Soil Brief *China 1*

PEOPLE'S REPUBLIC OF CHINA

Red reference soils of the subtropical Yunnan Province

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Institute of Soil Science - Academia Sinica

International Soil Reference and Information Centre

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ISRIC Soil Monoliths:

Number	*FAO-Unesco*	*Soil Taxonomy*	*Chinese classification*
CN 43	Haplic Lixisol	Mollic Kandiudalf	Argillic Red Soil
CN 45	Haplic Phaeozem	Ruptic-Lithic Haplustoll	Haplic Dry Red Soil
CN 46	Stagnic Luvisol	Aquic Haplustalf	Haplic Red Cinnamon Soil

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ABSTRACT

Three representative soils, located in different subregions of the northern part of the Subtropical Yunnan Province were studied for the establishment of a Chinese soil reference collection and pedon database. Description and sampling was carried out in the framework of an European Community supported cooperation programme between the "Institute of Soil Science, Academia Sinica", Nanjing, People's Republic of China and the "International Soil Reference and Information Centre", Wageningen, The Netherlands.

The first subregion, the eastern part of the Yunnan Karst Plateau is characterized by high temperatures and an unevenly distributed precipitation resulting in marked dry and wet seasons. Near Luliang, a very deep well drained, red clay developed from alluvial and colluvial deposits from limestone was studied. The soil is classified as an Argillic Red Soil (Chinese) or a Haplic Lixisol (FAO-Unesco).
The land was used for potatoes which were intercropped with mulberries. Rooting conditions, workability and the potential for mechanization are favourable. The soil has low level of available nutrients and low nutrient reserves. Precipitation in the winter months and the potential total soil moisture are low, so plants may develop water stress. There is a moderate erosion hazard, which requires conservation measures such as contour ploughing.

The climate of the second subregion, called "Narrow dissections of the Honghe River" is influenced by a foehn wind. This results in a long and hot dry season, and evaporation which is 2 to 3 times higher than precipitation. In the broad valley of the Yuan Jiang river, near Yuanjiang, a moderately deep, well drained, dark gravelly red clay developed from granite was studied. The soil is classified as a Haplic Dry Red Soil (Chinese) or a Ruptic-Lithic Haplustoll (USDA ST). In the Chinese classification, the dry climate of the region is well expressed, in USDA-ST the limited soil depth to the granitic parent material is expressed.

The land is cultivated with sugar cane, which is not yielding very well due to the low soil fertility and the deficiency of moisture, caused by the high evaporation and the small water storage capacity. Irrigation is not easy, due to the undulating topography. The limited soil depth and the surface stoniness reduce the potential for mechanization and reduces rooting.

The Central Yunnan Plateau and Lake Basins are the third subregion, and characterized by warm winter and cool summer temperatures. The precipitation is low and unevenly distributed. Near Yuanmou a shallow, moderately well drained, reddish brown sandy clay loam to silty clay derived from sandstone was studied. The soil is classified as a Haplic Red Cinnamon Soil (Chinese) or Stagnic Luvisol (FAO-Unesco).
Serious water erosion has degraded the area and formed the so called "soil forest". Gullies with a depth of more than 30 m are found, but also sheet and rill erosion occur. Conservation measures like reforestation as practised on the studied site, are needed to protect the area against further degradation.

摘 要

爲建立中國土壤樣品參比庫和土壤剖面數據庫，三個典型土壤剖面采自位于亞熱帶的雲南省北部三個不同地區。該項目在歐共體SIDA項目資助下，由中國科學院南京土壤所和荷蘭國際土壤信息參比中心合作實施。

第一個土壤剖面采集地位于雲南喀斯特高原東部陸良縣。氣候高熱，降雨不均，旱季和雨季分明。土層深厚，排水良好，紅色粘土質，發育于石灰岩沖積物和坡積物上。該土壤分類爲粘化紅壤（中國土壤系統分類，1990）即普通低活性淋溶土（FAO土壤分類，1989）。

現行土地利用方式爲土豆和桑樹間作。土壤根系條件良好，適耕性强并且機械化潛力高。但是土壤速效養分和緩效養分低。東季少雨，土壤温度低，作物受到水分脅迫。存在中度土壤侵蝕，應采取等高耕作等水土保持措施。

第二個土壤剖面采集地位于紅河河谷，受干熱焚風影響，夏季長而干熱，蒸發比降雨高2-3倍。土層較深，排水良好，暗紅色粘土質混有礫石，發育于元江河谷的花崗岩上。該土壤分類爲普通淋紅土（中國土壤系統分類，1990）即石質接觸弱發育干潤軟土（美國土壤系統分類，1992）。前者的命名干燥的氣候得以表達，后者的强調了石質接觸。

現行土地利用方式爲干蔗，由于受制于土壤養分和水分，産量不高。而起伏不平的地形不適于灌溉。由于土層深度有限并且表層多石礫，機械化耕作難以實現，同時也不利于根系生長。

第三個土壤剖面采集地位于雲南高原滇池盆地中部的熱帶經濟作物資源保護區。氣候呈東暖夏凉，少雨且分配不勻。土層較淺，排水中等，紅棕色砂粘壤土到粉砂粘土質地，發育于砂岩。該土壤分類爲普通紅褐土（中國土壤系統分類，1990）即潛水淋溶土（FAO土壤分類，1989）。

該地區水土侵蝕嚴重，形成所謂的"土林"。有時能看見深達30米的侵蝕溝，同時存在片蝕和細溝侵蝕。爲防止土地進一步退化，開展植樹造林等水土保護措施已成當務之急。

FOREWORD

The objective of a Soil Brief is to provide a description of a reference soil typical for a certain agro-ecological zone. The Soil Brief is composed of a text part which includes some graphical presentations of the most outstanding phenomena as well as data annexes. The reference soils are representative red soils situated in the northern part of the subtropical Yunnan Province of the People's Republic of China.

The Soil Brief is written for soil specialists and non-soil specialists. For the latter the comprehensive field and laboratory data as being processed with the ISRIC's Soil Information System (ISIS) are often too complex and/or too detailed and therefore require clarification in the text. For the soil scientist the text part can be of use as it summarizes the important land and soil qualities, relevant aspects of soil management and soil formation. Furthermore, it provides access to additional information from research and discussions, which cannot be stored in the computerized database. Also within the text reference is made to specific literature that can be consulted in order to enter more in detail.

In this Soil Brief, the text part includes a general characterization of the northern part of Yunnan Province presenting climate, geology and geomorphology (Chapter 1). Also a more specific description is given of the subregions in which the studied soils are situated (Chapter 2). Next a description and discussion of the major characteristics of each of the soils and their taxonomical classification follows, as well as their location and occurrence (Chapter 3). An evaluation of the land qualities and limitations for assessing appropriate land use is included. In the annexes the soil and environmental data, available from field, laboratory and office work are given.

In 1993 the "Institute of Soil Science, Academia Sinica" (ISS-AS), Nanjing, People's Republic of China and the "International Soil Reference and Information Centre" (ISRIC), Wageningen, The Netherlands described and sampled in SW-China nine reference soils for the establishment of a Chinese soil reference collection and pedon database at ISS-AS. Duplicates of these soils were collected for ISRIC's world soil collection. In this Soil Brief three of these reference soils are presented.

Valuable comments on draft versions of this report were received from ISSAS and ISRIC staff, and by Dr. T. de Meester. 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 Dr. E.M. Bridges (editing), Ms M.B. Clabaut (text processing) and Ms J.W. Resink (map compilation). Useful comments on the draft of this Soil Brief were obtained from Mr. A.E. Hartemink.

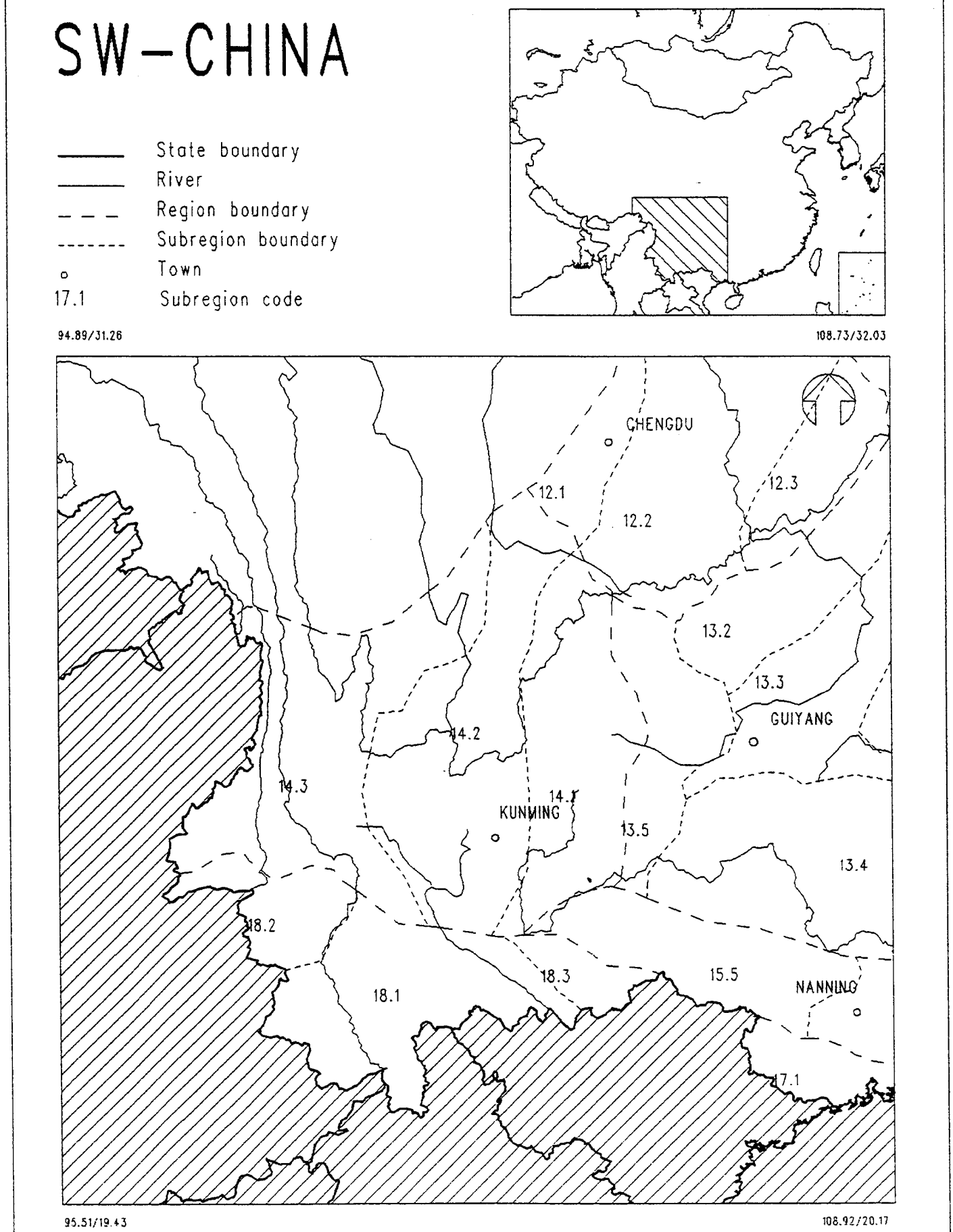


Figure 1 Major physiographic (sub)regions of South-western China.

