on location in the landscape and degree of slope. The original natural vegetation, a dense evergreen broad-leaved forest, is still present at higher elevations.

*Profile CN 20*
Site CN 20 is located on an erosion terrace, cut into granite, with an altitude of about 40 m. The soil of site CN 20 is representative of the east coast marine erosion terraces. The landscape is nearly flat to weakly undulating. Hilly parts interspersed with large flat valley plains which merge towards the level coastal plains. The soil developed in the granite is not very deep, generally varying between 0.5 to 1.5 m. Field observations reveal that the weathered rock below the soil extends to great depth, 10 meters or more. The original rainforest was cleared for rubber trees and upland crops.

## 3.2 Soil characterization

Detailed descriptions of soil horizons to at least a depth of 150 cm, according to the *Guidelines for Soil Profile Description* (FAO, 1990) are given in Annex 1.
Soil samples were analyzed in soil laboratories at ISRIC and ISSAS according the procedures as described by van Reeuwijk (1993).
In the following paragraphs field and analytical information are summarized and special attention is given to selected key properties.

### 3.2.1 Brief field descriptions

*Profile CN 17*
Very deep, well drained, reddish brown sandy clay loam derived from granite. There are many roots and is a highly porous soil resulting from a high biological activity. The deeper subsoil contains soft, weathered granite fragments. Frequent man-made disturbances were

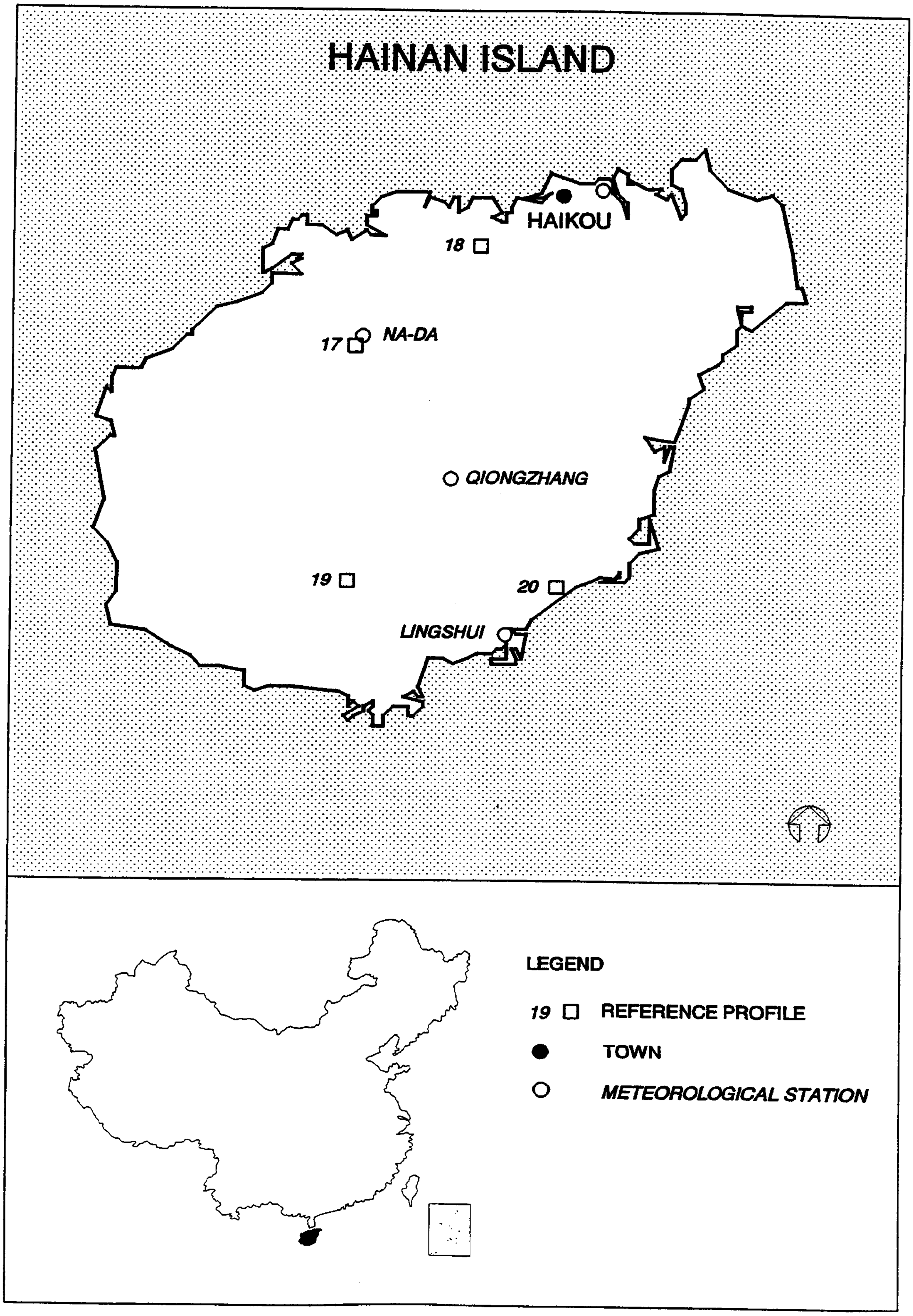



**Figure 11** Location map of soils and meteorological stations for sites of profiles CN 17 to CN 20.

observed in the topsoil, probably caused by management operations related to the present land-use of rubber trees (such as clearing of original forest, planting, terracing, weeding etc.).

*Profile CN 18*
Very deep, well drained, dark reddish brown clay derived from basalt. The soil morphology, such as colour, structure, is very uniform to a depth of at least 6 m. The soil has many roots of the rubber trees to about 3 m and it has a very high porosity resulting from a high biological activity (mainly termites were observed).

*Profile CN 19*
Very deep, well drained, yellowish brown sandy clay derived from granite. The soil has a distinct black topsoil over a bright yellowish subsoil. The soil depth to the weathered granite ranges from shallow to very deep depending on slope gradient and position in the landscape.

*Profile CN 20*
Very deep, well drained, bright reddish brown coarse sandy loam derived from acid igneous rock. The deeper subsoil is a strongly mottled saprolite (weathered granite). This material has a strong resemblance to plinthite or lateritic soils from e.g. SW-India. However, the material does not harden upon repeated drying and wetting and is therefore considered to be a 'pseudo-plinthite'. The soil texture is judged in the field to be a coarse sandy loam, however, laboratory analysis show a higher clay content and the texture is classified as a sandy clay.

Colour pictures of all four soil profiles are given on the central photo-page.

### 3.2.2 Brief analytical characterization

A summary of selected analytical properties, taken from annex 1, is presented in Table 1.

The percentage content of sand, silt and clay in all horizons of soils CN 17, 18, 19 and 20 are plotted on the textural triangle diagram in figure 12. The diagram shows that clay content varies considerably. Soil CN 18 has the highest content, whilst the other profiles are in the range of 30 to 40% clay. The silt content is low in all soils, 10 to 20%, which corresponds well with the low silt content generally found in strongly weathered tropical soils. The very high clay content of CN 18 is indicative of basalt, a basic parent material. The other soils have a higher sand content, in accordance with granite, being an acid parent material.

**Table 1** Key properties of soils CN 17, CN 18, CN 19 and CN 20

| | CN 17 | CN 18 | CN 19 | CN 20 |
|---|---|---|---|---|
| Clay | clay increases with depth (from 19 to 37%) in the upper 50 cm | very high clay content (80%) throughout, fine sand content less than 10% | clay increases with depth (from 27 to 42%) in the upper 80 cm | clay increases (from 33 to 45%) in the upper 110 cm |
| Organic Carbon | low (1%) in the topsoil | medium (1.5%) in the topsoil gradually decreasing with depth till 0.2% at 300cm | medium (1.7%) in first 25 cm, low (0.6) in subsoil | medium (1.6%) in the first 25 cm, low (0.4) in the subsoil |
| Acidity (pH-$H_2O$) | strongly acid (4.2 - 4.8) throughout | strongly acid (4.3 to 4.8) throughout | strongly acid (4.2 to 4,6) throughout | strongly acid bordering to extremely acid (3.9 to 4.1) |
| Sum of bases [cmol(+)/kg soil] | very low (0.1 - 0.5) throughout | very low (0.5 to 1.0) | low (1.2) in topsoil, very low (0.1 to 0.5) in subsoil | very low (0.1 to 0.7) throughout |
| Cation exch. cap. [cmol(+)/kg soil] | very low (1.5 - 3.5) throughout | topsoil low (6) and very low (1.8 to 2.3) in subsoil | low (6.2) in topsoil, very low (3.7 to 4.1) in subsoil | very low (2.8 to 3.8) throughout |
| Exchang. Aluminium | low to medium (15 - 40%) in the first 100 cm | low (15 to 30%) in topsoil, nil in subsoil | moderate (30 to 45%) throughout | moderate to high (40 to 60%) |
| Clay mineralogy | kaolinite dominant | kaolinite dominant, mixed with some chlorite | kaolinite dominant, mixed with small quantities of mica and chlorite | kaolinite dominant |
| Air capacity [$\phi$(pF0-pF2.0)] | medium (12) in the topsoil, low (7) in the subsoil | medium (13) throughout | very low to low (5 to 8) | no data, probably moderate |
| Available moisture [$\phi$(pF2.0-pF4.2)] | medium (12) throughout | medium to high (14 to 17) | high to very high (15 to 21) | no data, probably low |

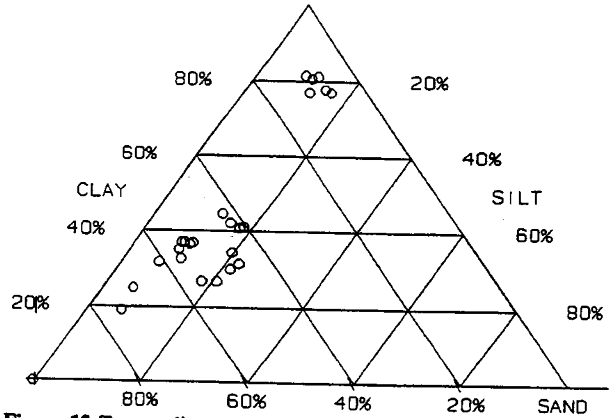



**Figure 12** Texture diagram of CN 17, CN 18, CN 19 and CN 20.

The sand, silt and clay percentages of all soil samples from the four soil profiles are plotted against depth and shown in figures 13, 14, 15 and 16.

In all profiles the silt fraction is low and remains nearly constant with depth. Therefore, the clay and sand content are complementary to each other. Except for CN 18, which has a very uniform clay and sand distribution with depth, all other profiles show clay content to increase with depth in the upper 50 to 100 cm. These clay increases fulfil the requirement of the argic B horizon (see paragraph on classification). After the clay content has increased, its amount stays more or less uniform with depth in soils CN 17 and 19. Such an increase is probably indicative that the clay in the upper soil has been removed through surface run-off. The clay content in CN 20 increases to about 80 cm, but further down it decreases. Such an accumulation 'bulge' is indicative of vertical clay illuviation.

From the chemical properties, the percentage organic carbon, sum of bases, pH-$H_2O$ & pH-KCl were selected for graphical presentation. The distribution of these four soil properties of all soil profiles are plotted with depth and are presented in figures 17, 18, 19 and 20.

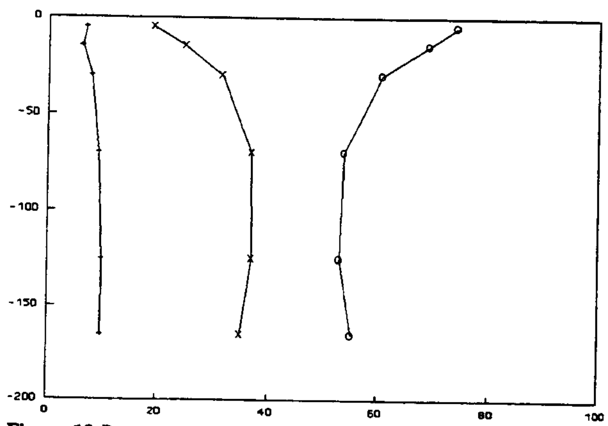


**Figure 13** Percentages clay (x), silt (+) and sand (o) versus depth (cm) in profile CN 17.

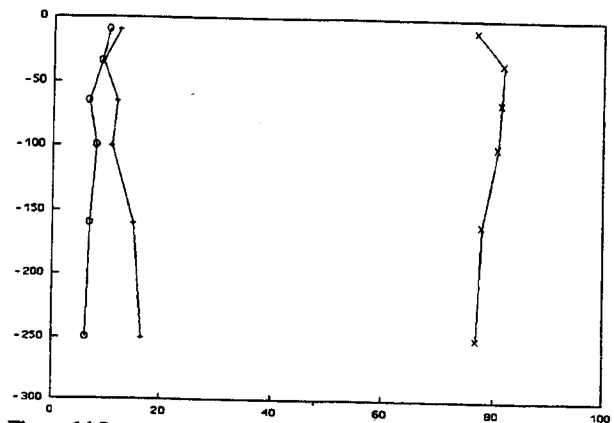


**Figure 14** Percentages clay (x), silt (+) and sand (o) versus depth (cm) in profile CN 18.

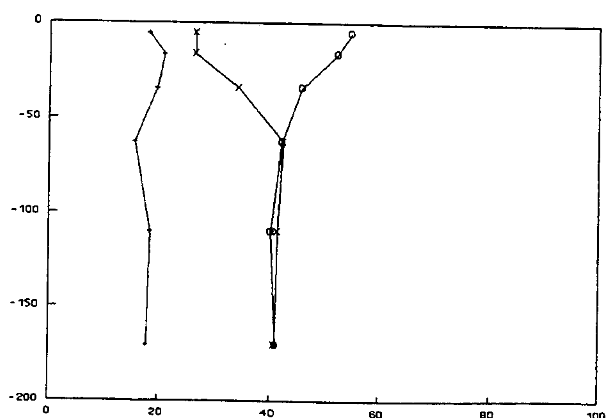


**Figure 15** Percentages clay (x), silt (+) and sand (o) versus depth (cm) in profile CN 19.

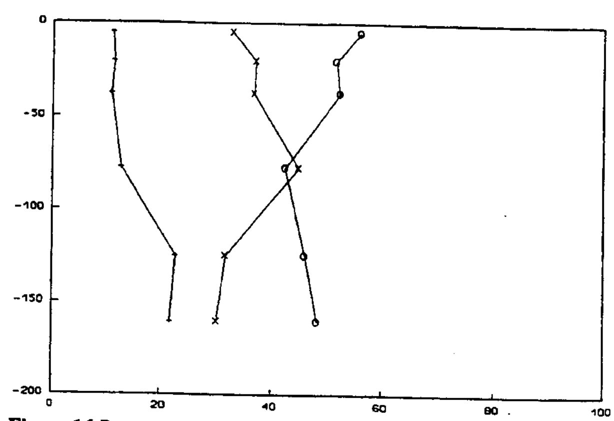


**Figure 16** Percentages clay (x), silt (+) and sand (o) versus depth (cm) in profile CN 20.

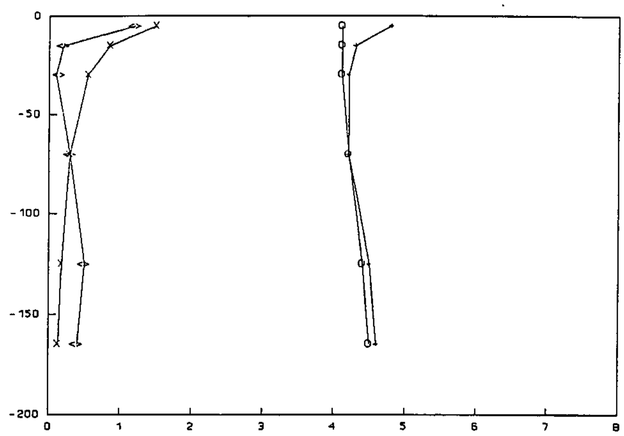



**Figure 17** Sum of bases (cmol/kg soil) (◇), pH-$H_2O$ (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile CN 17.