1 THE YUNNAN PLATEAU

1.1 Introduction

The Yunnan Plateau is located roughly between 24 to 28°N and 98 to 105°E, and covers an area of about 300,000 km^2. It is the transitional belt between two great natural realms in China: the Qinghai-Xizang Plateau and the Eastern Humid Monsoon Realm.

1.2 Climate

The area is dominated by the so-called plateau monsoon- the southwestern (Indian) monsoon in the western part and the southeastern (Pacific) monsoon in the eastern part. Due to its topographic conditions and latitudinal location, the weather is mild all year round. Annual precipitation totals 1000 to 1200 mm, decreasing from southeast and southwest to middle north. The distinction between the rainy season (May to October) and the dry season (November to April) is clear, with "winter" (December to February) accounting for only 5% of total annual precipitation.
According to the Köppen classification system the Yunnan Plateau belongs to the area with a Humid Subtropical Climate, characterised by a humid warm summer and a dry winter (Caw).

1.3 Geomorphology

The Yunnan Plateau was formed by a strong uplift of the surface in the late Pliocene and early Pleistocene. The area is higher in the northwestern part where the Meli Snow Mountain reaches an altitude of 6740 m a.s.l. The southeastern valley of the Honghe river is only 76 m high. The landscape is characterized by a well preserved undulating plateau surface and broad like basins, mostly with elevations ranging from 1500 to 3000 m a.s.l. In the southern part of the Hengduan Mountains area, a series of north-south oriented elevated mountain ridges occur which are running parallel to large river gorges. This ridge and gorge topography is particularly prominent north of 25°N. In the eastern part of the Plateau the karst topography is extensively present.

1.4 Vegetation and land use

The zonal vegetation type is evergreen broad-leave forest, with *Cyclobalanopsis glaucoides*, *Cyclobalanopsis delavayi*, and *Castanopsis delavayi* as dominant trees. After human intervention the drought tolerant Yunnan Pine (*Pinus yunnanensis*) forest now prevails, intermingled also with *Pinus armandii* and *Keteleeria evelyniana*.

Agriculture is related to altitude. Semiarid, subtropical valleys below 1000 m a.s.l. are used as farmland with double-cropping of rice if irrigation water is available. Farmland between 1000 and 2400 m a.s.l. is generally under a rice-wheat cropping system. Farmland above 2400 m a.s.l. is characterized by a one-crop dryfarming system (Zhao Songqiao, 1986).
About 40 million people are living in this part of China. Of the 300,000 km^2 only 7% is cultivated, while about 30% has an agricultural potential. Tobacco, tea and rubber are cash crops. Seasonal droughts form the major limitation.

2 SUBREGIONS OF THE YUNNAN PLATEAU

The Yunnan Plateau can be subdivided into different subregions (Fig. 1). A physiographic description of three of the regions is presented in the following paragraphs. Each of them matches with one of the soil types discussed in the next chapter.

2.1 The Eastern Yunnan Karst Plateau

This subregion is indicated within Fig. 1 with the code 14.1.

2.1.1 Geology and geomorphology

Carbonate rock occupies more than 50% of the total land area. The thickness is more than 3300 m. Karst topography is widely distributed. The distinction between mountains covered by vegetation and denudated ones is quite significant in the subregion. Soil conservation and reforestation are the most important measures to transform the present poverty-stricken landscape.

2.1.2 Climate

The climatic conditions are characterized by a frostless season of 240- 300 days and average temperatures which are 7 to 18°C. The precipitation is distributed unevenly, most of it is concentrated from March to June. It normally comes in the form of strong winds and heavy rainshowers resulting in severe soil erosion. Drought often occurs in July and August (Zhao Qiguo *et al.*, 1990).
Fig. 2 and 3 show monthly data of the maximum, average and minimum temperatures, from the meteorological station Luliang, located at about 12 km from the studied site CN 43. Fig. 3 presents mean monthly data for precipitation and evaporation measured in Luliang. Both figures were made with SOLGRAPH (Brunt & Kauffman, 1995). The distribution of rainfall is directly related to the cultivation of potatoes, a traditional crop of great importance in this part of China (see section 3.6.1).

2.1.3 Vegetation and land use

The primary vegetation is subtropical evergreen broad-leaved forests predominated by genera of beech family including evergreen Chinkapins (*Castnopsis Spach*), and tan oaks (*Lithocarpus Bl.*). The soils can produce three crops annually, and many subtropical cash crops can be planted in addition to food crops (Zhao Qiguo *et al.*, 1990). Once the original vegetation has been destroyed on limestone hills and mountains, shrubby grassland or even bare rocks tend to emerge. Due to the uneven distributed rainfall and the lack of surface and ground water, agriculture is restricted to dryfarming.

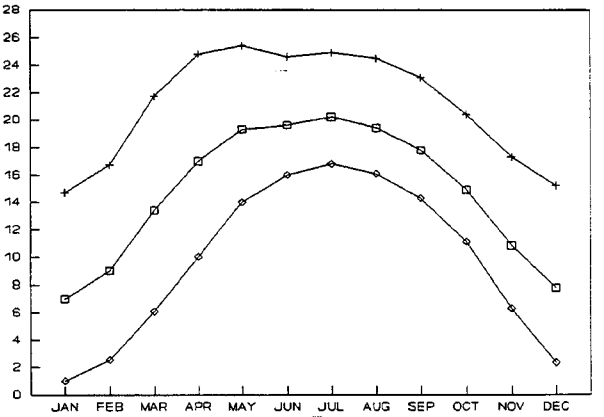


Figure 2 Maximum (+), average (□) and minimum (◊) temperature in °C at Luliang meteorological station.

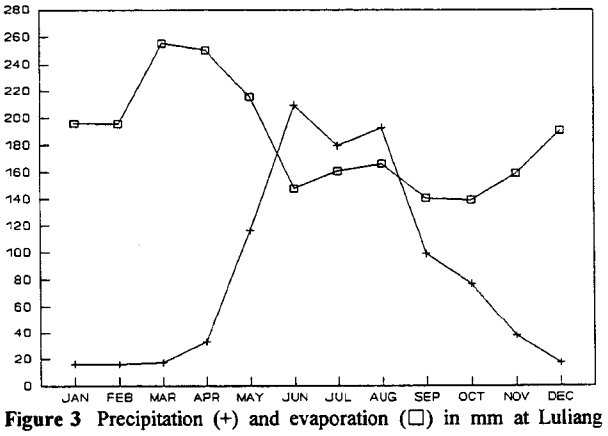


Figure 3 Precipitation (+) and evaporation (□) in mm at Luliang meteorological station.

2.2 Narrow dissections of the Honghe River

This subregion is too small to be identified within Fig. 1.

2.2.1 Climate

Due to the great difference of height between mountains and valleys, a dry and hot foehn wind frequently occurs in the area. This results in a long arid and hot season (7 months) with high temperatures (annual temperature is 24 to 25°C, the mean temperature in January is 16 to 18°C, the highest temperature can be up to 42°C), little precipitation (750 to 1000 mm per annum), and a evaporation which is 2 to 3 times higher than the precipitation.

Fig. 4 and 5 show monthly data of the maximum, average and minimum temperature and mean precipitation c.q. evaporation, from the meteorological station "Yuanjiang", located 10 km from site CN 45.

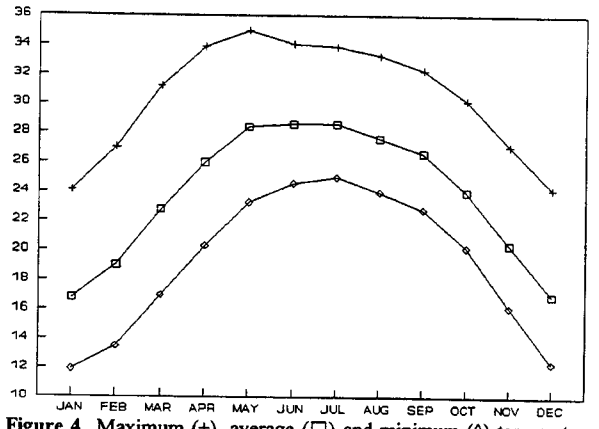


Figure 4 Maximum (+), average (□) and minimum (◊) temperature in °C at Yuanjiang meteorological station.

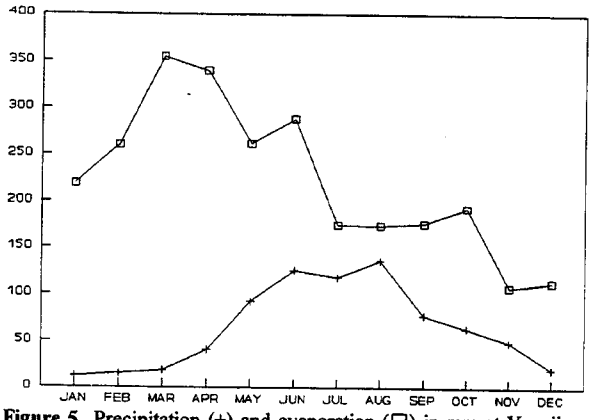


Figure 5 Precipitation (+) and evaporation (□) in mm at Yuanjiang meteorological station.

2.2.2 Vegetation and land use

The vegetative cover is of the type of savanna or tropical arid shrubby steppe. The shrubs include governorsplum (*Flacourtia indica*), boxleaf atalantia (*Atalantia buxifolia*) and the grasses are dominated by tangle head (*Heteropogon pers*). There are also xerophilous plants including cholla, panderia and beancaper (*Zygophyllum L.*). Casuarina grows well on the soil and is commonly planted on road sides.

Without irrigation the soils can be only used for planting xerophilous plants like sisal, or produce low yields of traditional crops. With irrigation the soils can be used for rice, sugar-cane, flowering quince, water melon and peanut.

2.3 Central Yunnan Plateau and Lake Basins

Within Fig. 1 this subregion is indicated with the code 14.2.

2.3.1 Geology and geomorphology

The region is mainly located in a water-divide area, and comparatively well preserved. Near rivers, the plateau is dissected into four main erosion surfaces of different levels: 4000 to 4100 m, 3600 to 3700 m, 2400 to 2500 m, and 1800 to 2100 m a.s.l.

2.3.2 Climate

From a climatic point of view, this is a land of eternal spring, with one of the warmest mean January temperatures (8 to 10°C) and the coolest mean July temperatures (19 to 22°C) in China. Annual precipitation totals 700 to 1200 mm. Droughts in spring, however, are a problem for agricultural production. Under influence of a descending air flow that is known as the "foehn wind effect", the area is low in rainfall with an annual precipitation of less than 1000 mm. The annual mean air temperature is more than 22°C and more than 240 days in a year are without frost. There are distinct dry (6-7 months) and moist seasons in a year.

Fig. 6 and 7 show monthly data of the maximum, average and minimum temperature and mean precipitation c.q. evaporation, from the meteorological station "Yuanmou", located 1 km from site CN 46.

2.3.3 Vegetation and land use

The vegetation is dominated by broad leaf oaks, short thorn shrubs or xeromorphic grasses, typical for an arid ecosystem. The natural vegetation is severely degenerated.

The cultivation of upland rice, maize and corn which are all harvested twice a year, in addition to subtropical crops is very common. The tobacco is of high quality and famous in the whole country. More attention should be paid to irrigation and fertilization to overcome seasonal droughts and nutrient deficiencies (phosphorus), respectively. The soils along rivers or in valleys with irrigation facilities can also be used for rice cultivation.

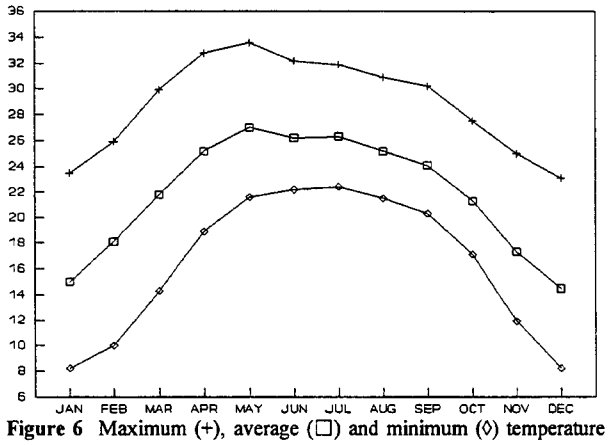


Figure 6 Maximum (+), average (□) and minimum (◊) temperature in °C at Yuanmou meteorological station.

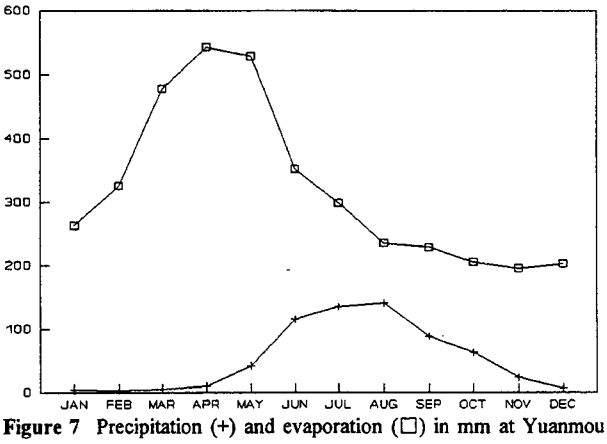


Figure 7 Precipitation (+) and evaporation (□) in mm at Yuanmou meteorological station.

3 THE REFERENCE SOILS

3.1 The relation between the studied sites

In this chapter, a selection of data and research information of reference soil CN 43, CN 45 and CN 46 is discussed. The soils are part of a serie, which belongs to the group of Red Soils.

The Red Soil region of China borders the Pacific Ocean on the east and the Indian Ocean on the south and benefits from the monsoon climate of East Asia. Extending across 12° latitude and 28° longitude, the region covers one-fifth of the total of the country. The eastern part of the region (plains, hills and mountains) differs from the western part (plateaux and basins) in temperature regimes, humidity and landscape. In the western part, there is a clear alternate wetting and drying in a year but this is absent in the eastern part. The climatic regimes have strongly affected vegetation development and soil formation (Eswaran and Bossio, 1984).

The Red Soil group consists mainly of laterite, lateritic red soils, red soils and yellow soils. They are distributed widely in the tropical and subtropical areas of China. The total area of Red Soils is about 2.03 million km^2, which is 21% of the total land area of China. The potential of red soils is characterized by "acidity, deficiencies, compactness and drought" (He Dian-yuan, 1988).

Detailed description, sampling and the taking of monoliths of three reference soils was carried out in 1993 by scientists of ISRIC and the Chinese Institute of Soil Science. Comprehensive field and laboratory data are given in Annex 1A, 1B and 1C: Soil and other environmental data, stored by ISRIC Soil Information System (Waveren van *et al.*, 1988).

3.2 Location

Reference soil CN 43 is located along a dirt road to the small village Ma Se Shuo. The distance from the profile pit to this village is about 2 km and to Luliang 12 km (Fig. 8). The area of the Typic Red Soils is the important base of agricultural and forest products of South China. The soil type mainly occurs in Jiangxi, Hunan, Hubei, Fujian and the south part of Zhejiang. Yellow Limestone Soils and Paddy Soils are the major soil types which are found near the area with Red Soils around Luliang.

Reference soil CN 45 is located near the Institute of Agricultural Science of Yuanjiang County, Yunnan Province, about 10 km from the small town Yuanjiang (Fig. 8). Dry (or torrid) Red Soils have also been called savanna red soils, red brown soils, red cinnamon soils or red purple soils. Small areas of dry red soils occur in the tropical arid areas of South China, e.g. in the southwest part of Hainan Island and in the narrow valleys formed by the dissection of the Yuan Jiang (Hong Ha) River in the southern part of Yunnan. They are mostly developed on weathering materials of callys and granite or old deposits. Part of the soil occurs in limestone regions, where there are lime concretions in the solum. The small elongated area with dry red soils near Yuanjiang, is bordered by Yellow Latored Soils on both sides of the Yuan Jiangy valley.

Reference soil CN 46 is located in the backyard of the Resources Nursery for Tropical Economic Crops in Yuanmou (Fig. 8). Cinnamon red soils are mainly distributed on the Yunnan-Guizhou Plateau and in the incised valleys at the edge of the Plateau. The distribution pattern of the Cinnamon Red Soils near Yuanmou is rather irregular, since the soil type is alternated with Typic Red Soils, Paddy Soils and Brown Soils.

3.3 Landscape, geology, vegetation and land use

Soil CN 43 is situated within a basin characterised by an undulating topography. Steep limestone hills form part of the basin, which slope gradients of 2-8%. The parent material is limestone mixed with alluvial and colluvial deposits.

The area was deforestated in 1958 for agricultural purposes. As a result severe wind and water erosion took place. In 1980 a reforestation programme started to protect fragile areas, making use of wind-breaks (*Eucalyptus*) in order to reduce wind erosion. Marginal areas are successfully reforestated with *Pinus* and *Eucalyptus* species.

Nowadays intercropping is a normal practice in many areas. Fruit trees and tobacco with maize, maize with potatoes and also potatoes with mulberry are intercropped. The present land use around the site where soil CN 43 was studied, is potatoes intercropped with mulberry, making use of medium level of inputs. NPK fertilisers are applied in combination with manure. Weeding is done manually and pesticides are widely used. Potatoes can be sown three times a year (April/ May, August and January) in one field, if the climate permits and no drought occurs. The mulberry leaves are

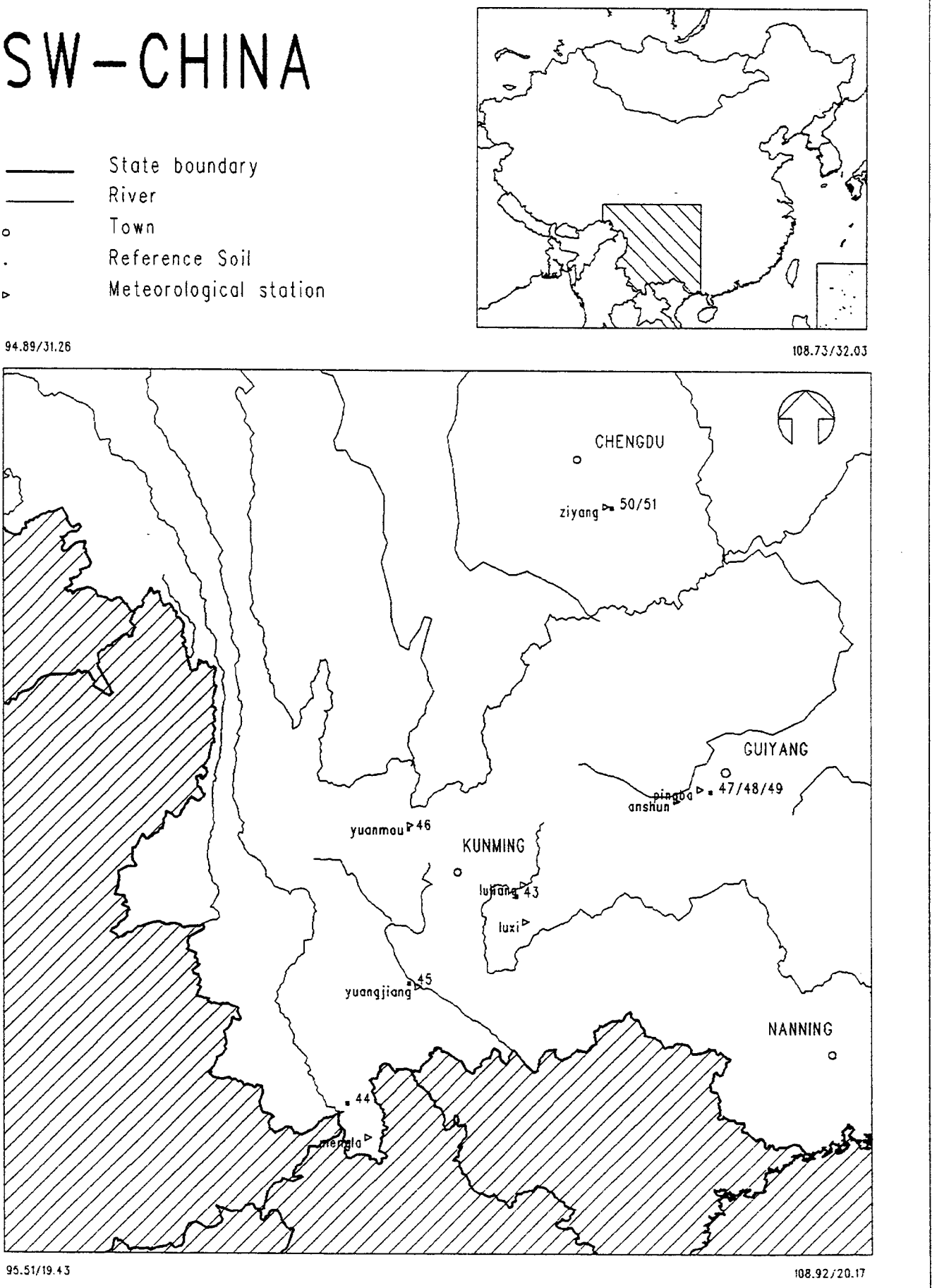


Figure 8 Location and number of the reference soils.

harvested after one year and are collected for about 10 years. After three years the mulberry is too high to permit intercropping. At that time it is very deep rooting and fertilisation stops.
The topography of the land surrounding the site where reference soil CN 45 was studied, is undulating. On the top of a hill which is part of a broad river valley the slopes have a gradient of less than 3%. The parent material is granite. Present land use is arable farming, with a medium level of inputs, like fertilizers (N and P) and pesticides. K applications are needed but in this part of China K-fertilizers are difficult to obtain. Ca is also applied in order to raise the pH of the soil, however the measured pH values (6.0- 6.4) do not directly indicate the need for lime. Tillage and harvesting are realized by ox-drawn implements and hand tools. The present crop is sugar-cane, which is rainfed because in the higher parts of the valley the topography is too undulating for irrigation. In spring and autumn, sugar cane stakes are planted. On the site of CN 45, spring sugar cane is cultivated, planted in March-April and harvested in December. The autumn sugar cane, sown in August-September gives normally a better yield, because of higher rainfall with planting. The two types are used in order to spread labour over the year, since sowing is done manually. The plant is grown for three years, whereafter the soil is ploughed and new stakes are planted. In the second year, the production is good but in the last year the production decreases. Maize and young mango trees are found along the studied site. Maize is poorly developed, while mango is producing well and the fruits make a good price. In the lower parts of the valley, irrigated sugar-cane on small plots is found next to paddy rice.