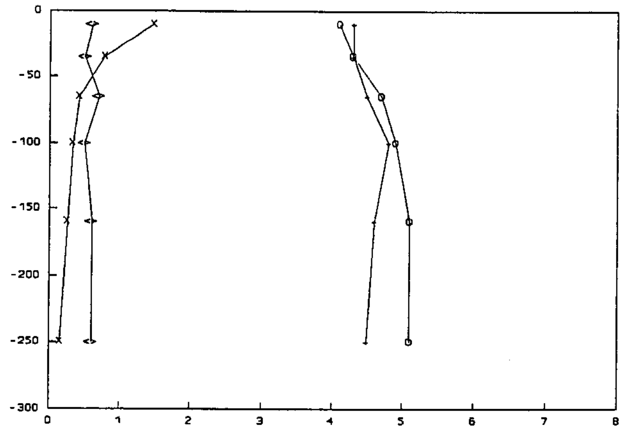



**Figure 18** Sum of bases (cmol/kg soil) (◇), pH-$H_2O$ (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile CN 18.

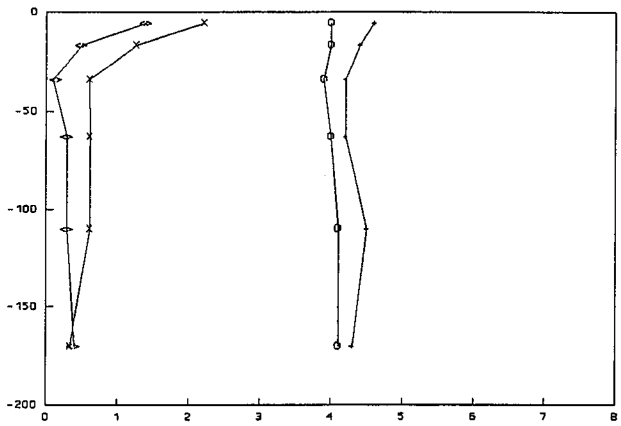



**Figure 19** Sum of bases (cmol/kg soil) (◇), pH-$H_2O$ (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile CN 19.

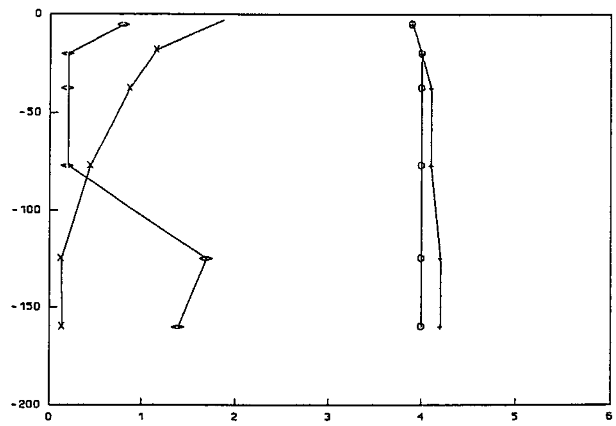



**Figure 20** Sum of bases (cmol/kg soil) (◇), pH-$H_2O$ (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile CN 20.

A comparison of the relationship between organic carbon and depth, hereafter called a 'carbon profile', shows similarity between the carbon profiles of the lowland soils CN 17, 18 and 20. These show a gradual decrease of the organic carbon content from about 1.5 to 2.0 % in the topsoil to less then 0.5 % below 60 cm. The carbon profile of the highland soil, CN 19, has a somewhat higher content in the topsoil (2.2%) decreasing to 0.6 % at a depth of 40 cm but remaining at 0.6 % level untill 110 cm depth. The distinctly higher level of organic carbon of profile CN 19 is caused by the cooler and moister climate of the central mountain area of Hainan island.

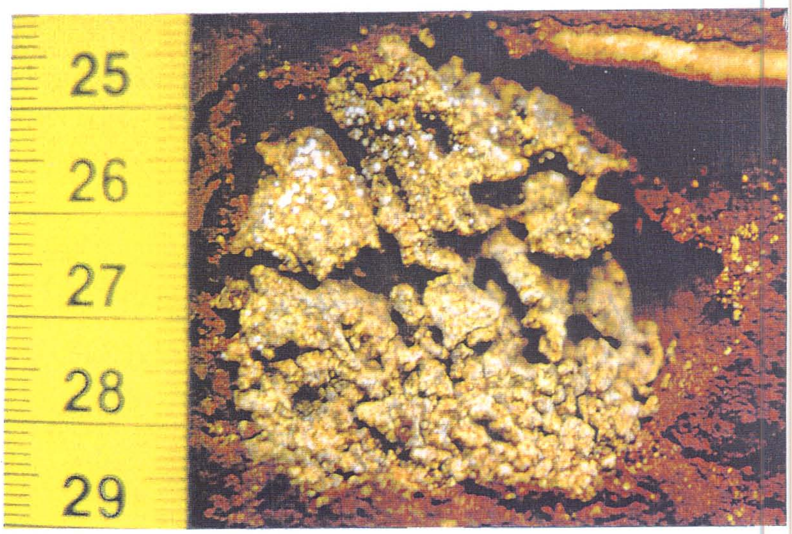
The organic carbon content of profile CN 19 is considered to show approximately the equilibrium situation of the natural soil under original forest. In an equilibrium profile, the organic matter accumulation at any depth is related to the speed and nature of organic matter decomposition (Bennema, 1974). A comparison of the present organic carbon profile with the carbon profile as developed after some years of cultivation will be useful to study the changes caused by a future different land-use.

The sum of bases shows a great similarity between all four soils. The topsoils have a slight higher sum of bases, although still (very) low, mainly determined by the presence of a higher organic carbon content in the topsoil. All soils show a very low sum of bases until great depth. There is no significant difference in the sum of bases content between the different parent materials, basalt and granite. Such a low level of bases in the soil to great depth is indicative of the strongly leached (old) soils of the humid tropics.

The acidity, i.e. pH-$H_2O$ & pH-KCl, of all four soils shows that these soils are very acid throughout. The 'delta pH', the difference between pH-KCL and pH-$H_2O$, is negative and about 0.5 pH unit for soil CN 19, very close to zero for soils CN 17 and CN 20, and positive up to 0.6 pH unit for CN 18. A very small and positive delta pH is also indicative for strongly leached old soils of the humid tropics (see 'geric' properties in the paragraph about classification). Soil CN 18, a very deep red clay soil derived from basalt, is a typical example of such a very old, extremely weathered soil.

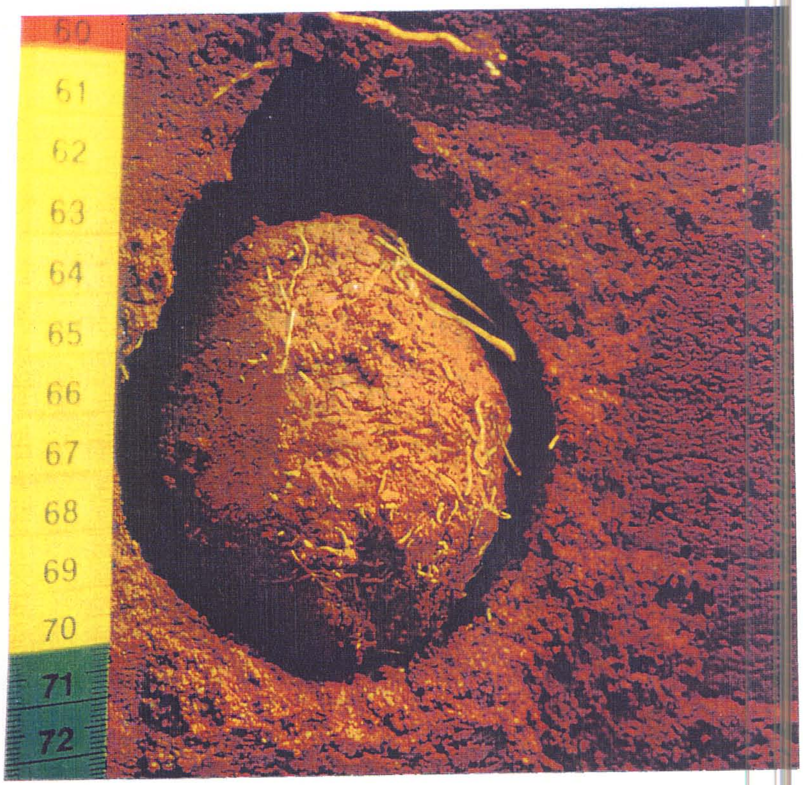
Rubber plantation

Profile CN 17




Fungus combs in termite chamber


Empty termite chamber




Nest of dung beetle

The moisture retention (or pF) curves are given in figures 21, 22 and 22. Generally pF-ring samples were taken at three depths (i.e. in the topsoil, shallow subsoil and deeper subsoil). Triplicate samples were taken to verify the variability, which proved to be very low. The average result of each layer is given in figures 21-23.

The moisture retention curves of soils CN 17, 18 and 20 have comparable forms, showing a gradual release of moisture in response to increasing tension. Although tropical clay soils with a high content of kaolinitic clay generally have pF curves more comparable to those of sandy soils, this is not the case for the four Hainan soils. The reason for this is not known.

Air capacity, defined as the amount of pore space in the soil moisture tension range between 0 to 2 [$\phi$(pF0-pF2.0), is rather low for CN 19 and moderate for the other soils. The available moisture content, defined as the amount of soil moisture held between the soil moisture tension range of 2 to 4.2 [$\phi$(pF2.0-pF4.2)] is medium for CN 18 and high for CN 18 and 19.

## 3.3 Soil classification

### 3.3.1 Soil classification of CN 17

FAO-Unesco: Haplic Acrisol (1988) and Orthic Acrisol (1974)
USDA Soil Taxonomy: Rhodic Kandiudult (1992) and Rhodic Paleudult (1975)
Chinese classification: Haplic Latosols (1992) and Red Latosol (granite (1978)

FAO-Unesco (1988)
The soil is classified as an Haplic Acrisol because it has an ochric A horizon, an increase of clay content which fulfils the requirements for an argic horizon, a CEC of less than 24 cmol(+)/kg$^{-1}$ clay and a base saturation of less than 50 percent. The soil nearly classifies as an Ferralsol, because it fulfils nearly all the requirements for an ferralic B horizon except for the water dispersible clay content, which is more than 10%.

USDA Soil Taxonomy (1992)
The soil is classified as a Rhodic Kandiudult, because it fulfils the requirements for an kandic horizon. The soil nearly classifies as an Oxisol, because it fulfils almost all the requirements for an oxic horizon except for the clay increase, which is higher than 4 % absolute over 15 cm.

Chinese soil classification (1991)
The soil is classified as Haplic Latosols because it has an udic soil moisture regime and a sub-B horizon with an ECEC less than 2.5 units. The soil nearly classifies as a Ferrallisol, because it fulfils all the requirements for Ferrallic properties.

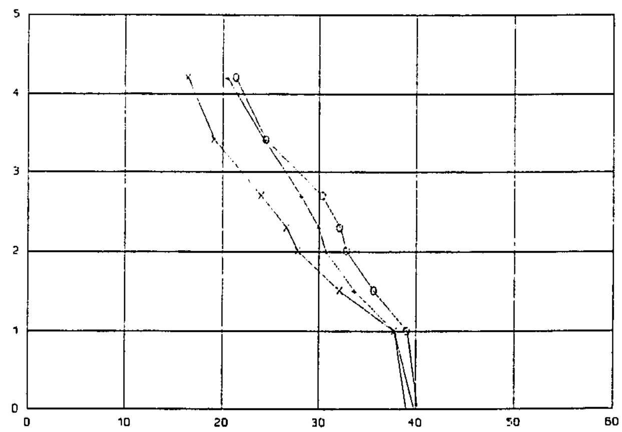


**Figure 21** Moisture retention curves (water content in vol % versus suction) at depth 5-20 cm (x), 40-100 cm (+) and 100-150 cm (o) of soil CN 17.

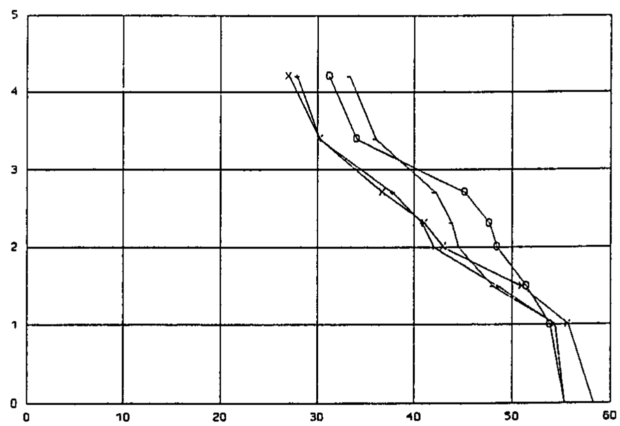


**Figure 22** Moisture retention curves (water content in vol % versus suction) at depth 0-20 cm (x), 50-80 cm (+), 120-200 cm (o) and 200-300 cm (-) of soil CN 18.