Soil CN 46 is located in an area with badlands, in which slopes are severely dissected due to water erosion. Gullies are formed with depths of 30 m, but also sheet and rill erosion take place. Because of the peculiar land forms the area is known as "the soil forest". The parent material is sandstone.
Before 1949, there was a forest but large areas in the valley were taken into agricultural use for rainfed rice and cereals. The valley is about 20 km from the Yangtse river and the government ordered the municipalities to reforest large parts within the catchment area of the river. Steep lands are already replanted with trees and xeromorphic plants. However, only local initiatives on a small scale are developed. The Resources Nursery for Tropical Economic Crops started in 1991 with the reforestation of steeply dissected land making use of *Leucaena* on man-made terraces. The *Leucaena* is used for firewood.

3.4 Soil characterisation

3.4.1 Brief field description

CN 43 is a very deep, moderately well drained, dark red to red, clay soil, mixed with medium weathered sand/ limestone fragments. The structure is moderate to strong and the soil is highly porous. At about 40 cm depth an illuvial horizon is observed with clay cutans, with a well developed columnar structure and manganiferous concretions.
CN 45 is a moderately deep, well drained, dark reddish brown to (dark) red, clay soil mixed with fresh granite fragments. The structure is moderate to strong in the topsoil and weak in the subsoil. The topsoil is highly porous. The depth of the parent material (granite) varies.
CN 46 is a deep, somewhat excessively drained, reddish brown, sandy clay loam to silty clay soil mixed with very few sandstone fragments. The structure is moderate to strong and the soil is moderately porous. At about 30 cm depth, an illuvial horizon is found with mottles and thin cutans.

3.4.2 Brief analytical characterisation

Soil samples were analyzed at ISRIC's soil laboratory according to the procedures described by van Reeuwijk (1992). The analytical data are presented in Annex 1A, 1B and 1C. Table 1 summarizes key properties.
Some important soil analytical data were selected for presentation in a graphical way, using SOLGRAPH (Brunt & Kauffman, 1995).
Fig. 9, 10 and 11 show the textural composition of the three soils CN 43, CN 45 and CN 46 for different depths. The clay content of soil CN 43 is increasing with depth (clay illuviation), while the sand content is low in the subsoil compared to the topsoil. The silt content of CN 45 is constant with depth, the clay content decreases after a small increase in the subsurface horizon. The sand content of soil CN 46 sharply decreases with depth and the clay content shows an accumulation in the subsurface horizon (illuvial B horizon).
The presence of adhering particles of iron oxides (goethite) may have prevented proper soil dispersion, or have affected grossly the sedimentation rate of the soil particles (Loveland and Whalley, 1991). No special pretreatment was used for the removal of these coatings and the textural composition should therefore be interpreted with care.

Fig. 12, 13 and 14 present chemical properties with depth. The organic C content, the sum of the exchangeable cations (Ca, Mg, K and Na), and soil acidity (pH-H_2O and pH-KCl). The sum of exchangeable cations of the topsoil of CN 43 is very high but it is considerably lower in the subsoil. The organic C content as well as the pH decrease with depth. The topsoil of

CN 45 is more acid in comparison with the lower layers in the profile. The organic C content decreases with depth and the sum of the exchangeable bases is constant throughout the profile. Due to a weak eluviation process, high evaporation in the arid season and intensive biological activity, soils like CN 45 commonly have a high base saturation of almost 100%. Exchangeable bases and pH are not fluctuating in soil profile CN 46. The organic C content of the topsoil of this soil is somewhat higher than of the subsoil but is in general low to very low.

Table 1 Key properties of soils CN 43/45/46

	CN 43	CN 45	CN 46
Texture	clay throughout the profile	gravelly clay in the topsoil to sandy clay in the deeper subsoil	sandy clay loam in the topsoil to silty clay in the subsoil
Organic carbon	medium in the topsoil	medium in the topsoil	very low throughout the profile
pH-H_2O	neutral (pH-H_2O 6.7) in the topsoil and slightly acid to strongly acid (pH-H_2O 4.8) in the subsoil	neutral throughout the profile (pH-H_2O 6.7)	slightly alkaline throughout the profile (pH-H_2O 8.2)
Sum of bases	very high (19 $cmol_c\ kg^{-1}$ soil) in the topsoil and medium (± 6 $cmol_c\ kg^{-1}$ soil) in the subsoil	high (± 13 $cmol_c\ kg^{-1}$ soil) and constant throughout the profile	very high (22 $cmol_c\ kg^{-1}$ soil) throughout the profile
Cation Exchange Capacity	low (8 $cmol_c\ kg^{-1}$ soil) in the topsoil to very low (3 $cmol_c\ kg^{-1}$ soil) in the subsoil	medium and constant throughout the profile (± 13 $cmol_c\ kg^{-1}$ soil)	low (9 $cmol_c\ kg^{-1}$ soil) in the topsoil to medium (20 $cmol_c\ kg^{-1}$ soil) in the subsoil
Exch. aluminium	high (± 80%) in the deep subsoil		
Phosphorus	medium (12 mg/kg) in the topsoil to low (4 mg/kg) in the subsoil	low (2.5 mg/kg) in the topsoil but fluctuating with depth	low (4 mg/kg) in the topsoil and decreasing with depth
Nitrogen	low (0.12%) in the topsoil to very low (0.05%) in the subsoil	low (0.13%) in the topsoil to very low (0.06%) in the subsoil	very low (0.05%) throughout the profile
Clay mineralogy	kaolinite, chlorite, gibbsite	kaolinite, mica/illite	kaolinite, mica/illite, smectite
Air capacity	medium (14%) in the topsoil and slowly decreasing with depth	medium (12%) in the topsoil and low (9%) in the subsoil	very low (4%) throughout the profile
Available soil moisture	low (9%) throughout the profile	high (17%) in the topsoil and medium (10%) in the subsoil	high (17%) in the topsoil and low (8%) in the subsoil
Bulk density	medium (1.3 kg/dm^3) throughout the profile	medium (1.3 kg/dm^3) throughout the profile	high (1.5 kg/dm^3) throughout the profile

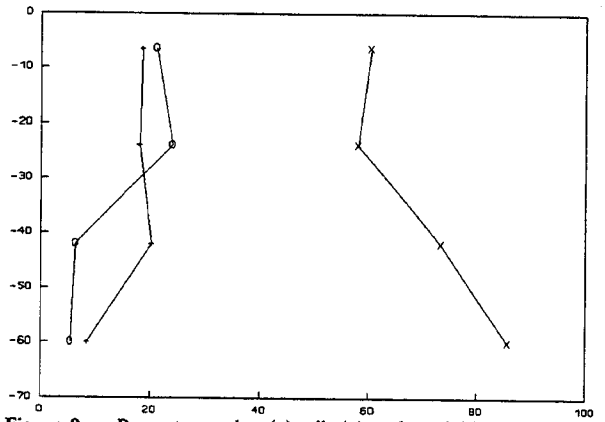


Figure 9 Percentages clay (×), silt (+) and sand (o) versus depth (cm) in profile CN 43.

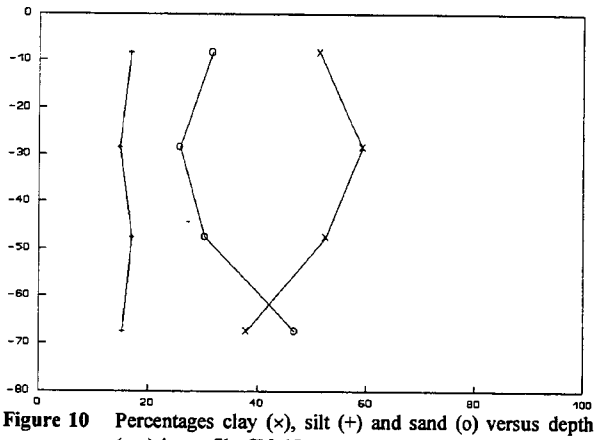


Figure 10 Percentages clay (×), silt (+) and sand (o) versus depth (cm) in profile CN 45.

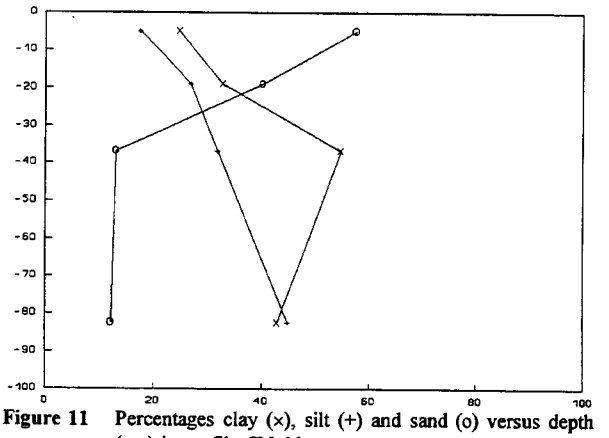


Figure 11 Percentages clay (×), silt (+) and sand (o) versus depth (cm) in profile CN 46.

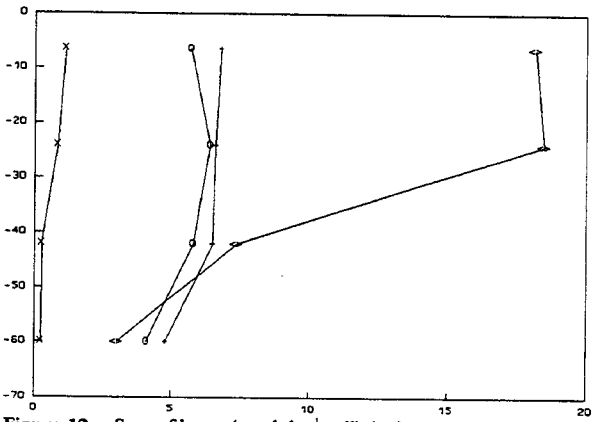


Figure 12 Sum of bases ($cmol_c\ kg^{-1}$ soil) (<>), pH-H_2O (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile CN 43.

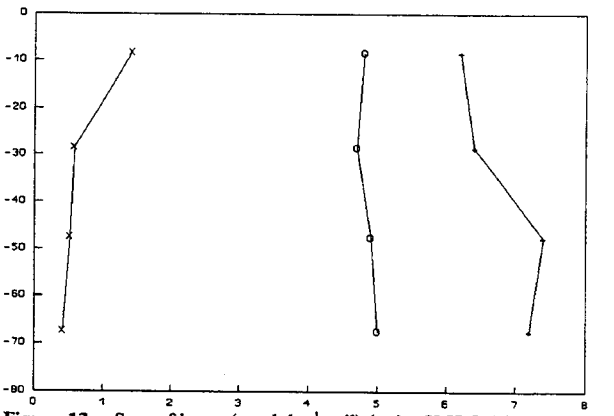


Figure 13 Sum of bases ($cmol_c\ kg^{-1}$ soil) (<>), pH-H_2O (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile CN 45.