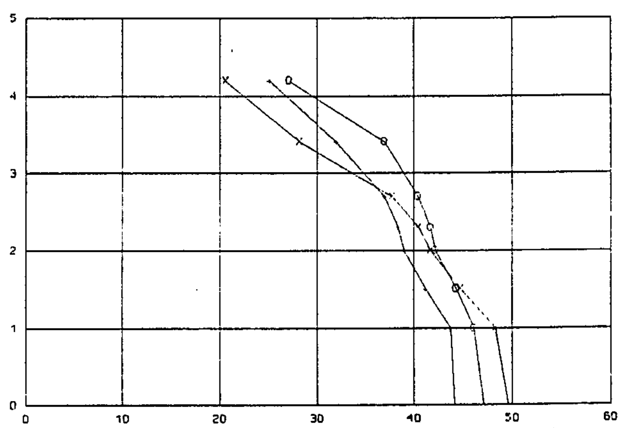
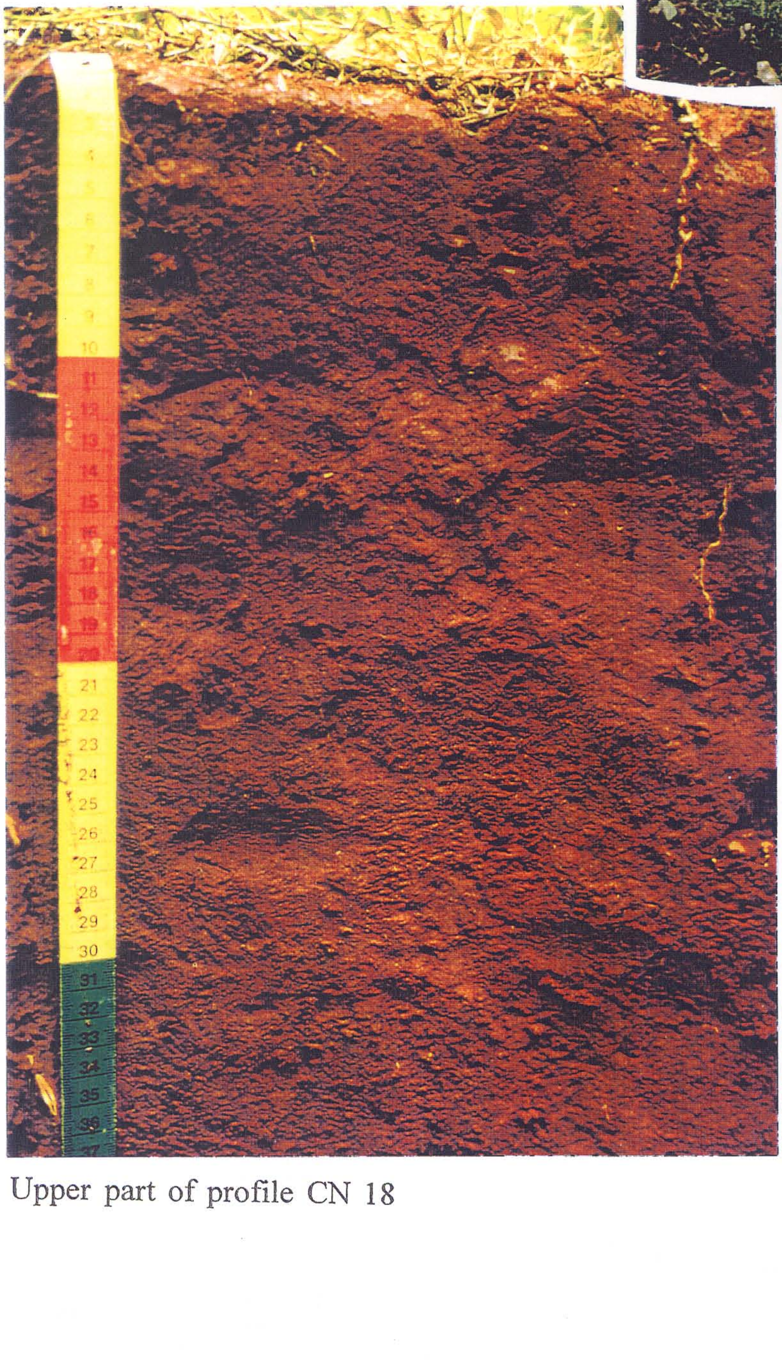


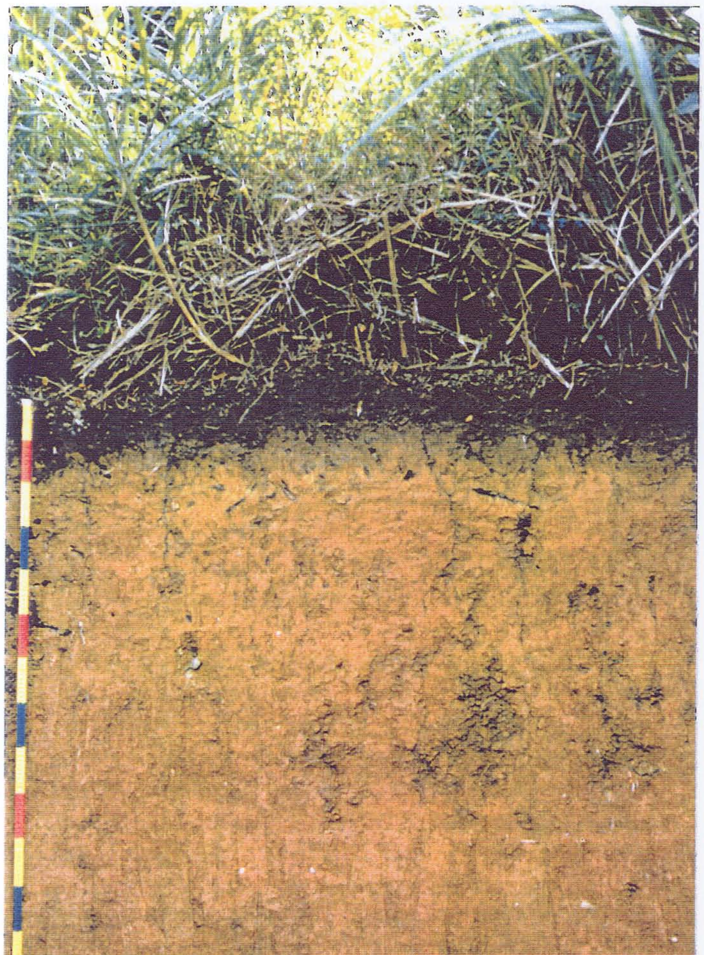
**Figure 23** Moisture retention curves (water content in vol % versus suction) at depth 11-20 cm (x), 22-40 cm (+) and 80-140 cm (o) of soil CN 19.

Land use at site CN 18: rubber plantation



Upper part of profile CN 18

Landscape of CN 19: Central mountains of Hainan Island



Profile CN 19

Rocky hill slope near site CN 19

### 3.3.2 Soil classification of CN 18

FAO-Unesco: Geric Ferralsol (1988) and Acric Ferralsol (1974)
USDA Soil Taxonomy: Rhodic Acrudox (1992) and Haplic Acrorthox (1975)
Chinese classification: Haplic Latosol

FAO-Unesco (1988)

The soil has all the properties required for the ferralic horizon. It has geric properties, a very low sum of bases and exchangeable acidity, and a positive delta pH. The soil is classified therefore as a Geric Ferralsol.

USDA Soil Taxonomy (1987)
Similar to the FAO classification, the soil has all the properties required for an oxic horizon. It is classified as Anionic Acrudox because of its very low sum of bases and exchangeable cations, and its positive delta pH.

Chinese classification (1991)
The soil is classified as a Haplic Latosol, because it has an udic soil moisture regime and a sub-B horizon with an ECEC less than 2.5 units. The soil nearly classifies as a Ferrallisol, because it fulfils all the requirements for Ferrallic properties.

### 3.3.3 Soil classification of CN 19

FAO-Unesco: Haplic Acrisol (1988) and Ferric Acrisol (1974)
USDA Soil Taxonomy: Typic Kandiudult (1992) and Typic Paleudult (1975)
Chinese classification: Yellow Latosol

FAO-Unesco (1988)
The soil is classified as an Haplic Acrisol because it has an increase of clay content which fulfils the requirements for an argic horizon, a CEC of less than 24 cmol(+)/kg clay and a base saturation of less than 50 percent. However, it presents many of the properties required for an ferralic horizon except for a silt/clay ratio larger than 0.2 and more than 10% water dispersible clay.

USDA Soil Taxonomy (1987)
The soil presents nearly all properties required for an oxic horizon except for the clay increase which fulfils the requirement for the kandic horizon. Therefore the soil is classified as a Typic Kandiudult.

Chinese soil classification (1992)
The soil is classified as Yellow Latosol, because it has a perudic soil moisture regime and a sub-B horizon with an ECEC less than 2.5 units. The soil nearly classifies as a Ferrallisol, because it fulfils all the requirements for Ferrallic properties.

### 3.3.4 Soil classification of CN 20

FAO-Unesco: Haplic Acrisol (1988) and Orthic Acrisol (1974)
USDA Soil Taxonomy: Typic Hapludult (1992) and Orthoxic Tropudult (1975)
Chinese classification: Yellow Latosol

FAO-Unesco (1988)
Except for the silt/clay ratio of more than 0.2, the soil fulfils all the requirements for the ferralic B-horizon. The clay increase is sufficient for an argic B-horizon, the soil is classified therefore as Haplic Acrisol.

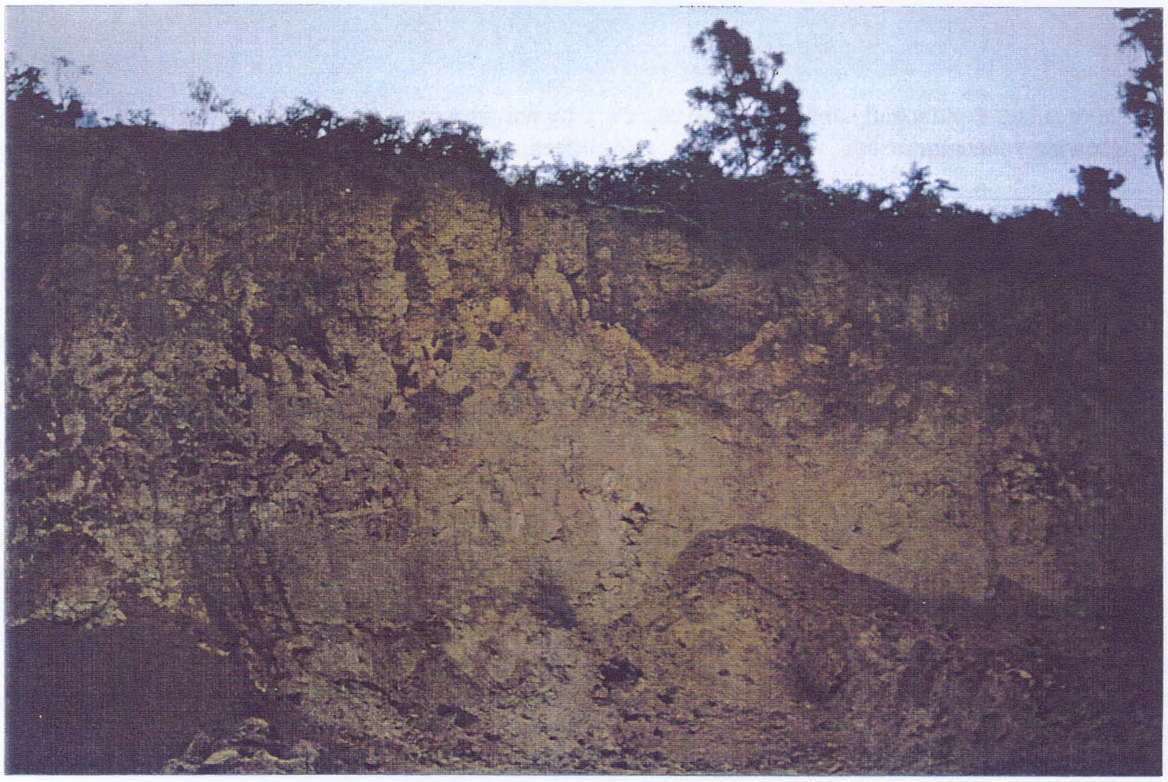
USDA Soil Taxonomy (1987)
Similar to the FAO classification, the soil has many characteristics of the oxic horizon, except for the increase of clay with depth which is insufficient for an kandic horizon, but does meet the criteria for an argillic horizon. The soil is classified as Typic Hapludult.

Chinese soil classification (1991)
The soil is classified as Yellow Latosol, because it has a perudic soil moisture regime and a sub-B horizon with an ECEC less than 2.5 units. The soil nearly classifies as a Ferrallisol, because it fulfils all the requirements for Ferrallic properties.

*Discussion*
All four reference soil profiles have (nearly) all properties for a ferralic B horizon (FAO, 1988). The texture is finer than sandy loam, ferralic B-horizon is thicker than 30 cm, the CEC less than 16 cmol(+)/$Kg^{-1}$ clay, there are most probably less than 10 % weatherable minerals, and there is less than 10% water dispersible clay. The ferralic properties of all four soils are more strongly expressed than the weak clay increase. The only property which excludes classification as a Ferralsol is the silt/clay ratio, which is higher than 0.2. It is proposed that the required silt/clay ratio should be waived to make the classification more consistent.