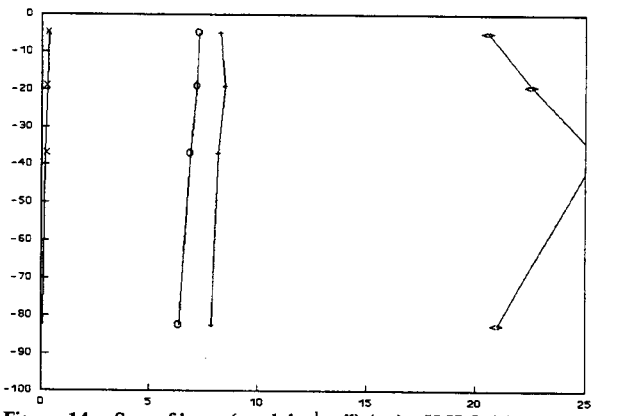


Figure 14 Sum of bases ($cmol_c\ kg^{-1}$ soil) (<>), pH-H_2O (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile CN 46.

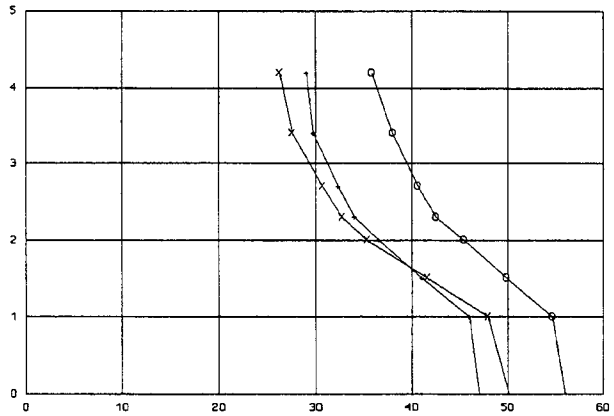


Figure 15 pF or moisture retention curves (water content in vol % versus suction) at depth 0-13 cm (x), 13-35 cm (+), 35-85 cm (o) in profile CN 43.

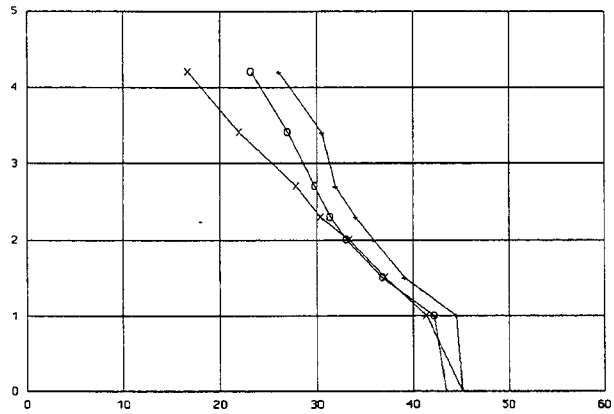


Figure 16 pF or moisture retention curves (water content in vol % versus suction) at depth 0-17 cm (x), 17-40 cm (+), 40-55 cm (o) in profile CN 45.

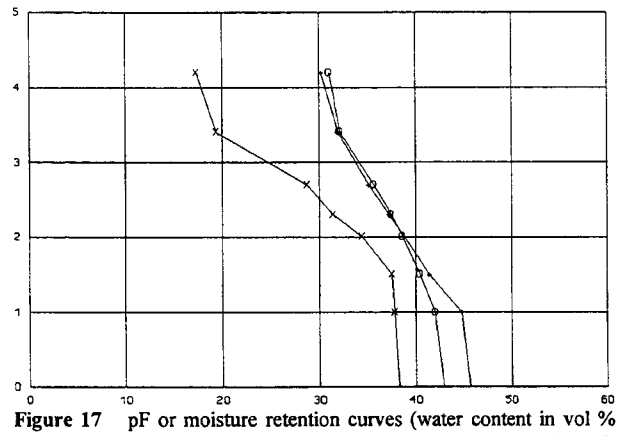


Figure 17 pF or moisture retention curves (water content in vol % versus suction) at depth 0-10 cm (x), 28-46 cm (+), 46-119 cm (o) in profile CN 46.

Fig. 15, 16 and 17 present the moisture retention curves or pF graphs. The intersection point of each curve with the x-axis gives the water content of the soils under saturated conditions, which equals total pore-volume. The quantity of soil moisture between pF 0 and pF 2 is expressed by the air capacity which is a measure for the drainage and aeration conditions of a soil. The available soil moisture (ASM) for plant growth is the quantity of moisture between pF 2 (field capacity) and pF 4.2 (permanent wilting point). The available soil moisture of soil CN 43 is constant throughout the profile. The aeration status of the topsoil is better than the subsoil which is expressed by the higher air capacity. The total pore volume increases with depth which coincides with the accumulation of clay in the subsoil. The total pore volume and the air capacity of soil CN 45 does not fluctuate very much with depth. The available soil moisture is higher in the topsoil than in the subsoil. Soil CN 46 has a higher total pore volume in the B horizon (higher clay content) than in the overlying and underlying horizons. Also the air capacity is highest in the B horizon. The available soil moisture is decreasing with depth.

3.5 Soil classification

3.5.1 Soil classification of CN 43

FAO-Unesco (1988)

The soil classifies as a Haplic Lixisol, because the soil shows an argic B horizon (subsurface horizon with a distinctly higher clay content than the overlying horizon) which has a CEC of 6 $cmol_c$ kg^{-1} clay and a base saturation of > 50% throughout the B horizon. It is lacking a mollic A horizon because it does not meet the colour criteria. It is lacking a E horizon, ferric properties and plinthite within 125 cm of the surface as well as gleyic and stagnic properties within 100 cm of the surface.

USDA Soil Taxonomy (1992)

The soil classifies as a Mollic Kandiudalf, because it has a kandic B horizon. The ratio of clay in the illuvial horizon to that in the eluvial horizon is > 1.2; the CEC is < 16 $cmol_c$ kg^{-1} clay and the texture as well as the depth meet its requirements. Base saturation is > 35% and with hue of 2.5YR and a value, moist of > 3. It is assumed that there is no clay decrease with increasing depth of ≥ 20% from the maximum clay content. The region is characterized by an udic soil moisture regime and the color value (moist) of the Ap horizon is ≤ 3.

Chinese Soil Classification System (Soil Taxonomic Classification Research Group, 1993)

The soil belongs to the suborder of Udic Ferrallisols, although this is questionable considering the mineralogical composition. The soil has an umbrihumic epipedon (color is dark enough and the organic matter content is high enough) and an argillic B horizon and keys out as an Argillic Red Soil.

3.5.2 Soil classification of CN 45

FAO-Unesco (1988)

The soil shows a mollic A horizon (well structured and dark with moderately high organic matter content and base saturation > 50%), and a base saturation which is ≥ 50% throughout within 125 cm of the surface. It is questionable if the soil meets the thickness requirements of a mollic A horizon, but due to the variable depth of the profile it is assumed so. In case the A is not mollic the soil keys out as a Ferralic Cambisol.

The soil meets most of the requirements of an argic B horizon, like a fine texture, and a clay accumulation of 8%. Clay skins are however not identified and the increase in clay content between the B horizon and the overlying horizon is not reached within a vertical distance of 15 cm. So the B horizon is classified as a cambic B horizon. The soil is lacking gleyic and stagnic properties and is not calcareous so the soil keys out as a Haplic Phaeozem.

In spite of its low CEC the B horizon is not classified as a ferralic B horizon due to its silt-clay ratio and the amount of stones which are both too high.

USDA Soil Taxonomy (1992)

The soil has a mollic epipedon (surface horizon that when mixed to a depth of 18 cm, contains ≥ 1% organic matter, colour values darker than 5.5 dry and 3.5 moist; the structure cannot be massive and hard, base saturation > 50%). The soil moisture regime is ustic and the soil meets most of the requirements for an argillic horizon. The eluvial horizon has > 40% clay of a kaolinitic type with a blocky structure which does not show clay films on peds and in pores within the lower part of the B horizon. The B horizon is therefore classified as a cambic B horizon. The varying depth of the profile is taken into account, by classifying it as a Ruptic-Lihic Haplustoll, which expresses that in part of each pedon a lithic contact within 50 cm of the mineral soil surface is present. Also the hypothermic soil temperature regime can be taken into account by classifying the soil as an Aridic Haplustoll.

Chinese Soil Classification System (Soil Taxonomic Classification Research Group, 1993)

The soil belongs to the suborder of Ustic Ferrallisols, because of its soil moisture regime. It has a B horizon with a hue redder than 7.5YR and a subhorizon with a thickness of more than 10 cm whose upper boundary is within 50 cm of the surface and has a base saturation of ≥ 35% as well as a CEC of fine earth divided by the clay percentage of < 0.24. An argillic B horizon is not found because clay cutans are not observed. Therefore the soil keys out as a Haplic Dry Red Soil.

3.5.3 Soil classification of CN 46

FAO-Unesco (1988)

The soil classifies as a Stagnic Luvisol, as the argic B horizon has a CEC of > 24 $cmol_c\ kg^{-1}$ clay and a base saturation of > 50%. It does not have a mollic A horizon because its organic carbon content is too low and the colour criteria are insufficient. It is lacking an E horizon, ferric properties and plinthite within 125 cm of the surface as well as gleyic properties within 100 cm of the surface. Stagnic properties, related to the saturation by surface water are reflected by clear dark mottles and iron-manganese concretions.

USDA Soil Taxonomy (1992)

An argillic horizon (the ratio of clay in the illuvial horizon to that in the eluvial horizon is > 1.2) with a base saturation of more than 35% is found. The area is characterized by an ustic soil moisture regime. From the AB-horizon to the B-horizon there is probably an increase of < 20% clay within a vertical distance of 7.5 cm and therefore the soil is not classified as a Paleustalf. Because the mottles in the B-horizon have a chroma of less than 2 within 75 cm of the soil surface, the soil keys out as an Aquic Haplustalf.

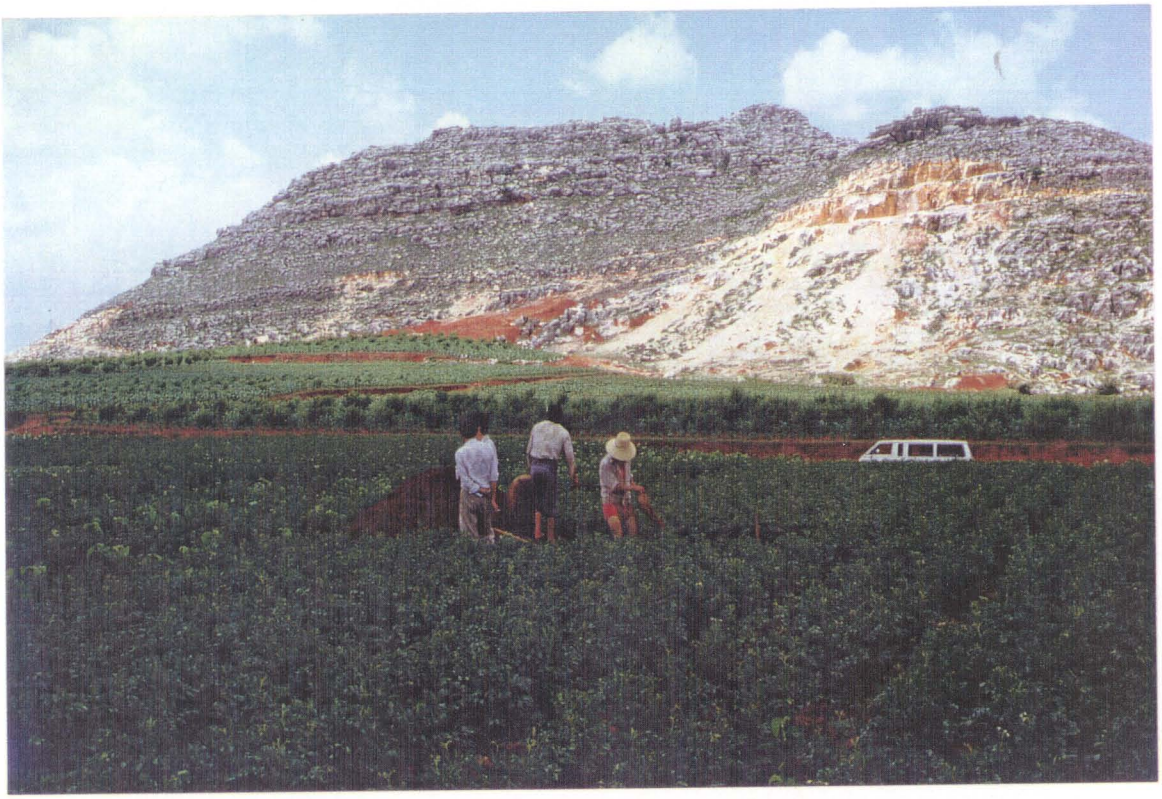
The hue of the argillic horizon is red enough to meet the requirements of a Rhodustalfs, the color value, moist is however too high.

Chinese Soil Classification System (Soil Taxonomic Classification Research Group, 1993)

The soil belongs to the suborder of Ustic Fersiallisols, characterized by an ustic soil moisture regime. It classifies as a Haplic Red Cinnamon Soil, a northern variant of the red soil with a lower organic matter content (Organic C content in the A-horizon is 0.4%). It has an ochrihumic epipedon and probably an argillic horizon which does not match completely with the concept of a Haplic Red Cinnamon Soil. A separate subgroup of Argillic Red Cinnamon Soils does not however exist within the Chinese soil classification system.

3.6 Soil suitability

A qualitative evaluation of relevant land qualities according to the Framework for Land Evaluation (FAO, 1983) was carried out. According to this methodology an evaluation should be made for different land use types. However, soil CN 43 was only evaluated for potatoes, a traditional crop of great importance in this part of China. Soil CN 45 is evaluated for sugar-cane, a cash crop of which three ratoons are cut in three subsequent years before the stubble is ploughed in. Soil CN 46 was not evaluated for an agricultural use, taking into account its severe environmental degradation.



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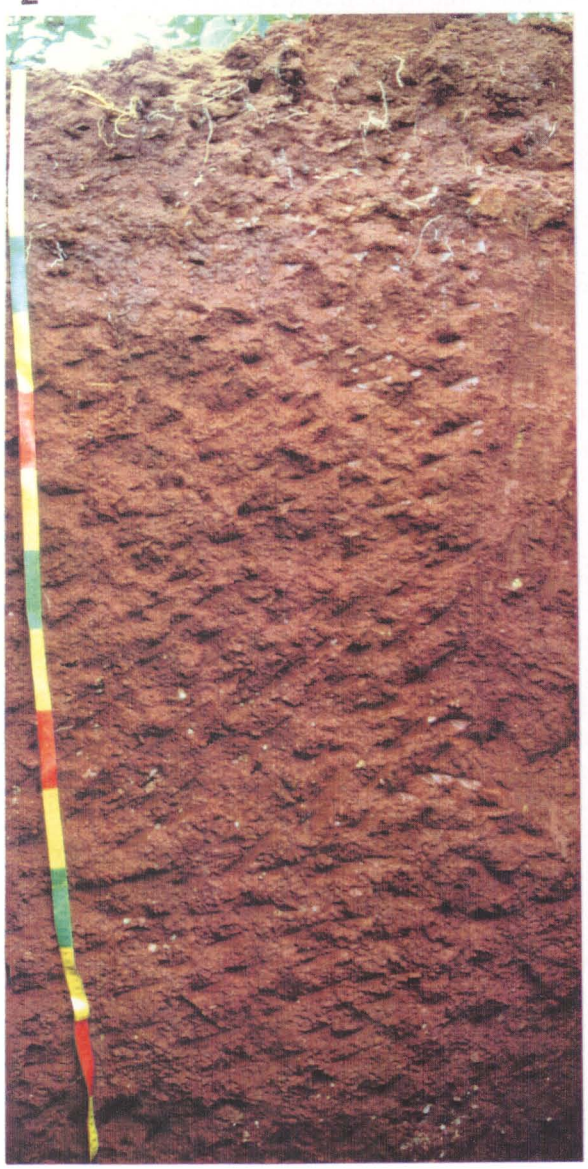

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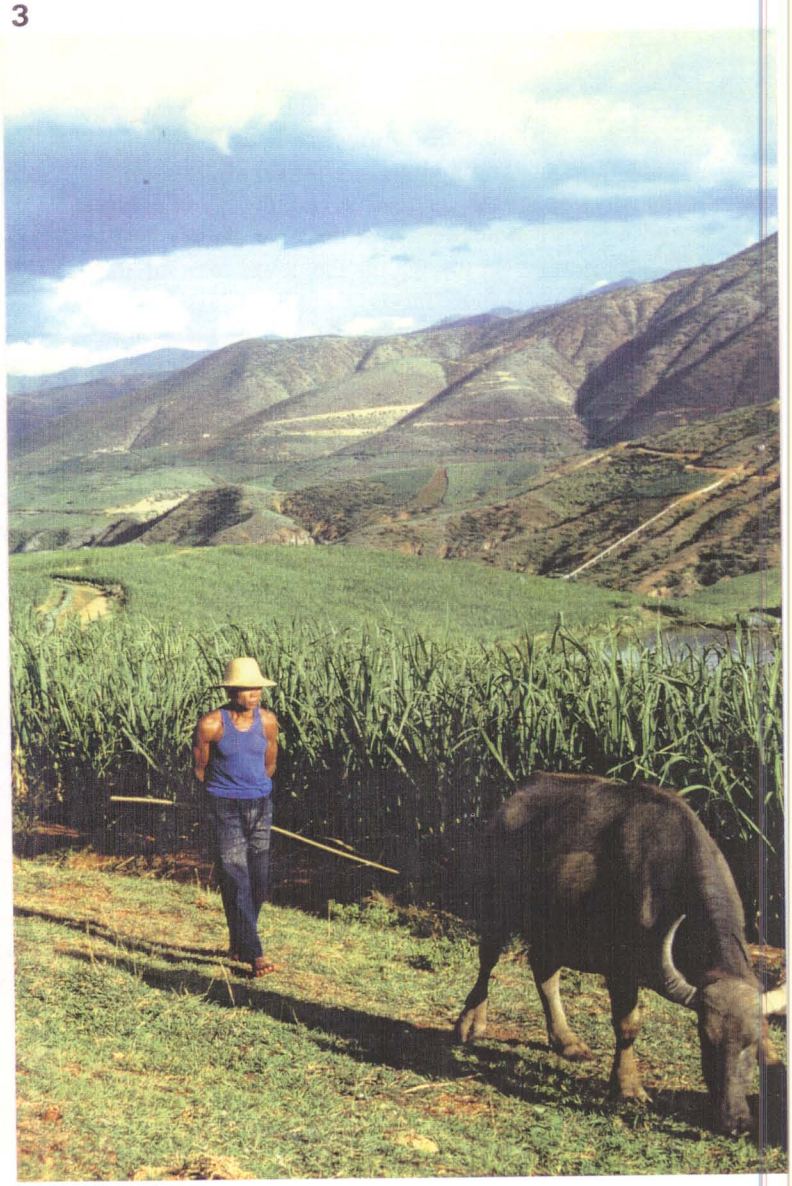
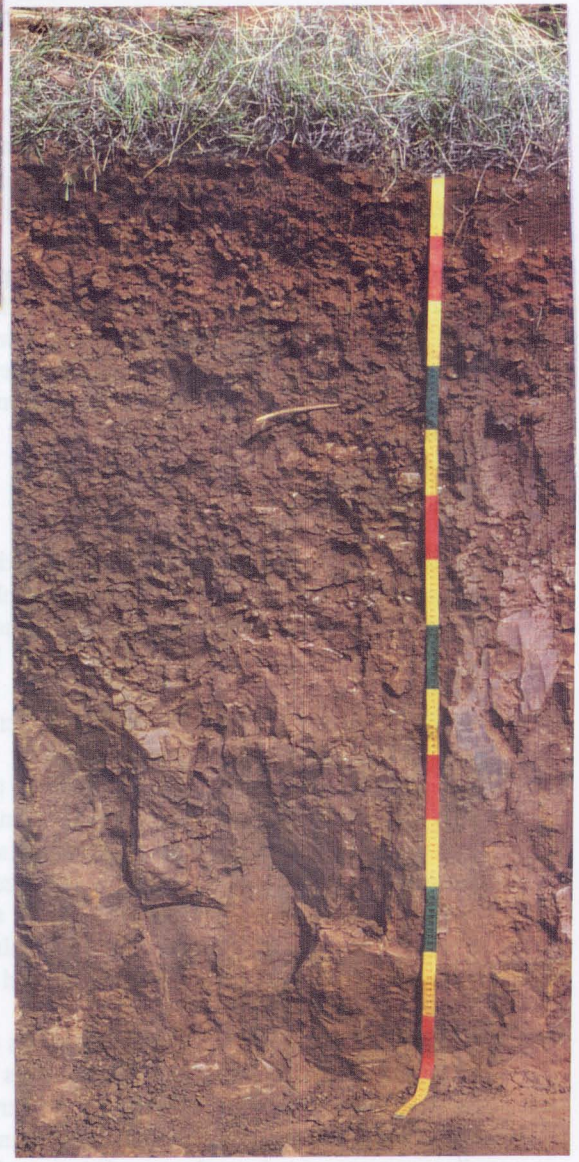


5

1. Landscape CN 43
2. Profile CN 43

3. Landuse CN 45
4. Profile CN 45

5. Landscape CN 46
6. Profile CN 46



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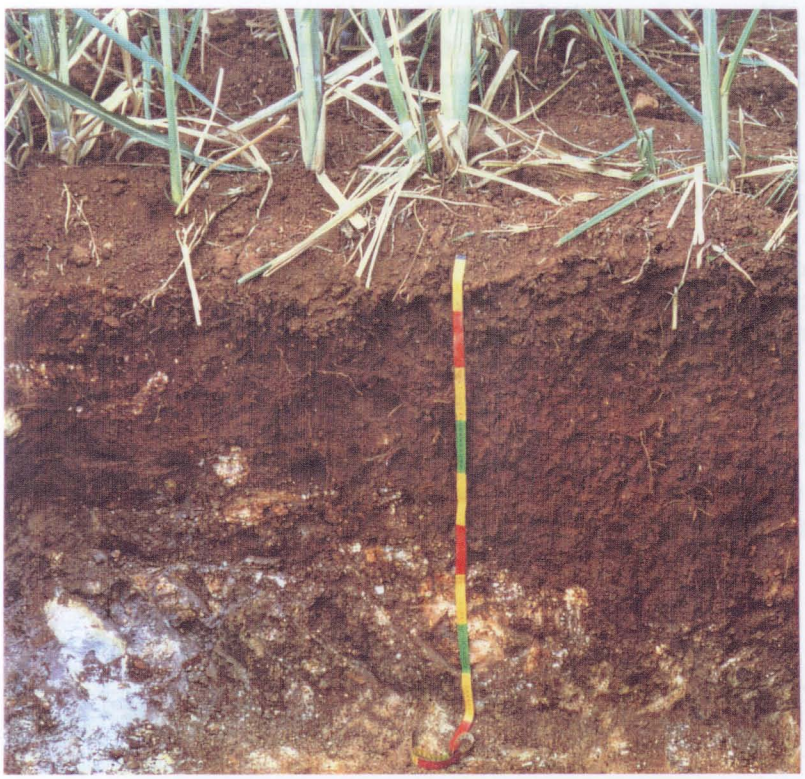

Optimal crop growth criteria of the different crops were taken from ILACO (1981) and Landon (1991) and are summarized in the following paragraphs. The results of each evaluation are presented in a list of soil/land qualities in Annex 2.