## 3.4 Soil/Land suitability and environmental assessment

The original vegetation of Hainan island was tropical rain forest, most of which has been cleared but it is still present in mountainous and thinly populated areas. The tropical rain forest impresses by its enormous biomass and species variation per unit area. The suggestion that the soil therefore must have high fertility, has already been disproved by soil scientists many years ago. Abundant precipitation and high temperatures throughout the year are the primary cause of the high biomass production. The nutrients necessary for plant growth are for the greater part locked-up in the biomass itself. Dead



Quarry near CN 20 showing undulating character of substratum

Profile CN 20

organic material mineralizes rapidly and is quickly taken up again by the growing vegetation.

As the most southerly region of China, Hainan Island is where a large variety of tropical crops can be grown. Since 1960, a great effort has been made to increase the plantations of rubber trees, now amounting to more than 600.000 ha. Other major tropical crops are sugar cane, cashew nuts, coconuts and many fruits.

### 3.4.1 Major constraints for agriculture

For the purpose of highlighting major soil/land constraints, a qualitative evaluation of the relevant land qualities was made with STRESS, an ALES programme (ISRIC, 1994) and based on the Framework for Land Evaluation (FAO, 1983).
The evaluation was made for an idealized deep rooting, high plant nutrient demanding annual crop (e.g. maize). The results of this exercise for the four reference soils are presented in a table with 22 climate, soil and land management qualities (Annex 2). The lay-out of the table is such that it directly reveals the major constraints for agriculture, which are briefly discussed here.

Major climate-related constraints for all four reference soils:
- occurrence of typhoons
- although rare and restricted to northern Hainan, occurrence of temperatures below 0 °C. (Celsius)

Major soil-related constraints for all four reference soils:
- (very) low availability of plant nutrients
- (very) low capacity of nutrient retention
- strong soil acidity
- moderate to high level of toxic exchangeable aluminium

Major land management-related constraint, only for reference soil CN 19:
- because of the steep slope gradient the site possesses a low potential for mechanization and low accessibility.

Reference is made to the detailed information and distribution maps given in "Report of the Agricultural Regionalization of Hainan" for the risk caused by typhoons and (very rare) frosts (ARC/TAST, 1981).

A major soil-related constraint of the four soils is the very low plant nutrient availability. Most plant nutrients are stored in the topsoils, while subsoils have very low levels. In general, a low nutrient level can be corrected with fertilizers. However, addition of fertilizers should be carefully managed, because all soils have a very low nutrient retention capacity. Examples of techniques are: repeated small applications, application of the fertilizer near the plant-root system, slow releasing fertilizers and the agro-forestry techniques. The very low nutrient capacity has, as a consequence, a high risk of leaching of fertilizers, this generally results in a low efficiency in their use. In this respect, the soil behaves as a sandy soil. The nutrient retention capacity of these soils can be improved by raising the level of soil organic matter, however, in practice this is very difficult to accomplish. The high acidity and exchangeable aluminium can be overcome by application of lime to the soil. Much experience with this soil management technique on Ferralsols has been acquired in Brazil. For further information on this subject reference is made to Ahn (1993), ILACO (1981) and Landon (1991).

Although a more detailed land evaluation analysis based on a soil survey will give more information, the present rapid land quality assessment leads to the preliminary conclusion that sustainable permanent agriculture needs careful management and inputs of lime and fertilizers to increase and maintain soil fertility and organic matter content.

In view of the low nutrient retention capacity, annual crops are not very satisfactory, instead deep rooting perennials are preferable. The present land-use, rubber and fruit trees is good within the present soil and climatic conditions. A summary of soil management in Hainan's rubber plantations is given by Lu Xing-zheng (1986).

The humid ecological zone of Hainan is very suitable for the adoption of different agroforestry techniques. For further reading on agroforestry and hedgerow (alley) cropping techniques, reference is made to Steppler and Nair (1987), Huxley (1986) and Sanchez (1989).

### 3.4.2 Risk of land degradation

*Erosion risk*
The distinction between sensitivity to erosion and susceptibility as used by Arens (1986) is adopted here. Sensitivity refers to the relative influence of erosion on soil productivity (so-called crop response to erosion). Susceptibility refers to the relative ease by which soil can be eroded (soil erodibility).

Except for CN 18, the Hainan reference soils have the major part of available plant nutrients stored in the topsoil layer. The subsoils have very low plant nutrient reserve. The sensitivity for erosion is therefore considered to be high and the 'tolerable soil loss' should be in the order of less than 2 tons per hectare.

Fortunately, most reference soils have a relative low susceptibility to erosion. The properties most resistant to soil erosion - high porosity, high aggregate stability, etc. -are present in soil CN 18. Profile CN 17 has the lowest resistance to erosion, which has the tendency for soft crust formation because of the combination of a relative low organic and a more sandy texture in the topsoil. The relatively high water-dispersible clay percentage indicates that the soil will disperse by rainwater impact when the soil surface is left exposed. A permanent protective vegetative cover is necessary to prevent a high erosion rate. The other soils do not have such a crust formation and have a lower water dispersible clay content, although in these cases, in view of the high erosivity of the rain the protective vegetative cover is still recommended as a pre-requisite to prevent soil erosion. The latter is especially necessary for soil CN 19, being located in the mountainous area where very steep slopes occur.

*Leaching of elements*
Because of the high porosity and the very low nutrient capacity all the soils are behaving as sandy soils. Therefore, all the soils have a high risk of leaching of lime and fertilizers added to improve soil fertility.

### 3.5 Soil formation

According to Jenny (1941), the classic factors responsible for soil formation were climate, plant and animal organisms, relief, parent material and time. Some authorities consider that other factors such as mankind, hydrology and the history of the landscape are important. For Hainan Island, they may be summarized as follows:

*Parent material*
The soils of Hainan are derived from various strongly weathered rock types, granite being dominant in the southern mountains, but basalt occurs in the northern part of the Island.

*Climate*
The greater part of Hainan has a humid tropical climate with moderate to high Leaching Rainfall. Temperature is mainly determined by altitude. Typhoons may cause flooding and accelerate erosion.

*Hydrology*
Most upland soils are freely drained, being sufficiently permeable to transmit the percolating excess of rainfall (Leaching Rainfall).

*Landforms*
Flat to weakly undulating plains are typical of the coastal regions; steeply sloping land occurs in the central and southern mountainous region.

*Time*
Soil formation *in situ* has taken place throughout a very long period of time, resulting in deep mature profiles.

*Man*
Dense rainforest has been cleared over large areas in this century. As a result, some erosion has occured on cultivated areas and fertility has been changed.

The dense forest vegetation, the warm humid tropical climate and the long un-interrupted time for soil formation are major factors in the development of the very deep, strongly weathered/leached soils of Hainan Island. The balance between rainfall and evapotranspiration results in a high surplus of precipitation, which mostly percolates through the soil, leaching bases and silica. This 'allitic' soil process has resulted in soils with kaolinite as dominant clay mineral. The presence of gibbsite indicates also the advanced weathering stage of the soils.

Differences between soils based on parent material are mostly reflected in soil physical properties such as texture and aggregate stability. The soils derived from basalt have a very high clay content, but the sand content is considerably higher in soils derived from granite. It is assumed that the (weak) texture differentiation between topsoil and subsoil can be attributed to the leaching of clay to the deeper subsoil and to the downslope removal of clay by run-off water during very high rainfall intensities. Because of the strongly leached status of the soils, parent material is not or only little reflected in chemical properties: e.g. there is no difference, or only a slight difference in the level of exchangeable bases between the four reference soils.

The dense forest vegetation minimizes the rate of natural soil erosion, which is less than the rate of soil formation.

Significant quantities of organic carbon occur only in the upper 40 cm, gradually decreasing to a very low level in the deeper subsoil. The accumulation of organic matter is greater in the more cool and moist high mountains of central Hainan.

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## Annex 1A ISIS Data Sheet CN 17

ISIS 4.0 data sheet of monolith CN 17 Country : PEOPLE'S REPUBLIC OF CHINA Print date (dd/mm/yy) : 21/11/94

FAO/UNESCO (1988) : Veti-Haplic Acrisol (Pachic and Chromic) (1974 : Ferric Acrisol)

USDA/SCS SOIL TAXONOMY (1992) : Typic Kandiudult, clayey, kaolinitic, isohyperthermic (1975 : Typic Paleudult)
CSTC (1991) : Haplic latosol

DIAGNOSTIC CRITERIA FAO (1988) : ochric A, argic B horizon
USDA/SCS (1992) : ochric epipedon, kandic horizon
Soil moisture regime : udic

LOCATION : Hainan Island, Dan Xiang county, 8 km W of Na-da city, in rubber plantation
Latitude : 19°29' N Longitude : 109°29' E Altitude : 140 m a.s.l.
AUTHOR(S) : Kauffman, J.H. / Liang / Wang Date (mm/yy) : 10/92

GENERAL LANDFORM : plain Topography : undulating
PHYSIOGRAPHIC UNIT : low, broad hill
SLOPE Gradient : 2% Form : straight
POSITION OF SITE : upper slope
MICRO RELIEF Kind :
SURFACE CHAR. Rock outcrop : nil Stoniness : nil
Cracking : nil Slaking/crusting :
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : not observed

PARENT MATERIAL : residual material from highly weathered coarse-acid igneous rock (granite)

EFFECTIVE SOIL DEPTH : > 150 cm

WATER TABLE : not observed
DRAINAGE : well
PERMEABILITY : no slowly permeable layers
FLOODING Frequency : nil
MOISTURE CONDITIONS PROFILE : 0 - 50 cm dry 50 - 155 cm moist

LAND USE : Crops : rubber, planted in 1963
VEGETATION Type : evergreen forest Status : cut over

ADDITIONAL REMARKS :
Original vegetation is a deciduous tropical forest. Before 1963 secondary forest, in 1963 planting of rubber trees. Tree distance 6 x 3 meter. Fertilizer use: Urea and Phosphorus. Yield about 3 ton/ha/year.
Soil map 1:500.000 indicates that CN 17 is located in the largest map unit, i.e. Latosol derived form granite. This soil type covers the largest part of Hainan Island. Granite is the dominant parent rock of Hainan Island. Field observations show that besides this reddish-brown clayey soil, other variants exist. The soil varies from reddish brown clay to light greyish sandy loam/loamy sand. The greyish colour is caused by groundwater influence but probably also induced by a coarser, more acid granite type resulting in a sandy soil. No detailed maps were made available, but field observations in a transect from West to East show that both soil types appeared to be representative for large areas.
The soil is formed in an erosion terrace in granite. The altitude of the terrace is around 150 meter. The landscape has a plain-like appearance and consists of low, broad interfluves (hills). CN 17 is located on an upper slope postion of broad, low hill, being representative for the larger part of the hill. On the lower slope, transitional to the valley, soil colours become more yellow and the subsoil strongly mottled.
The soil has a high biological activity. Pores and cavities are made by termites (dominant), ants and worms. Spherical termite cavities occur having a diameter of about 5 to 6 cm and flat floor, with or without fungus gardens. Their density is about 2 per m2.
Penetrometer readings in the moist B horizon are about 4 kg/cm2.
FAO/Unesco (1974) soil classification assumes presence of an argillic horizon overlying an oxic horizon, however, clay cutans are lacking. In view of clay increase between 0 and 40 cm depth this soil fits the concept of a Ferric Acrisol.

Slides in the ISRIC collection: landscape, soil, rubber trees.

**CLIMATE :** Köppen: Am

Station: NADA 19 30 N/109 30 E 148 m a.s.l. 3 km W of site Relevance: very good

| | | No. years of record | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pan evaporation | mm | 22 | 101 | 109 | 153 | 189 | 217 | 194 | 212 | 179 | 145 | 145 | 109 | 101 | 1853 |
| PET (P.-M.) | mm | 26 | 71 | 73 | 105 | 126 | 149 | 141 | 152 | 136 | 117 | 105 | 81 | 71 | 1328 |
| relative humidity | % | 26 | 84 | 84 | 82 | 79 | 80 | 81 | 81 | 85 | 87 | 84 | 84 | 84 | 83 |
| precipitation | mm | 27 | 22 | 24 | 37 | 90 | 210 | 216 | 236 | 306 | 354 | 202 | 84 | 35 | 1816 |
| no. of raindays | | 27 | 10 | 10 | 9 | 11 | 17 | 17 | 16 | 19 | 19 | 14 | 11 | 9 | 163 |
| T mean | °C | 26 | 16.9 | 18.2 | 21.6 | 24.9 | 26.9 | 27.4 | 27.5 | 26.7 | 25.7 | 23.6 | 20.5 | 18.0 | 23.2 |
| T max | °C | 26 | 22.2 | 24.0 | 27.8 | 31.4 | 32.9 | 32.9 | 33.0 | 32.0 | 30.6 | 28.3 | 25.2 | 22.9 | 28.6 |
| T min | °C | 26 | 13.5 | 14.7 | 17.8 | 21.0 | 23.2 | 24.1 | 23.9 | 23.5 | 22.8 | 20.6 | 17.5 | 14.8 | 19.8 |
| windspeed(at 2m) | m/s | 26 | 2.0 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 | 1.7 | 1.9 | 2.4 | 2.2 | 2.0 | 2.0 | 1.9 |
| bright sunshine | h/d | 27 | 4.3 | 4.4 | 5.0 | 6.1 | 7.1 | 6.9 | 7.6 | 6.4 | 6.6 | 5.5 | 4.7 | 4.3 | 5.7 |
| bright sunshine | % | 27 | 39 | 38 | 42 | 48 | 55 | 52 | 58 | 50 | 46 | 47 | 42 | 40 | 47 |

**PROFILE DESCRIPTION :**

Very deep, well drained, reddish brown sandy clay loam derived from granite. Soil structure is only weakly expressed. It is highly porous and well rooted, shows a strong biological activity and contains in the deeper subsoil weathered granite fragments.