3.6.1 Requirements and limitations for potatoes

Potatoes need about 500-700 mm of precipitation, of which 100 mm must fall monthly during the growing period. Daily temperatures should be between 15°C and 20°C (range 10- 25°C), while night temperatures of < 15°C improve tuber formation. However, the crop is sensitive to frost, especially in a young stage.
Potatoes are a deep rooting crop (60-90 cm), but make use of the upper 30 cm of the soil to obtain 70% of water needs. Potatoes are moderately nutrient demanding (P and especially K which improves the storage quality; pH range for satisfactory yield is 4.5- 7.0), and present a medium erosion hazard. The tolerance to periods with water saturation of the soil or to periods with drought is low. The soil, preferably of medium to coarse texture, must be well structured with enough pores and well drained. Heavy soils restrict tuber formation and complicate harvesting.

3.6.2 Evaluation of CN 43

Temperatures are adequate for potato cultivation, but can decrease in winter time to a critical level. Monthly precipitation in the winter months is less than 100 mm and regular droughts occur in the region. Due to the somewhat limited amount of water stored in the soil (Available Water Capacity is 76 mm/85 cm soil) the plant can develop water stress, especially in January when potatoes are planted. For overcoming the drought stress and soil erosion, water conservation and measures such as water reservoirs on mountain lands, early seedling, dense planting, mulching with maize stalks and contour farming are promoted by local agricultural stations. The interest of the farmers has already been risen, despite the extra labour needed for soil conservation measures.
The soil has low levels of available nutrients (medium P and low N content) and low nutrients reserves (low CEC, low organic C content). Applications of fertilizers are needed for good yields. The deep, well drained, porous soil guarantees good rooting conditions and sufficient oxygen for the potato roots. The soil has a high potential for mechanization.
There is a moderate erosion hazard, both for wind and water, although the risk may be reduced by intercropping potatoes with mulberry. Conservation practices as contour ploughing are encouraged. Gully control by tree planting (*Eucalyptus*) is carried out, although the impact may be little regarding the large gullies.
After one year of potato cultivation a different crop is cultivated because of potato sickness.
The soil is rather poor in permeability and aeration due to its heavy texture. Although the Red Soils have a high clay content, their hydrological behaviour is similar to that of a sandy soil (Horne *et al.*, 1991).

3.6.3 Requirements and limitations for sugar cane

Sugar-cane (*Saccharum officinarum*) needs about 1600 mm of precipitation. Adequate ripening must be completed during a dry period of 4-5 months and the resistance against drought is low. Optimum average daily temperature is about 28°C, mean daily temperature for growth optimum 22°C- 30°C. Growth is impeded at temperatures below 15°C. Wind may cause lodging of the cane, especially when it is not properly planted.
Sugar cane is a deep rooting (90 cm), nutrient demanding crop (especially nitrogen; pH 5- 8; optimum pH 6.0-7.5). The available water capacity must be high (1500-2500 mm/ year). The soil should be well drained, although an imperfect drainage is tolerated. The tolerance to periods with water saturation is medium. At a young stage, there is a low resistance to waterlogging. The soil must have a good structure and heavy to medium texture. On heavy clay soils, sugar-cane responds well to deep-ripping. In conditions before full canopy development, erosion hazard is high, later in the vegetation cycle it decreases.

3.6.4 Evaluation of CN 45

The soil is well drained, and porous but its depth is variable. The limited soil depth together with the stoniness at the surface and the very hard consistence of the dry soil, reduces the potential for mechanization. The shallowness and stoniness limit rooting depth. The accessibility of the land, important for the transport of the harvest is, however, favourable.
The major problem in the utilization of the land is the water availability. Evaporation is 2 to 3 times higher than the precipitation. The amount of water stored in the soil is not sufficient for high and sustainable yields (available Water Capacity is 66 mm/55 cm soil). Therefore, development of irrigation in the region could be an effective way for improving the productivity of the soil. However irrigation is difficult due to the undulating topography, the lack of surface water, and the deep groundwater level.
Nutrient availability is limited (low N and P content). In the second and third year of sugar-cane cultivation, when the second and third ratoon are cut, fertilizers need to be applied in order to prevent a yield decline.
Sugar cane yield a good prices in this part of China and there are no reasons to look for alternative crops in the valley. Next to the site were soil CN 45 was studied, a

plot with maize and mango was found. The maize yields were very poor, but the mango yielded good.

3.6.5 Evaluation of CN 46

Considering the severe water erosion taking place around Yuanmou, it is recommended to protect the area against further degradation. Conservation measures like reforestation as practised on the studied site are therefore appropriate and it is recommended for other areas as well. Agroforestry experiments should be encouraged since the soils have a low natural fertility which can be compensated for by N fixing species, like *Leucaena*. For the control of gully erosion, more comprehensive measures have to be adopted. Possible options are: runoff at the head of the gully has to be diverted, the mouth of the gully dammed, and trees planted on inside and outside slopes.
In general, CN 46 can be used for cultivation of upland rice and corn in addition to subtropical crops. However, more attention should be paid to their irrigation and fertilization. The soils along rivers or in valleys with irrigation facilities may also be used for planting rice (Zhao Qiguo *et al.*, 1990).

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Annex 1A ISIS Data Sheet CN 43

ISIS 4.0 data sheet of monolith CN 43 Country : PEOPLE'S REPUBLIC OF CHINA Print date (dd/mm/yy) : 27/05/94

FAO/UNESCO (1988) : Pachi-Haplic Lixisol (Chromic) (1974 : Ferric Luvisol)
USDA/SCS SOIL TAXONOMY (1992) : Mollic Kandiudalf, very-fine, mixed, mesic (1975 : Typic Paleudalf)
CSTC (1991) : Argillic red soil

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

LOCATION : Main road 324 to Luliang, km 2542.5; dirt road to Ma Se Shuo, km 2
Latitude : 24°52' 0'' N Longitude : 103°34' 0'' E Altitude : 1800 m a.s.l.
AUTHOR(S) : Vogel, A.W., Huang Xiaoqing Date (mm/yy) : 7/93

GENERAL LANDFORM : basin Topography : undulating
PHYSIOGRAPHIC UNIT : basin with steep limestone hills
SLOPE Gradient : 3% Aspect : SW Form : straight
POSITION OF SITE : slope
MICRO RELIEF Kind : ripples Pattern : linear Height : 10 cm
SURFACE CHAR. Rock outcrop : nil Stoniness : very few stones
Form : angular irregular Average size : 2 cm
Cracking : nil Slaking/crusting : partly slaked
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : moderate rill and severe wind Aggradation : nil
Slope stability : stable

PARENT MATERIAL 1 : alluvium derived from : limestone
2 : colluvium derived from : limestone
Depth lithological boundary : 500 cm
Remarks : Quaternary red clay

EFFECTIVE SOIL DEPTH : 280 cm

WATER TABLE : no watertable observed
DRAINAGE : moderately well to well
PERMEABILITY : no slowly permeable layer(s)
FLOODING Frequency : nil Run off : medium
MOISTURE CONDITIONS PROFILE : 0 - 280 cm moist

LAND USE : medium level arable farming
Landuse/vegetation remarks : potatoes intercropped with mulberry

ADDITIONAL REMARKS
Classification: it is assumed that the Bt2 horizon does not qualify for ferralic B horizon on the account of the mixed character of the clay mineralogy (--> more than 10% weatherable minerals in the 50-200 μm fraction). If ferralic B horizon is assumed, soil classifies according to FAO (1988) as Lixi-Haplic Ferralsol.

CLIMATE : Köppen: Caw
Station: LULIANG 25 2 N/103 40 E 1840 m a.s.l 12 km W of site Relevance: good
Station: LUXI 24 32 N/103 44 E 1703 m a.s.l 41 km SSE of site Relevance: moderate

	No. years of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
LULIANG														
pan evaporation mm	20	196	195	255	251	216	148	161	166	141	139	159	190	2217
relative humidity %	20	72	67	59	59	69	79	83	84	83	82	80	76	75
precipitation mm	20	16	16	17	33	116	209	180	193	99	77	38	17	1011
T mean °C	20	7.0	9.0	13.4	17.0	19.3	19.6	20.2	19.4	17.8	14.9	10.8	7.8	14.7
T max °C	20	14.7	16.7	21.7	24.8	25.4	24.6	24.9	24.5	23.1	20.4	17.3	15.2	21.1
T min °C	20	1.0	2.5	6.1	10.0	14.0	16.0	16.8	16.1	14.3	11.1	6.3	2.3	9.7
windspeed(at 2m) m/s	20	2.4	2.9	3.2	3.1	2.6	2.2	1.8	1.5	2.1	1.8	1.9	2.1	2.2
bright sunshine h/d	20	6.3	7.0	8.2	8.4	7.0	4.9	5.2	5.4	4.7	4.5	5.3	6.1	6.1
LUXI														
no. of raindays	23	8	7	6	8	13	18	22	21	16	14	9	6	146
tot.glob.rad. MJ/m2		13.8	16.2	18.5	19.6	18.7	15.3	13.3	14.8	16.2	14.0	13.8	13.5	15.6
bright sunshine %	23	55	56	66	63	50	33	36	38	38	36	47	55	47

ISIS 4.0 data sheet of monolith CN 43 Country : PEOPLE'S REPUBLIC OF CHINA Print date (dd/mm/yy) : 27/05/94

PROFILE DESCRIPTION :
Very deep, well drained, red clay developed from alluvial and colluvial deposits derived from limestone. Moderately to strongly structured and highly porous. Manganiferous concretions are present in the subsurface horizon.