Ah 0 - 20 cm Dark reddish brown (2.5YR 3/4, moist) to reddish brown (2.5YR 4/4, dry) sandy clay loam; weak fine subangular blocky structure; slightly sticky, slightly plastic, friable, slightly hard; many very fine and fine tubular pores; many fine and coarse roots throughout; gradual smooth boundary to

AB 20 - 40 cm Dark red (2.5YR 3/6, moist) sandy loam; weak fine subangular blocky structure; slightly sticky, slightly plastic, friable; many very fine to fine tubular pores; many fine roots throughout; very frequent termite channels; gradual smooth boundary to

Bw 40 - 155 cm Red (2.5YR 4/7, moist) sandy clay loam; weakly coherent porous massive to weak fine subangular blocky structure; slightly sticky, slightly plastic, friable; many very fine to fine tubular pores; common fine roots throughout; very frequent termite channels; gradual smooth boundary to

BC 155 - 175 cm Red (2.5YR 4/7, moist) sandy loam; weakly coherent porous massive structure; non sticky, non plastic, friable; many very fine tubular pores; few fine roots throughout; frequent fine strongly weathered granite fragments

**ANALYTICAL DATA :**

| Hor. no. | Top - Bot | >2 mm | 2000 1000 | 1000 500 | 500 250 | 250 100 | 100 50 | TOT SAND | 50 20 | 20 2 | TOT SILT | <2 $\mu m$ | DISP | BULK DENS | pF- 0.0 | 1.0 | 1.5 | 2.0 | 2.3 | 2.7 | 3.4 | 4.2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 - 5 | - | 5 | 18 | 22 | 24 | 5 | 74 | 1 | 6 | 7 | 19 | 13.9 | - | - | - | - | - | - | - | - | - |
| 2 | 5 - 20 | - | 5 | 14 | 19 | 23 | 7 | 69 | 1 | 5 | 6 | 25 | 17.0 | 1.42 | 40 | 38 | 32 | 28 | 27 | 24 | 19 | 17 |
| 3 | 20 - 40 | - | 6 | 14 | 17 | 20 | 4 | 61 | 1 | 7 | 8 | 32 | 17.6 | - | - | - | - | - | - | - | - | - |
| 4 | 40 - 100 | - | 8 | 12 | 14 | 15 | 5 | 54 | 1 | 8 | 9 | 37 | 2.9 | 1.40 | 39 | 38 | 34 | 31 | 30 | 28 | 24 | 21 |
| 5 | 100 - 150 | - | 10 | 13 | 13 | 14 | 3 | 53 | 2 | 8 | 10 | 37 | 4.4 | 1.35 | 40 | 39 | 36 | 33 | 32 | 30 | 25 | 21 |
| 6 | 150 - 180 | - | 21 | 12 | 9 | 10 | 4 | 55 | 1 | 9 | 10 | 35 | 3.4 | - | - | - | - | - | - | - | - | - |

| Hor. no. | Top - Bot | pH- H2O | KCl | CaCO3 % | ORG- C % | MAT. N % | EXCH CAT. Ca | Mg | K | Na | sum | EXCH AC. H+Al | Al | CEC soil | clay | OrgC | ECEC | BASE SAT % | Al SAT % | EC 2.5 ms $cm^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | cmol$_c$ $kg^{-1}$ | | | | | | | | | | | | | |
| 1 | 0 - 5 | 4.8 | 4.1 | - | 1.50 | 0.12 | 0.6 | 0.3 | 0.2 | 0.1 | 1.2 | 0.7 | 0.5 | 3.5 | 18 | 5.2 | 1.9 | 34 | 14 | 0.16 |
| 2 | 5 - 20 | 4.3 | 4.1 | - | 0.85 | 0.08 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 1.2 | 0.9 | 2.5 | 10 | 3.0 | 1.4 | 8 | 36 | 0.11 |
| 3 | 20 - 40 | 4.2 | 4.1 | - | 0.55 | 0.06 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 1.2 | 0.9 | 2.3 | 7 | 1.9 | 1.3 | 4 | 39 | 0.06 |
| 4 | 40 - 100 | 4.2 | 4.2 | - | 0.29 | 0.04 | 0.2 | 0.0 | 0.1 | 0.0 | 0.3 | 1.0 | 0.5 | 1.6 | 4 | 1.0 | 1.3 | 19 | 31 | 0.06 |
| 5 | 100 - 150 | 4.5 | 4.4 | - | 0.18 | 0.03 | 0.0 | 0.3 | 0.1 | 0.1 | 0.5 | 0.3 | 0.0 | 1.6 | 4 | 0.6 | 0.8 | 31 | 0 | 0.05 |
| 6 | 150 - 180 | 4.6 | 4.5 | - | 0.13 | 0.05 | 0.0 | 0.3 | 0.1 | 0.0 | 0.4 | 0.3 | 0.0 | 1.4 | 4 | 0.5 | 0.7 | 29 | 0 | 0.02 |

CLAY MINERALOGY (1 very weak, ..., 8 very strong) / EXTRACTABLE Fe & Al by Na DITHIONITE / AVAIL. P (Bray)

| Hor. no. | Top - Bot | MICA /ILL | KAOL | MIX | GIBB | GOET | Fe | Al | AVAIL. P (Bray) mg $kg^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 - 5 | 2 | 8 | - | 3 | 3 | 1.4 | 0.2 | 3.3 |
| 2 | 5 - 20 | 2 | 8 | 3 | 3 | 3 | 1.6 | 0.2 | 1.0 |
| 3 | 20 - 40 | 2 | 8 | 3 | 3 | 3 | 2.1 | 0.2 | 0.0 |
| 4 | 40 - 100 | 2 | 8 | 3 | 3 | 3 | 2.7 | 0.2 | 0.0 |
| 5 | 100 - 150 | 2 | 8 | 3 | 3 | 3 | 2.8 | 0.2 | 0.0 |
| 6 | 150 - 180 | - | 8 | - | 3 | 3 | 2.8 | 0.2 | 0.0 |

## Annex 1B ISIS Data Sheet CN 18

ISIS 4.0 data sheet of monolith CN 18 Country : PEOPLE'S REPUBLIC OF CHINA Print date (dd/mm/yy) : 18/11/94

FAO/UNESCO (1988) : Rhodi-Geric Ferralsol (1974 : Acric Ferralsol)
USDA/SCS SOIL TAXONOMY (1992) : Anionic Acrudox, very-fine, kaolinitic, isohyperthermic (1975 : Typic Acrorthox)
CSTC (1991) : Haplic latosol

DIAGNOSTIC CRITERIA FAO (1988) : ochric A, ferralic B horizon; geric properties
USDA/SCS (1992) : ochric epipedon, oxic horizon
Soil moisture regime : udic
Soil temperature regime : isohyperthermic

LOCATION : Hai Nan, Chang Ma County, 2 km W of Fu-shang Town, Hong Guang St. farm
Latitude : 19°50' N Longitude : 109°54' E Altitude : 105 m a.s.l.
AUTHOR(S) : Kauffman, J.H. / Wang Minzhu Date (mm/yy) : 10/92

GENERAL LANDFORM : peneplain Topography : flat or almost flat
PHYSIOGRAPHIC UNIT : low broad nearly level hill
SLOPE Gradient : 1% Form : straight
POSITION OF SITE : crest
MICRO RELIEF Kind :
SURFACE CHAR. Rock outcrop : nil Stoniness : nil
Cracking : nil Slaking/crusting :
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : not observed

PARENT MATERIAL : residual material derived from fine-basic igneous rock (basalt)

EFFECTIVE SOIL DEPTH : > 300 cm

WATER TABLE : not observed, estimated to be at a depth of 20 meters (verbal comm.)
DRAINAGE : well
PERMEABILITY : no slowly permeable layers observed
MOISTURE CONDITIONS PROFILE : 0 - 50 cm dry 50 - 300 cm moist

LAND USE : Crops : rubber, planted in 1966. Rubber yield is about 1000 kg/ha

ADDITIONAL REMARKS :
Northern Hainan Island has a series of extensive, terrace-like basalt plains ranging in elevation from about 50 to 150 m.
CN 18 is representative for the very deep, dark red clay soils derived from basalt. The profile is comparable to the very deep Brazilian Ferralsols developed on basalt in e.g. the Sao Paolo region.
Penetrometer reading in the slightly moist soil is about 2 to 2.5 kg/cm2.

CLIMATE : Köppen: Am
Station: HAIKOU 20 2 N/110 21 E 14 m a.s.l. 50 km W of site Relevance: very good
Station: NADA 19 30 N/109 30 E 148 m a.s.l. 60 km SW of site Relevance: good

| HAIKOU | No. years of record | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pan evaporation mm | 27 | 102 | 96 | 138 | 182 | 211 | 197 | 216 | 178 | 155 | 160 | 130 | 110 | 1874 |
| PET (P.-M.) mm | 27 | 71 | 67 | 99 | 123 | 152 | 147 | 161 | 140 | 123 | 115 | 90 | 74 | 1362 |
| relative humidity % | 30 | 85 | 87 | 87 | 85 | 84 | 84 | 83 | 86 | 86 | 83 | 82 | 83 | 85 |
| precipitation mm | 30 | 24 | 30 | 52 | 93 | 188 | 241 | 207 | 240 | 303 | 172 | 98 | 38 | 1685 |
| no. of raindays | 30 | 9 | 10 | 10 | 11 | 16 | 16 | 14 | 16 | 16 | 12 | 10 | 9 | 150 |
| T mean °C | 30 | 17.2 | 18.2 | 21.6 | 24.9 | 27.4 | 28.1 | 28.4 | 27.7 | 26.8 | 24.8 | 21.8 | 18.7 | 23.8 |
| T max °C | 30 | 20.9 | 22.3 | 26.2 | 29.8 | 32.4 | 32.8 | 33.2 | 32.0 | 30.6 | 28.3 | 25.1 | 22.2 | 28.0 |
| T min °C | 30 | 14.6 | 15.6 | 18.8 | 21.9 | 24.2 | 25.1 | 25.1 | 24.8 | 24.2 | 22.1 | 19.2 | 16.1 | 20.0 |
| windspeed(at 2m) m/s | 27 | 2.8 | 2.9 | 2.9 | 3.0 | 2.6 | 2.4 | 2.4 | 2.2 | 2.3 | 2.6 | 2.9 | 2.6 | 2.6 |
| bright sunshine h/d | 30 | 4.2 | 4.1 | 4.7 | 6.3 | 7.8 | 7.5 | 8.3 | 7.1 | 6.6 | 6.5 | 5.7 | 4.8 | 6.1 |
| bright sunshine % | 28 | 38 | 35 | 40 | 50 | 60 | 56 | 63 | 55 | 54 | 56 | 51 | 44 | 51 |

| NADA | No. years of record | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pot. evaporation mm | 22 | 101 | 109 | 153 | 189 | 217 | 194 | 212 | 179 | 145 | 145 | 109 | 101 | 1853 |
| PET (P.-M.) mm | 22 | 71 | 73 | 105 | 126 | 149 | 141 | 152 | 136 | 117 | 105 | 81 | 71 | 1328 |
| relative humidity % | 26 | 84 | 84 | 82 | 79 | 80 | 81 | 81 | 85 | 87 | 84 | 84 | 84 | 83 |
| precipitation mm | 27 | 22 | 24 | 37 | 90 | 210 | 216 | 236 | 306 | 354 | 202 | 84 | 35 | 1816 |
| no. of raindays | 27 | 10 | 10 | 9 | 11 | 17 | 17 | 16 | 19 | 19 | 14 | 11 | 9 | 163 |
| T mean °C | 26 | 16.9 | 18.2 | 21.6 | 24.9 | 26.9 | 27.4 | 27.5 | 26.7 | 25.7 | 23.6 | 20.5 | 18.0 | 23.2 |
| T max °C | 26 | 22.2 | 24.0 | 27.8 | 31.4 | 32.9 | 32.9 | 33.0 | 32.0 | 30.6 | 28.3 | 25.2 | 22.9 | 28.6 |
| T min °C | 26 | 13.5 | 14.7 | 17.8 | 21.0 | 23.2 | 24.1 | 23.9 | 23.5 | 22.8 | 20.6 | 17.5 | 14.8 | 19.8 |
| windspeed(at 2m) m/s | 26 | 2.0 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 | 1.7 | 1.9 | 2.4 | 2.2 | 2.0 | 2.0 | 1.9 |
| bright sunshine h/d | 27 | 4.3 | 4.4 | 5.0 | 6.1 | 7.1 | 6.8 | 7.6 | 6.4 | 5.7 | 5.5 | 4.7 | 4.3 | 5.7 |
| bright sunshine % | 27 | 39 | 38 | 42 | 48 | 55 | 52 | 58 | 50 | 46 | 47 | 42 | 40 | 47 |

PROFILE DESCRIPTION :

Very deep, well drained, dark reddish brown clay derived from basalt. Soil colour, structure and other properties are uniform to a depth of about 6 meters. Rooting is as deep as 3 meters. There is a very high biological activity caused by termites.

| | | |
|---|---|---|
| Ah | 0 - 20 cm | Dark reddish brown (2.5YR 3/4, moist) clay; moderately coherent porous massive to weak fine subangular blocky structure; slightly sticky, slightly plastic, friable, hard; many very fine and common fine pores; many fine and common medium roots throughout; diffuse smooth boundary to |
| Bo1 | 20 - 120 cm | Dark reddish brown (2.5YR 3/4, moist) clay; weakly coherent porous massive to weak fine subangular blocky structure; slightly sticky, slightly plastic, very friable; many very fine and common fine random tubular pores; common fine roots throughout; frequent termite channels |
| Bo2 | 120 - 300 cm | Dark reddish brown (2.5YR 3/4, moist) clay; weakly coherent porous massive to weak fine subangular blocky structure; slightly sticky, slightly plastic, very friable; many very fine and common fine random tubular pores; frequent termite channels |

ANALYTICAL DATA :

| Hor. no. | Top - Bot | >2 mm | 2000 1000 | 1000 500 | 500 250 | 250 100 | 100 50 | TOT SAND | 50 20 | 20 2 | TOT SILT | <2 µm | DISP | BULK DENS | pF- 0.0 | 1.0 | 1.5 | 2.0 | 2.3 | 2.7 | 3.4 | 4.2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 - 20 | - | 1 | 1 | 2 | 5 | 2 | 11 | 1 | 12 | 12 | 77 | 1.9 | 1.10 | 58 | 56 | 51 | 43 | 41 | 37 | 30 | 27 |
| 2 | 20 - 50 | - | 1 | 1 | 2 | 4 | 2 | 9 | 2 | 7 | 9 | 82 | 4.7 | - | - | - | - | - | - | - | - | - |
| 3 | 50 - 80 | - | 0 | 1 | 2 | 3 | 1 | 7 | 6 | 6 | 12 | 81 | 5.5 | 1.01 | 55 | 54 | 49 | 42 | 41 | 38 | 30 | 28 |
| 4 | 80 - 120 | - | 0 | 1 | 2 | 3 | 2 | 8 | 0 | 11 | 11 | 81 | 2.0 | - | - | - | - | - | - | - | - | - |
| 5 | 120 - 200 | - | 1 | 1 | 2 | 3 | 2 | 7 | 1 | 14 | 15 | 78 | 2.4 | 1.10 | 55 | 54 | 52 | 49 | 48 | 45 | 34 | 31 |
| 6 | 200 - 300 | - | 0 | 1 | 1 | 2 | 2 | 6 | 2 | 15 | 17 | 77 | 3.6 | 1.11 | 55 | 54 | 48 | 45 | 44 | 42 | 36 | 33 |

| Hor. no. | Top - Bot | pH- H2O | KCl | CaCO3 % | ORG- C % | MAT. N % | EXCH CAT. Ca | Mg | K | Na | sum | EXCH AC. H+Al | Al | CEC soil | clay | OrgC | ECEC | BASE SAT % | Al SAT % | EC 2.5 ms $cm^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | cmol$_c$ $kg^{-1}$ | | | | | | | | | | | | | |
| 1 | 0 - 20 | 4.3 | 4.1 | - | 1.48 | 0.13 | 0.2 | 0.3 | 0.0 | 0.1 | 0.6 | 1.5 | 0.9 | 5.9 | 8 | 5.2 | 2.1 | 10 | 15 | 0.06 |
| 2 | 20 - 50 | 4.3 | 4.3 | - | 0.78 | 0.08 | 0.0 | 0.3 | 0.1 | 0.1 | 0.5 | 0.8 | 0.5 | 1.8 | 2 | 2.7 | 1.3 | 28 | 28 | 0.04 |
| 3 | 50 - 80 | 4.5 | 4.7 | - | 0.42 | 0.05 | 0.0 | 0.3 | 0.1 | 0.3 | 0.7 | 0.2 | 0.0 | 2.1 | 3 | 1.5 | 0.9 | 33 | 0 | 0.02 |
| 4 | 80 - 120 | 4.8 | 4.9 | - | 0.33 | 0.04 | 0.0 | 0.3 | 0.0 | 0.2 | 0.5 | 0.0 | 0.0 | 2.0 | 2 | 1.2 | 0.5 | 25 | 0 | 0.02 |
| 5 | 120 - 200 | 4.6 | 5.1 | - | 0.26 | 0.04 | 0.2 | 0.3 | 0.0 | 0.1 | 0.6 | 0.0 | 0.0 | 2.3 | 3 | 0.9 | 0.6 | 26 | 0 | 0.03 |
| 6 | 200 - 300 | 4.5 | 5.1 | - | 0.16 | 0.03 | 0.2 | 0.3 | 0.0 | 0.1 | 0.6 | 0.1 | 0.0 | 2.1 | 3 | 0.6 | 0.7 | 29 | 0 | 0.03 |

CLAY MINERALOGY (1 very weak, ..., 8 very strong); EXTRACTABLE Fe & Al by Na DITHIONITE; AVAIL. P (Bray) mg $kg^{-1}$

| Hor. no. | Top - Bot | CHLO | KAOL | GIBB | GOET | Fe | Al | AVAIL. P (Bray) mg $kg^{-1}$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 - 20 | 2 | 6 | 3 | 3 | 7.8 | 0.7 | 0.0 |
| 2 | 20 - 50 | 2 | 6 | 3 | 3 | 8.1 | 0.7 | 0.0 |
| 3 | 50 - 80 | 2 | 6 | 3 | 3 | 8.3 | 0.8 | 0.0 |
| 4 | 80 - 120 | 2 | 6 | 3 | 3 | 7.2 | 0.6 | 0.0 |
| 5 | 120 - 200 | 2 | 6 | 3 | 3 | 7.6 | 0.7 | 0.0 |
| 6 | 200 - 300 | 2 | 6 | 3 | 3 | 7.9 | 0.7 | 0.0 |

# Annex 1C ISIS Data Sheet CN 19

ISIS 4.0 data sheet of monolith CN 19 Country : PEOPLE'S REPUBLIC OF CHINA Print date (dd/mm/yy) : 21/11/94

| | | |
|---|---|---|
| FAO/UNESCO (1988) | : Veti-Haplic Acrisol (Pachic and Xanthic) | (1974 : Ferric Acrisol) |
| USDA/SCS SOIL TAXONOMY (1992) | : Typic Kandiudult, clayey, kaolinitic, isohyperthermic | (1975 : Typic Paleudult) |
| CSTC (1991) | : Argillic latored soil | |

DIAGNOSTIC CRITERIA FAO (1988) : ochric A, argic B horizon
USDA/SCS (1992) : ochric epipedon, kandic horizon
Soil moisture regime : udic

LOCATION : Hainan, 15 km north of Tong Zha City, about 500 m from road to the Antenne
Latitude : 18° 45′ 00″ N Longitude : 109° 28′ 45″ E Altitude : 770 m a.s.l.
AUTHOR(S) : Kauffman, J.H. / Wang Date (mm/yy) : 10/92

GENERAL LANDFORM : mountain Topography : steeply dissected
PHYSIOGRAPHIC UNIT : Toen-ling mountains
SLOPE Gradient : 40% Form : straight
POSITION OF SITE : middle slope
MICRO RELIEF Kind :
SURFACE CHAR. Rock outcrop : nil Stoniness : nil
Cracking : nil Slaking/crusting :
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : not observed

PARENT MATERIAL : residual material derived from coarse-acid igneous rocks (granite)
Weathering degree : high

EFFECTIVE SOIL DEPTH : > 250 cm

WATER TABLE : not observed
DRAINAGE : moderately well to well
PERMEABILITY : no slowly permeable layers
FLOODING Frequency : nil
MOISTURE CONDITIONS PROFILE : 0 - 10 cm dry 10 - 250 cm moist

LAND USE : (semi-) natural vegetation
VEGETATION Type : semi deciduous forest Status : secondary

ADDITIONAL REMARKS :
CN 19 is representative for soils of the central highlands, consisting of middle high mountains, dominantly composed of granite. The depth of the solum may vary from shallow to very deep. The underlying granite is nearly always strongly weathered.
The original forest has been cut over large areas, replaced by secondary forest, but generally natural grassland (tufted tall grasses) takes over.
The first half meter below the A-horizon (approx. the AB and Bw1 horizons) have common coarse old root channels filled with dark topsoil material. The AB horizon is multicoloured. Besides the given matrix colour, frequent patches of A and Bw1 colours occur.
The soil has nearly a ferralic B horizon below 46 cm, however, silt/clay ratio is a too high. The requirements for a kandic horizon are met which starts at about 30 cm depth.

CLIMATE : Köppen: Am
Station: QIONGZHONG 19 2 N / 109 50 E 250 m a.s.l. 30 km W of site Relevance: moderate

| | No. years of record | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pan evaporation mm | 20 | 95 | 101 | 163 | 200 | 218 | 195 | 218 | 185 | 150 | 127 | 90 | 84 | 18[illegible]4 |
| PET (P.-M.) mm | 21 | 59 | 64 | 99 | 117 | 130 | 123 | 136 | 121 | 102 | 87 | 63 | 59 | 11[illegible]1 |
| relative humidity % | 21 | 87 | 87 | 83 | 82 | 82 | 84 | 82 | 86 | 89 | 88 | 89 | 88 | [illegible]6 |
| precipitation mm | 21 | 37 | 39 | 44 | 101 | 239 | 226 | 253 | 306 | 484 | 451 | 208 | 59 | 24[illegible]7 |
| no. of raindays | 21 | 14 | 13 | 10 | 11 | 18 | 18 | 17 | 21 | 22 | 19 | 17 | 14 | 1[illegible]4 |
| T mean °C | 21 | 16.5 | 17.7 | 21.2 | 23.8 | 25.9 | 26.4 | 26.6 | 25.9 | 24.8 | 22.9 | 20.0 | 17.5 | 2[illegible].4 |
| T max °C | 21 | 21.8 | 23.2 | 27.2 | 30.1 | 32.2 | 32.1 | 32.4 | 31.5 | 29.9 | 27.4 | 24.4 | 22.3 | 2[illegible].9 |
| T min °C | 21 | 12.7 | 14.0 | 16.8 | 19.2 | 21.5 | 22.5 | 22.4 | 22.3 | 21.6 | 19.8 | 16.9 | 14.0 | 1[illegible].7 |
| windspeed(at 2m) m/s | 21 | 0.8 | 1.0 | 1.3 | 1.3 | 1.0 | 1.0 | 1.1 | 0.9 | 0.9 | 0.9 | 0.6 | 0.6 | [illegible].0 |
| bright sunshine h/d | 21 | 3.6 | 3.8 | 4.8 | 5.9 | 6.4 | 5.6 | 6.6 | 5.6 | 4.7 | 3.9 | 3.2 | 3.3 | [illegible].8 |
| bright sunshine % | 21 | 33 | 33 | 44 | 47 | 49 | 43 | 50 | 44 | 39 | 33 | 29 | 31 | [illegible]0 |

PROFILE DESCRIPTION :

Very deep, well drained, yellowish brown sandy clay derived from granite with a prominent thin dark topsoil.

| | | |
|---|---|---|
| Ah | 0 - 11 cm | Very dark grayish brown (10YR 3/2, moist) sandy clay; weak to moderate fine to medium subangular blocky structure; slightly sticky, slightly plastic, friable, slightly hard; many fine and common medium random tubular pores; many fine and common medium roots throughout; clear smooth boundary to |
| AB | 11 - 22 cm | Dark yellowish brown (10YR 4/4 moist) sandy clay; moderate fine to medium subangular blocky structure; slightly sticky, slightly plastic, friable; few fine distinct clear yellowish red (5YR 5/6) mottles and many fine faint diffuse mottles; many fine and few medium random tubular pores; many fine and few medium roots throughout; clear wavy boundary to |
| Bw1 | 22 - 46 cm | Yellowish brown (10YR 5/6, moist) sandy clay; weak medium subangular blocky parting to weak fine subangular blocky structure; slightly sticky, slightly plastic, friable; few fine faint mottles; many fine tubular pores; common medium and many fine roots throughout; gradual smooth boundary to |
| Bw2 | 46 - 80 cm | Brownish yellow (10YR 6/6, moist) sandy clay; weak medium subangular blocky parting to weak fine subangular blocky structure; slightly sticky, slightly plastic, friable; many fine tubular pores; many fine roots throughout; diffuse smooth boundary to |
| Bw3 | 80 - 140 cm | Yellowish brown (9YR 5/8, moist) sandy clay; weak medium subangular blocky parting to weak fine subangular blocky structure; slightly sticky, slightly plastic, very friable; many fine tubular pores; common fine roots throughout; diffuse smooth boundary to |
| Bw4 | 140 - 200 cm | Strong brown (7.5YR 5/8, moist) sandy clay; weakly coherent porous massive structure; slightly sticky, slightly plastic, very friable; many fine tubular pores; few fine roots throughout; |

ANALYTICAL DATA :

| Hor. no. | Top - Bot | >2 mm | 2000 1000 | 1000 500 | 500 250 | 250 100 | 100 50 | TOT SAND | 50 20 | 20 2 | TOT SILT | <2 μm | DISP | BULK DENS | pF- 0.0 | 1.0 | 1.5 | 2.0 | 2.3 | 2.7 | 3.4 | 4.2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 - 11 | - | 8 | 17 | 14 | 12 | 4 | 55 | 2 | 16 | 18 | 27 | 13.8 | - | - | - | - | - | - | - | - | - |
| 2 | 11 - 22 | - | 9 | 16 | 12 | 9 | 6 | 52 | 7 | 14 | 21 | 27 | 15.5 | 1.23 | 50 | 48 | 45 | 42 | 41 | 38 | 28 | 21 |
| 3 | 22 - 46 | - | 10 | 14 | 10 | 9 | 4 | 46 | 5 | 14 | 20 | 35 | 19.9 | 1.40 | 44 | 44 | 41 | 39 | 38 | 37 | 32 | 25 |
| 4 | 46 - 80 | - | 9 | 13 | 9 | 7 | 4 | 42 | 2 | 13 | 16 | 42 | 7.4 | - | - | - | - | - | - | - | - | - |
| 5 | 80 - 140 | - | 10 | 11 | 8 | 8 | 3 | 40 | 6 | 13 | 19 | 41 | 5.5 | 1.27 | 47 | 46 | 44 | 42 | 42 | 40 | 37 | 27 |
| 6 | 140 - 200 | - | 7 | 12 | 9 | 8 | 5 | 41 | 4 | 14 | 18 | 41 | 3.0 | - | - | - | - | - | - | - | - | - |

| Hor. no. | Top - Bot | pH- H2O | KCl | CaCO3 % | ORG- C % | MAT. N % | EXCH CAT. Ca | Mg | K | Na | sum | EXCH AC. H+Al | Al | CEC soil | clay | OrgC | ECEC | BASE SAT % | Al SAT % | EC 2.5 ms $cm^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | cmol$_c$ $kg^{-1}$ | | | | | | | | | | | | | |
| 1 | 0 - 11 | 4.6 | 4.0 | - | 2.22 | 0.16 | 0.6 | 0.3 | 0.4 | 0.1 | 1.4 | 1.5 | 0.9 | 6.2 | 23 | 7.8 | 2.9 | 23 | 15 | 0.07 |
| 2 | 11 - 22 | 4.4 | 4.0 | - | 1.26 | 0.10 | 0.0 | 0.3 | 0.2 | 0.0 | 0.5 | 1.8 | 1.4 | 3.9 | 15 | 4.4 | 2.3 | 13 | 36 | 0.05 |
| 3 | 22 - 46 | 4.2 | 3.9 | - | 0.61 | 0.07 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 1.8 | 1.6 | 3.7 | 11 | 2.1 | 1.9 | 3 | 43 | 0.03 |
| 4 | 46 - 80 | 4.2 | 4.0 | - | 0.62 | 0.06 | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 2.1 | 1.8 | 4.3 | 10 | 2.2 | 2.4 | 7 | 42 | 0.03 |
| 5 | 80 - 140 | 4.5 | 4.1 | - | 0.62 | 0.06 | 0.2 | 0.0 | 0.1 | 0.0 | 0.3 | 1.8 | 1.4 | 4.1 | 10 | 2.2 | 2.1 | 7 | 34 | 0.02 |
| 6 | 140 - 200 | 4.3 | 4.1 | - | 0.34 | 0.04 | 0.2 | 0.0 | 0.1 | 0.1 | 0.4 | 1.7 | 1.4 | 4.4 | 11 | 1.2 | 2.1 | 9 | 32 | 0.02 |

CLAY MINERALOGY (1 very weak, ..., 8 very strong) — EXTRACTABLE Fe & Al by Na DITHIONITE — AVAIL. P (Bray) mg $kg^{-1}$

| Hor. no. | Top - Bot | MICA /ILL | CHLO | KAOL | MIX | GIBB | GOET | Fe | Al | AVAIL. P (Bray) mg $kg^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 - 11 | 3 | 3 | 8 | 3 | 3 | 3 | 1.0 | 0.2 | 0.0 |
| 2 | 11 - 22 | 3 | 3 | 8 | 3 | 3 | 3 | 1.1 | 0.2 | 0.0 |
| 3 | 22 - 46 | 3 | 3 | 8 | 3 | 3 | 3 | 1.6 | 0.3 | 0.0 |
| 4 | 46 - 80 | 3 | 3 | 8 | 3 | 3 | 3 | 1.9 | 0.4 | 0.0 |
| 5 | 80 - 140 | 2 | 3 | 8 | 3 | 3 | 3 | 2.0 | 0.4 | 0.7 |
| 6 | 140 - 200 | 1 | 2 | 8 | 2 | 3 | 3 | 2.1 | 0.4 | 0.0 |

## Annex 1D ISIS Data Sheet CN 20

ISIS 4.0 data sheet of monolith CN 20 Country : PEOPLE'S REPUBLIC OF CHINA Print date (dd/mm/yy) : 2[illegible]/1[illegible]/94

FAO/UNESCO (1988) : Veti-Ferralic Cambisol (Chromic) (1974 : Orthic Ferralsol)
USDA/SCS SOIL TAXONOMY (1992) : Typic Hapludox, fine, kaolinitic, isohyperthermic (1975 : Typic Haplorthox)

CSTC (1991) : Haplic latored soil

DIAGNOSTIC CRITERIA FAO (1988) : ochric A, cambic B horizon; ferralic properties
USDA/SCS (1992) : ochric epipedon, oxic horizon
Soil moisture regime : udic

Remarks: FAO (1988) classification is "Ferralic Cambisol" because the silt/clay ratio in the soil is too high for a ferralic B horizon. All other criteria for ferralic B horizon are met.

---

LOCATION : Hainan, Wan-Ning county, Xing-Long town, east of Tai Yang River
Latitude : 18°46′ N Longitude : 110°20′ E Altitude : 40 m a.s.l.
AUTHOR(S) : Kauffman, J.H. / Wang Minzhu and Liang Date (mm/yy) : 10/9[illegible]

---

GENERAL LANDFORM : plain Topography : undulating
PHYSIOGRAPHIC UNIT : low, broad, interfluve (hill)
SLOPE Gradient : 2% Form : convex
POSITION OF SITE : crest
MICRO RELIEF Kind :
SURFACE CHAR. Rock outcrop : nil Stoniness : nil
Cracking : Slaking/crusting :
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : not observed

---

PARENT MATERIAL : residual material derived from coarse-acid igneous rock (granite)
Weathering degree : slight

---

EFFECTIVE SOIL DEPTH : 200 cm

---

WATER TABLE : no watertable observed
DRAINAGE : well
PERMEABILITY : no slowly permeable layer(s)
FLOODING Frequency : nil
MOISTURE CONDITIONS PROFILE : 0 - 20 cm dry 20 - 200 cm moist

---

LAND USE : fallow. Former land-use rubber trees

---

ADDITIONAL REMARKS :
The east coastal erosion terrace in the granite consists of an undulating to nearly flat landscape. Hilly parts alternate with large flat valley plains merging towards the coastal plains. The soils developed in the granite hills are not very deep, generally between 0.5 to 1.5 meter. The granite rock is weathered to great depth (> 10 meter). The deeper subsoils frequently show strong mottling probably caused by past high groundwater levels ('pseudo plinthite'?).
10 km north of the site the upper half of the soil consists of 50% or more coarse ironstone gravel overlying the weathered granite saprolite. It is not clear if the ironstone gravel is the result of in situ soil forming processes, or results from deposition (alluvial/colluvial processes).

---

CLIMATE : Köppen: Am
Station: LINGSHUI 18 30 N / 110 2 E 10 m a.s.l. 30 km SE of site Relevance: good

| | | No. years of record | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pan evaporation | mm | 25 | 149 | 132 | 154 | 166 | 190 | 170 | 182 | 159 | 145 | 161 | 158 | 153 | 19[illegible]9 |
| PET (P.-M.) | mm | 25 | 90 | 84 | 109 | 123 | 146 | 138 | 149 | 136 | 120 | 121 | 105 | 96 | 14[illegible]6 |
| relative humidity | % | 25 | 78 | 81 | 83 | 84 | 83 | 85 | 84 | 86 | 86 | 81 | 77 | 77 | [illegible]2 |
| precipitation | mm | 25 | 10 | 13 | 24 | 65 | 148 | 229 | 155 | 271 | 343 | 278 | 99 | 19 | 16[illegible]4 |
| no. of raindays | | 25 | 5 | 5 | 5 | 7 | 13 | 17 | 15 | 18 | 19 | 16 | 9 | 5 | 1[illegible]2 |
| T mean | °C | 25 | 19.8 | 20.7 | 23.2 | 25.6 | 27.6 | 28.0 | 28.0 | 27.4 | 26.7 | 25.2 | 23.1 | 20.9 | 2[illegible].7 |
| T max | °C | 25 | 24.3 | 25.0 | 27.3 | 29.6 | 31.6 | 31.6 | 31.8 | 31.3 | 30.6 | 29.0 | 26.9 | 25.1 | 2[illegible].7 |
| T min | °C | 25 | 16.6 | 17.9 | 20.5 | 22.8 | 24.8 | 25.4 | 25.3 | 24.7 | 24.0 | 22.4 | 20.2 | 17.9 | 2[illegible].9 |
| windspeed(at 2m) | m/s | 25 | 2.3 | 2.0 | 1.8 | 1.7 | 1.7 | 1.6 | 1.6 | 1.4 | 1.7 | 2.5 | 2.7 | 2.5 | [illegible].9 |
| bright sunshine | h/d | 25 | 6.3 | 5.7 | 5.8 | 6.9 | 7.8 | 7.5 | 8.2 | 7.1 | 6.6 | 6.6 | 6.4 | 6.4 | [illegible].8 |
| bright sunshine | % | 25 | 57 | 49 | 49 | 55 | 61 | 57 | 63 | 56 | 54 | 57 | 57 | 58 | [illegible]6 |

PROFILE DESCRIPTION :

Very deep, well drained, yellowish red coarse sandy loam; deeper subsoil is strongly mottled. The soil colour of the BA horizon is slightly darker. It is assumed that the overlying topsoil is strongly influenced by human activity.

| | | |
|---|---|---|
| Ap | 0 - 6 cm | Dark brown (7.5YR 3/4, moist) coarse loamy sand (field), sandy clay loam (lab); structureless to weak crumb structure; non sticky, non plastic, loose, loose; many fine and common coarse roots throughout; clear smooth boundary to |
| AB | 6 - 30 cm | Strong brown (7.5YR 5/6, moist) sandy loam (field), sandy clay (lab); weakly coherent porous massive to weak medium subangular blocky structure; slightly sticky, slightly plastic, very friable, slightly hard; many fine interstitial pores; many fine and few coarse roots throughout; clear smooth boundary to |
| BA | 30 - 45 cm | Dark brown (7.5YR 4/6, moist) sandy loam (field), sandy clay (lab); weakly coherent porous massive to weak medium subangular blocky structure; slightly sticky, slightly plastic, very friable; many fine interstitial pores; common fine roots throughout; clear smooth boundary to |
| Bw | 45 - 110 cm | Yellowish red (5YR 5/8 moist) sandy loam (field), clay (lab); weakly coherent porous massive structure; slightly sticky, slightly plastic, very friable; many fine interstitial pores; common fine roots throughout; diffuse smooth boundary to |
| BC(g) | 110 - 140 cm | Yellowish red (5YR 5/8, moist) coarse loamy sand (field), sandy clay loam (lab); porous massive structure; non sticky, non plastic, very friable; few coarse distinct brownish yellow (10YR 6/8) mottles; many fine interstitial pores; few fine roots throughout; diffuse smooth boundary to |
| CB(g) | 140 - 200 cm | Yellowish red (5YR 5/8 moist) coarse loamy sand (field), sandy clay loam (lab); weakly coherent porous massive structure; non sticky, non plastic, very friable; many coarse prominent brownish yellow (10YR 6/8) mottles; many fine interstitial pores |

ANALYTICAL DATA :

| Hor. no. | Top - Bot | >2 mm | 2000 1000 | 1000 500 | 500 250 | 250 100 | 100 50 | TOT SAND | 50 20 | 20 2 | TOT SILT | <2 µm | DISP | BULK DENS | pF- 0.0 | 1.0 | 1.5 | 2.0 | 2.3 | 2.7 | 3.4 | 4.2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 - 6 | - | 27 | 12 | 7 | 7 | 2 | 56 | 1 | 10 | 11 | 33 | 19.0 | - | - | - | - | - | - | - | - | - |
| 2 | 6 - 30 | - | 24 | 11 | 6 | 7 | 3 | 52 | 1 | 10 | 12 | 37 | 7.4 | - | - | - | - | - | - | - | - | - |
| 3 | 30 - 45 | - | 28 | 10 | 6 | 7 | 2 | 52 | 2 | 9 | 11 | 37 | 6.6 | - | - | - | - | - | - | - | - | - |
| 4 | 45 - 110 | - | 23 | 8 | 4 | 4 | 3 | 42 | 4 | 9 | 13 | 45 | 2.3 | - | - | - | - | - | - | - | - | - |
| 5 | 110 - 140 | - | 22 | 9 | 5 | 7 | 3 | 46 | 7 | 16 | 23 | 32 | 2.9 | - | - | - | - | - | - | - | - | - |
| 6 | 140 - 180 | - | 21 | 10 | 6 | 8 | 5 | 48 | 6 | 16 | 22 | 30 | 5.5 | - | - | - | - | - | - | - | - | - |

| Hor. no. | Top - Bot | pH- H2O | KCl | CaCO3 % | ORG-C % | MAT. N % | EXCH CAT. Ca | Mg | K | Na | sum | EXCH AC. H+Al | Al | CEC soil | clay | OrgC | ECEC | BASE SAT % | Al SAT % | EC 2.5 ms $cm^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | cmol$_c$ $kg^{-1}$ | | | | | | | | | | | | | |
| 1 | 0 - 6 | 3.9 | 3.9 | - | 1.87 | 0.18 | 0.2 | 0.3 | 0.2 | 0.1 | 0.8 | 1.7 | 1.1 | 5.3 | 16 | 6.5 | 2.5 | 15 | 21 | 0.16 |
| 2 | 6 - 30 | 4.0 | 4.0 | - | 1.16 | 0.10 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 1.7 | 1.4 | 3.5 | 9 | 4.1 | 1.9 | 6 | 40 | 0.07 |
| 3 | 30 - 45 | 4.1 | 4.0 | - | 0.87 | 0.09 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 1.6 | 1.1 | 3.7 | 10 | 3.0 | 1.8 | 5 | 30 | 0.04 |
| 4 | 45 - 110 | 4.1 | 4.0 | - | 0.44 | 0.07 | 0.2 | 0.0 | 0.0 | 0.0 | 0.2 | 1.8 | 1.6 | 2.8 | 6 | 1.5 | 2.0 | 7 | 57 | 0.04 |
| 5 | 110 - 140 | 4.2 | 4.0 | - | 0.13 | 0.03 | 1.6 | 0.0 | 0.0 | 0.1 | 1.7 | 1.8 | 1.6 | 3.9 | 12 | 0.5 | 3.5 | 44 | 41 | 0.04 |
| 6 | 140 - 180 | 4.2 | 4.0 | - | 0.14 | 0.03 | 1.4 | 0.0 | 0.0 | 0.0 | 1.4 | 1.9 | 1.6 | 2.8 | 9 | 0.5 | 3.3 | 50 | 57 | 0.04 |

CLAY MINERALOGY (1 very weak, ..., 8 very strong) / EXTRACTABLE Fe & Al by Na DITHIONITE / AVAIL. P (Bray)

| Hor. no. | Top - Bot | CHLO | KAOL | MIX | GIBB | GOET | Fe | Al | AVAIL. P (Bray) mg $kg^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 - 6 | 2 | 8 | 2 | 2 | 4 | 1.8 | 0.3 | 1.9 |
| 2 | 6 - 30 | 2 | 8 | 2 | 2 | 4 | 1.8 | 0.3 | 2.9 |
| 3 | 30 - 45 | 2 | 8 | 2 | 2 | 4 | 2.0 | 0.4 | 1.1 |
| 4 | 45 - 110 | 2 | 8 | 2 | 2 | 4 | 2.6 | 0.4 | 0.3 |
| 5 | 110 - 140 | 2 | 8 | 2 | 2 | 4 | 2.0 | 0.2 | 0.8 |
| 6 | 140 - 180 | - | 8 | 1 | 2 | 4 | 2.0 | 0.3 | 0.9 |

# Annex 2 Evaluation of Soil/Land Qualities

**LAND QUALITY** Availability (1) | vh | h | m | l | vl |

vh=very high h=high m=moderate l=low vl=very low

Hazard/Limitation (2) | n | w | m | s | vs |

n=not present w=weak m=moderate s=serious vs=very serious

| | | CN 17 | | | | | CN 18 | | | | | CN 20 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CLIMATE** | | | | | | | | | | | | | | | | |
| Radiation regime - total radiation | 1 | | | | | | | | | | | | | | | |
| - day length | 1 | | | | | | | | | | | | | | | |
| Temperature regime | 1 | | | | | | | | | | | | | | | |
| Climatic hazards (typhoon) | 2 | | | ■ | ■ | | | | ■ | ■ | | | | ■ | ■ | |
| Conditions for ripening | 1 | | | | | | | | | | | | | | | |
| Length growing season | 1 | ■ | | | | | ■ | | | | | ■ | | | | |
| Drought hazard during growing season | 2 | ■ | | | | | ■ | | | | | ■ | | | | |
| **SOIL** | | | | | | | | | | | | | | | | |
| Potential total soil moisture | 1 | | ■ | | | | | ■ | | | | | | | | |
| Oxygen availability | 1 | ■ | | | | | ■ | | | | | ■ | | | | |
| Nutrient availability | 1 | | | | | ■ | | | | | ■ | | | | | ■ |
| Nutrient retention capacity | 1 | | | | | ■ | | | | | ■ | | | | | ■ |
| Rooting conditions | 1 | ■ | | | | | ■ | | | | | ■ | | | | |
| Conditions affecting germination | 1 | ■ | | | | | | | | | | | | | | |
| Excess of salts - salinity | 2 | ■ | | | | | ■ | | | | | ■ | | | | |
| - sodicity | 2 | ■ | | | | | ■ | | | | | ■ | | | | |
| Soil toxicities (e.g. high Al sat.) | 2 | | ■ | | | | | ■ | | | | | | ■ | | |
| **LAND MANAGEMENT** | | | | | | | | | | | | | | | | |
| Initial land preparation | 2 | | | | | | | | | | | | | | | |
| Workability | 1 | | ■ | | | | | ■ | | | | ■ | | | | |
| Potential for mechanization | 1 | ■ | | | | | ■ | | | | | ■ | | | | |
| Accessibility - existing | 1 | ■ | | | | | ■ | | | | | ■ | | | | |
| - potential | 1 | | | | | | | | | | | | | | | |
| Erosion hazard - wind | 2 | | | | | | | | | | | | | | | |
| - water | 2 | | | ■ | | | | | | | | | | | | |
| Flood hazard | 2 | ■ | | | | | ■ | | | | | ■ | | | | |
| Pests and diseases | 2 | | | | | | | | | | | | | | | |

***COMMENTS***

**LAND QUALITY** Availability (1)
Hazard/Limitation (2)

| | | | | | |
|---|---|---|---|---|---|
| (1) | vh | h | m | l | vl |
| (2) | n | w | m | s | vs |

vh = very high  n = not present
h = high  w = weak
m = moderate  m = moderate
l = low  s = serious
vl = very low  vs = very serious

## CN 19

### CLIMATE

| | | | | | | |
|---|---|---|---|---|---|---|
| Radiation regime - total radiation | 1 | | | | | |
| - day length | 1 | | | | | |
| Temperature regime | 1 | | | | | |
| Climatic hazards (typhoons) | 2 | | ■ | | | |
| Conditions for ripening | 1 | | | | | |
| Length growing season | 1 | | | | | |
| Drought hazard during growing season | 2 | ■ | | | | |

### SOIL

| | | | | | | |
|---|---|---|---|---|---|---|
| Potential total soil moisture | 1 | | ■ | | | |
| Oxygen availability | 1 | | ■ | | | |
| Nutrient availability | 1 | | | | | ■ |
| Nutrient retention capacity | 1 | | | | | ■ |
| Rooting conditions | 1 | ■ | | | | |
| Conditions affecting germination | 1 | | | | | |
| Excess of salts - salinity | 2 | ■ | | | | |
| - sodicity | 2 | ■ | | | | |
| Soil toxicities (e.g. high Al sat.) | 2 | | | ■ | | |

### LAND MANAGEMENT

| | | | | | | |
|---|---|---|---|---|---|---|
| Initial land preparation | 2 | | | | | |
| Workability | 1 | | ■ | | | |
| Potential for mechanization | 1 | | | | | ■ |
| Accessibility - existing | 1 | | | | | ■ |
| - potential | 1 | | | ■ | | |
| Erosion hazard - wind | 2 | | | | | |
| - water | 2 | | | | | ■ |
| Flood hazard | 2 | ■ | | | | |
| Pests and diseases | 2 | | | | | |

***COMMENTS***

# Annex 3 Units, Glossary, Classes and Acronyms

## UNITS

| Chinese weights and measures | SI equivalent |
|---|---|
| 1 mu | 0.067 ha |
| 1 jin | 0.5 kg |
| 1 jin/mu | 0.133 kg $ha^{-1}$ |

**Other units**

| | |
|---|---|
| $cmol_c\ kg^{-1}$ | centimol charge per kilogram (formerly meq/100 g; 1 meq/100 g = 1 $cmol_c\ kg^{-1}$) |
| $\mu m$ | micro-metre: 1/1000th of a millimetre. |
| $mg\ kg^{-1}$ | milligram per kilogram (formerly parts per million (ppm)) |
| $mS\ cm^{-1}$ | milliSiemens per cm at 25°C (formerly mmho $cm^{-1}$) |
| MJ | Megajoules (formerly kcal; 1 MJ = 4186.8 kcal) |

## GLOSSARY

| | |
|---|---|
| Air capacity | Amount of pore space filled with air 2 or 3 days after soil has been wetted. It is calculated from the difference between amount of water under almost saturated conditions (pF 0.0) and moisture retained at "field capacity" (pF 2.0), and expressed as volume percentage. |
| Al saturation | Ratio of exchangeable aluminium to the CEC, expressed as percentage. |
| Available soil moisture | Amount of moisture retained between "field capacity" (pF 2.0) and "wilting point" (pF 4.2), expressed as volume percentage (also called "available water capacity"). It is indicative of the amount of moisture available for plant growth. |
| Base saturation | Ratio of the sum of bases to the CEC, expressed as percentage. |
| Bulk density | Weight of an undisturbed soil sample divided by its volume. |
| CEC | Cation exchange capacity, indicative of the potential nutrient retention capacity of the soil. |
| Clay mineralogy | Type of clay-sized (< 2$\mu$m) particles. |
| kaolinite | Clay mineral with a low nutrient retention capacity, common in soils from (sub)tropical regions. |
| smectite | Silica-rich clay mineral with a high nutrient retention capacity and the ability to absorb water, resulting in swelling of the clay particles. |
| illite | Potassium-rich clay mineral with a moderately high nutrient retention capacity, common in soils from temperate regions and in alluvial soils. |
| vermiculite | Clay mineral with a high nutrient retention capacity and strong potassium-fixation. |
| chlorite | Aluminium-rich clay mineral with a moderately high nutrient retention capacity, occurring in variable quantities in soils rich in aluminium. |
| halloysite | Clay mineral with a moderately high nutrient retention capacity, common in soils derived from volcanic ashes. |
| quartz | Residual silica, resistant to weathering. |
| feldspar | Residual primary mineral, unstable in soil environments and, if present, indicative of a slight to moderate degree of weathering. |
| hematite | Reddish coloured iron oxide, common in well drained soils of tropical regions. |
| goethite | Yellowish coloured hydrated iron oxide, common in soils of temperate regions. |
| gibbsite | Aluminium hydroxide, indicative of a high degree of weathering. |
| Consistence | Refers to the degree and kind of cohesion and adhesion of the soil material, or to the resistance to deformation or rupture. |
| ECEC | Effective cation exchange capacity. It is calculated by addition of the sum of bases and exchangeable acidity, and reflects the actual nutrient retention capacity of the soil. |
| ESP | Exchangeable sodium percentage, ratio of exchangeable sodium to the CEC, expressed as percentage. |
| Exchangeable acidity | Sum of exchangeable hydrogen and aluminium. |
| Fine earth fraction | Part of the soil material with a particle-size of 2 mm or less (nearly all analyses are carried out on this soil fraction). |
| Horizon | Layer of soil or soil material approximately parallel to the earth's surface. |
| Land characteristic | Measurable property of land (e.g. texture). |
| Land quality | Set of interacting land characteristics which has a distinct influence on land suitability for a specified use (e.g. erosion hazard, which is a.o. influenced by slope, rainfall intensity, soil cover, infiltration rate, soil surface characteristics, texture). |
| Leaching | Downward or lateral movement of soil materials in solution or suspension. |
| Mottle | Spot or blotch differing in colour from its surroundings, usually indicative of poor soil drainage. |

| | |
|---|---|
| Organic carbon | Content of organic carbon as determined in the laboratory (% org. C x 1.72 = % org. matter) |
| Parent material | The unconsolidated mineral or organic material from which the soil is presumed to have been developed by pedogenetic processes. |
| pF value | Measure for soil moisture tension. |
| SAR | Sodium adsorption ratio of the soil solution, indicative of sodication hazard. |
| Soil reaction (pH) | Expression of the degree of acidity or alkalinity of the soil. |
| Soil structure | Aggregates of primary soil particles (sand, silt, clay) called peds, described according to grade, size and type. |
| Sum of bases | Total of exchangeable calcium ($Ca^{++}$), magnesium ($Mg^{++}$), potassium ($K^{+}$) and sodium ($Na^{+}$). |
| Texture | Refers to the particle-size distribution in a soil mass. The field description gives an estimate of the textural class (e.g. sandy loam, silty clay loam, clay); the analytical data represent the percentages sand, silt and clay measured in the laboratory. |
| Water soluble salts | Salts more soluble in water than gypsum. |

## CLASSES OF SOME ANALYTICAL SOIL PROPERTIES

**Organic Carbon - C (%)**

| | |
|---|---|
| < 0.3 | very low |
| 0.3 - 1.0 | low |
| 1.0 - 2.0 | medium |
| 2.0 - 5.0 | high |
| > 5.0 | very high |

**Acidity pH-$H_2O$**

| | |
|---|---|
| < 4.0 | extremely acid |
| 4.0 - 5.0 | strongly acid |
| 5.0 - 5.5 | acid |
| 5.5 - 6.0 | slightly acid |
| 6.0 - 7.5 | neutral |
| 7.5 - 8.0 | slightly alkaline |
| 8.0 - 9.0 | alkaline |
| > 9.0 | strongly alkaline |

| Available phosphorus (mg $kg^{-1}$) | Olsen | Bray |
|---|---|---|
| low | < 5 | < 15 |
| medium | 5 - 15 | 15 - 50 |
| high | > 15 | > 50 |

**CEC [pH7] (cmol$_c$ $kg^{-1}$ soil)**

| | |
|---|---|
| < 4 | very low |
| 04 - 10 | low |
| 10 - 20 | medium |
| 20 - 40 | high |
| > 40 | very high |

**Sum of bases (cmol$_c$ $kg^{-1}$ soil)**

| | |
|---|---|
| < 1 | very low |
| 1 - 4 | low |
| 4 - 8 | medium |
| 08 - 16 | high |
| > 16 | very high |

**Base saturation - BS [CEC pH7] (%)**

| | |
|---|---|
| < 10 | very low |
| 10 - 20 | low |
| 20 - 50 | medium |
| 50 - 80 | high |
| > 80 | very high |

**Aluminium saturation (%)**

| | |
|---|---|
| < 5 | very low |
| 05 - 30 | low |
| 30 - 60 | moderate |
| 60 - 85 | high |
| > 85 | very high |

**Exchangeable sodium percentage - ESP (%)**

| *Soil structure* | | *Crops* |
|---|---|---|
| < 5 | very low | < 2 |
| 05 - 10 | low | 02 - 20 |
| 10 - 15 | medium | 20 - 40 |
| 15 - 25 | high | 40 - 60 |
| > 25 | very high | > 60 |

**Bulk density (kg $dm^{-3}$)**

| | |
|---|---|
| < 0.9 | very low |
| 0.9 - 1.1 | low |
| 1.1 - 1.5 | medium |
| 1.5 - 1.7 | high |
| > 1.7 | very high |

## ACRONYMS

| | |
|---|---|
| FAO | Food and Agricultural Organization of the United Nations |
| ISIS | ISRIC Soil Information System |
| ISRIC | International Soil Reference and Information Centre |
| ISSAS | Institute of Soil Science - Academia Sinica |
| SCS | Soil Conservation Service |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| USDA | United States Department of Agriculture |

# Soil Briefs of China

(ISSN: 1381-6950)

| No. | Title | No. of soils* |
|---|---|---|
| CN 1 | Red reference soils of the subtropical Yunnan Province | 3 |
| CN 2 | Reference soil ("Latosol") of tropical southern Yunnan Province | 1 |
| CN 3 | Yellow/brown reference soils of subtropical Guizhou Province | 3 |
| CN 4 | Purple upland and lowland reference soils of subtropical Sichuan Province | 2 |
| CN 5 | Reference soils of the subtropical mountains of Jiangxi Province | 3 |
| CN 6 | Reference soils of the subtropical mountains of Guangdong Province | 3 |
| CN 7 | Reference soils of tropical China (Hainan Island) | 4 |
| CN 8 | Reference soils of the Red Basins of Jiangxi Province | 5 |
| CN 9 | Reference soil of Chaoyang County, typical of the formerly wooded hilly areas in the SW of Liaoning Province | 1 |
| CN 10 | Reference soils of the Liaohe plain, Liaoning Province | 2 |
| CN 11 | Reference soil of the Changbai Mountains, Jilin Province | 1 |
| CN 12 | Reference soils of the Songnen plain, Heilongjiang Province | 4 |
| CN 13 | Reference soil of the Wudalianchi volcanic area, Heilongjiang Province | 1 |
| CN 14 | Reference paddy soils of the eastern alluvial lowlands of China (in prep.) | 3 |

# Country Reports

(ISSN: 1381-5571)

| No. | Country | No. of soils* |
|---|---|---|
| 1 | Cuba | 22 |
| 2 | P.R. of China | 51 |
| 3 | Turkey | 15 |
| 4 | Côte d'Ivoire | 7 |
| 5 | Thailand | 13 |
| 6 | Colombia | 18 |
| 7 | Indonesia | 48 |
| 8 | Ecuador | in prep. |
| 9 | Brazil | 28 |
| 10 | Peru | 21 |
| 11 | Nicaragua | 11 |
| 12 | Costa Rica | 12 |
| 13 | Zambia | 11 |
| 14 | Uruguay | 10 |

| No. | Country | No. of soils* |
|---|---|---|
| 15 | Gabon | 6 |
| 16 | Ghana | in prep. |
| 17 | Philippines | 6 |
| 18 | Zimbabwe | 13 |
| 19 | Spain | 20 |
| 20 | Italy | 17 |
| 21 | Greece | in prep. |
| 22 | India | in prep. |
| 23 | Kenya | in prep. |
| 24 | Mali | in prep. |
| 25 | Nigeria | in prep. |
| 26 | Mozambique | in prep. |
| 27 | Botswana | in prep. |

* State of reference collections as of January 1995