Ap	0 - 13 cm	Dark red (2.5YR 3/6, moist) clay; moderate fine to medium granular structure; friable; many very fine continuous exped-inped tubular pores; highly porous; many fine and common medium roots throughout; few small irregular hard manganiferous concretions; very few fine weathered sand/limestone fragments; abrupt smooth boundary to
AB	13 - 35 cm	Red (2.5YR 4/6, moist) clay; strong medium to coarse angular blocky to moderate medium columnar structure; firm; patchy thin clay cutans in root channels and pores; many very fine continuous exped-inped tubular pores; highly porous; common very fine and fine roots between peds; frequent small irregular hard manganiferous concretions; gradual smooth boundary to
Bt1	35 - 85 cm	Red (2.5YR 4/8, moist) clay; strong medium to coarse angular blocky to strong medium columnar structure; firm; patchy thin clay cutans in root channels and pores; common very fine continuous exped-inped tubular pores; highly porous; few very fine roots between peds; frequent small irregular hard manganiferous concretions; abrupt wavy boundary to
Bt2	85 - 280 cm	Red (2.5YR 4/8, moist) clay; strong medium angular blocky to strong medium to coarse columnar structure; firm; few very fine continuous exped-inped tubular pores; moderately porous; few medium weathered sand/limestone fragments and frequent fine weathered sand/limestone 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 µm	DISP	BULK DENS	pF- 0.0	1.0	1.5	2.0	2.3	2.7	3.4	4.2
1	0 - 13	-	1	2	4	9	6	21	7	12	19	60	33.8	1.18	50	48	42	35	33	31	28	26
2	13 - 35	-	1	2	4	10	8	24	7	11	18	58	37.3	1.33	47	46	41	37	34	32	30	29
3	35 - 85	-	1	1	1	2	2	7	6	15	20	73	2.1	1.13	56	55	50	45	43	41	38	36
4	85 - -	-	1	1	1	2	1	6	4	5	9	86	1.1	-	-	-	-	-	-	-	-	-

Hor. no.	pH- H2O	pH- KCl	CaCO3 %	ORG-C %	MAT. N %	EXCH CAT. Ca	Mg	K	Na	sum	EXCH AC. H+Al	Al	CEC soil	CEC clay	CEC OrgC	ECEC	BASE SAT %	Al SAT %	EC 2.5 mS/cm
						cmol$_c$ kg^{-1}													
1	6.8	5.7	0.7	1.12	0.12	16.2	1.4	0.4	0.2	18.2	-	-	8.1	13	3.9	18.2	225	-	0.23
2	6.6	6.4	1.8	0.83	0.08	17.4	0.7	0.3	0.1	18.5	-	-	9.6	17	2.9	18.5	193	-	0.20
3	5.8	5.9	-	0.25	0.04	8.2	0.4	0.2	0.1	8.9	-	-	4.3	6	0.9	8.9	207	-	0.11
4	4.8	4.1	-	0.23	0.03	2.2	1.1	0.3	0.1	3.7	2.4	1.7	2.3	3	0.8	6.1	161	74	0.04

CLAY MINERALOGY (1 very weak, ..., 8 very strong) / AVAILABLE P (Bray & Olsen)

Hor. no.	MICA /ILL	CHLO	KAOL	MIX	FELD	GIBB	GOET	AVAIL. P mg/kg Bray	Olsen
1	3	4	4	2	1	4	2	11.7	12.9
2	3	4	4	2	1	4	2	3.6	11.8
3	2	3	4	3	2	5	1	0.7	4.4
4	3	3	4	3	2	4	1	0.8	3.5

Annex 1B ISIS Data Sheet CN 45

ISIS 4.0 data sheet of monolith CN 45 Country : PEOPLE'S REPUBLIC OF CHINA Print date (dd/mm/yy) : 27/05/94

FAO/UNESCO (1988) : Rupti-Ferralic Cambisol (Rhodic), rudic phase (1974 : Ferralic Cambisol, stony phase)
USDA/SCS SOIL TAXONOMY (1992) : Dystric Eutrochrept, clayey-skeletal, kaolinitic, hyperthermic
(1975) : Typic Eutrochrept
CSTC (1991) : Haplic dry red soil

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

LOCATION : Yuanjiang, next to road through valley to sugar-cane institute
Latitude : 23°36' 0'' N Longitude : 102° 1' 0'' E Altitude : 380 m a.s.l.
AUTHOR(S) : Vogel, A.W., Wang Mingzhu, Huang Xiaoqing Date (mm/yy) : 7/93

GENERAL LANDFORM : valley Topography : undulating
PHYSIOGRAPHIC UNIT : hill within river valley
SLOPE Gradient : 3% Aspect : NW Form : straight
POSITION OF SITE : upper slope
MICRO RELIEF Kind : ripples Pattern : linear Height : 20 cm
SURFACE CHAR. Rock outcrop : little rocky Stoniness : very stony
Form : angular blocky Average size : 3 cm
Cracking : nil Slaking/crusting : nil
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : slight sheet and slight rill Aggradation : nil
Slope stability : stable

PARENT MATERIAL : coarse-acid igneous rock (granite)
Texture : stony
Weathering degree : slight
Depth lithological boundary : 55 cm
Remarks : depth granite varies

EFFECTIVE SOIL DEPTH : 55 cm

WATER TABLE : no watertable observed
DRAINAGE : well
PERMEABILITY : no slowly permeable layer(s)
FLOODING Frequency : nil Run off : rapid
MOISTURE CONDITIONS PROFILE : 0 - 55 cm dry

LAND USE : medium level arable farming; crops : sugar cane; rotation : monoculture
Landuse/vegetation remarks : rainfed sugarcane standing for 3 years

ADDITIONAL REMARKS :
Within the broad valley of the Yuan Jiang River different terraces are found at various levels. Partly they are composed of alluvial materials and for the other part consist of granite, which is also the parent material of the nearby bordering mountains. Both materials lead to the formation of dry red soils. The actual river streams at a lower level at about 1 km (?) from the profile site. On lower parts of the terrace hills the red soils are more eroded and as a consequence more shallow.
Classification: the Ap horizon is variable in depth. If this horizon becomes thicker, the soil classifies as Haplic Phaeozem (FAO, 1988) and as Ruptic-Lithic Haplustoll (USDA/SCS, 1992).

CLIMATE : Köppen: Caw
Station: YUANJIANG 23 34 N/102 9 E 397 m a.s.l. 14 km WSW of site Relevance: good

	No. years of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
pan evaporation mm	36	219	260	355	340	262	288	175	174	176	193	108	113	2664
relative humidity %	36	65	61	58	59	63	70	72	77	75	74	73	71	68
precipitation mm	36	12	15	18	41	93	126	118	136	78	64	49	20	770
no. of raindays	26	3	3	4	7	12	7	17	17	11	11	6	4	113
tot.glob.rad. MJ/m2		12.2	14.8	17.7	19.0	15.8	15.9	16.6	15.8	12.6	12.0	11.5	15.2	15.2
T mean °C	36	16.8	19.0	22.8	26.0	28.4	28.6	28.6	27.6	26.6	24.0	20.4	17.0	23.8
T max °C	34	24.1	27.0	31.2	33.9	35.0	34.1	33.9	33.3	32.3	30.2	27.1	24.2	30.5
T min °C	34	11.9	13.5	17.0	20.3	23.3	24.6	25.0	24.0	22.8	20.2	16.2	12.4	19.3
windspeed(at 2m) m/s	36	3.8	4.2	4.7	2.9	2.6	2.3	1.9	1.2	1.4	1.8	2.3	1.3	2.6
bright sunshine h/d	36	5.7	7.5	7.8	7.5	7.1	5.1	5.1	5.8	5.8	5.3	5.7	6.0	6.2
bright sunshine %	26	61	64	66	60	52	37	38	44	48	45	53	59	52

ISIS 4.0 data sheet of monolith CN 45 Country : PEOPLE'S REPUBLIC OF CHINA Print date (dd/mm/yy) : 27/05/94

PROFILE DESCRIPTION :
Moderately deep, well drained, dark red clay derived from granite.

Ap	0 - 17 cm	Dark reddish brown (5YR 3/3, dry) very gravelly clay; moderate to strong fine to medium angular blocky and granular structure; very hard; many very fine inped tubular pores; highly porous; many fine and medium roots throughout; frequent very fine and fine fresh granite fragments; abrupt smooth boundary to
B	17 - 40 cm	Dark red (2.5YR 3/6, dry) very gravelly clay; moderate to strong fine to medium angular blocky structure; hard; common fine faint clear red (2.5YR 4/8) mottles; common very fine inped tubular pores; highly porous; common fine and medium roots throughout; frequent very fine and fine fresh granite fragments; clear irregular boundary to
BC	40 - 55 cm	Dark red (2.5YR 3/6, dry) gravelly clay; weak fine angular blocky structure; hard; common very fine inped tubular pores; moderately porous; few fine roots throughout; very frequent fine fresh granite fragments; clear irregular boundary to
C	55 - 80 cm	Red (2.5YR 4/8, dry) stony sandy clay; abrupt broken boundary to
R	80 cm +	granite

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	17	-	4	6	6	9	7	32	7	9	17	51	27.2	1.10	45	41	37	33	30	28	22	17
2	17	40	-	3	4	5	7	7	26	8	7	15	59	33.9	1.35	45	45	39	36	34	32	31	26
3	40	55	-	6	6	6	7	6	31	8	9	17	53	32.0	1.39	43	42	37	33	31	30	27	23
4	55	80	-	12	11	8	9	7	47	6	10	15	38	25.1	-	-	-	-	-	-	-	-	-

Hor. no.	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
						cmol$_c$ kg^{-1}													
1	6.2	4.8	-	1.41	0.13	10.2	2.7	0.7	0.3	13.9	-	-	13.2	26	4.9	13.9	105	-	0.04
2	6.4	4.7	-	0.58	0.07	10.3	2.8	0.4	0.4	13.9	-	-	13.7	23	2.0	13.9	101	-	0.03
3	7.4	4.9	0.3	0.52	0.06	10.8	2.4	0.4	0.1	13.7	-	-	13.7	26	1.8	13.7	100	-	0.04
4	7.2	5.0	0.0	0.41	0.04	9.8	2.4	0.4	0.4	13.0	-	-	12.1	32	1.4	13.0	107	-	0.04

CLAY MINERALOGY (1 very weak, ..., 8 very strong) / AVAILABLE P (Bray & Olsen)

Hor. no.	MICA /ILL	SMEC	KAOL	MIX	AVAIL. P mg/kg Bray	Olsen
1	4	3	6	3	1.8	2.5
2	4	3	6	3	0.0	0.6
3	4	3	6	3	0.0	1.9
4	4	3	6	3	0.7	4.9

Annex 1C ISIS Data Sheet CN 46

ISIS 4.0 data sheet of monolith CN 46 Country : PEOPLE'S REPUBLIC OF CHINA Print date (dd/mm/yy) : 27/05/94

FAO/UNESCO (1988) : Chromi-Stagnic Luvisol (1974 : Chromic Luvisol)
USDA/SCS SOIL TAXONOMY (1992) : Aquic Haplustalf, fine, montmorrilonitic, thermic (1975 : Aquic Haplustalf)
CSTC (1991) : Haplic red cinnamon soil

DIAGNOSTIC CRITERIA FAO (1988) : ochric A, argic B horizon; stagnic properties
USDA/SCS (1992) : ochric epipedon, argillic horizon; aquic conditions
Soil moisture regime : ustic

LOCATION : Yuanmou, backyard of the Resources Nursery for Tropical Economic Crops
Latitude : 25°40' 0'' N Longitude : 101°51' 0'' E Altitude : 1150 m a.s.l.
AUTHOR(S) : Vogel, A.W., Wang Mingzhu, Huang Xiaoqing Date (mm/yy) : 7/93

GENERAL LANDFORM : badlands Topography : steeply dissected
PHYSIOGRAPHIC UNIT : highly dissected slope
SLOPE Gradient : 4% Aspect : WSW Form : straight
POSITION OF SITE : upper slope
MICRO RELIEF Kind : artificial terracing Pattern : linear Height : 20 cm
SURFACE CHAR. Rock outcrop : nil Stoniness : very few stones
Form : angular blocky Average size : 1 cm
Cracking : nil Slaking/crusting : slaked
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : severe rill and severe gully Aggradation : nil
Slope stability : locally unstable

PARENT MATERIAL : sandstone
Weathering degree : partial or moderate Depth lithological boundary : 118 cm

EFFECTIVE SOIL DEPTH : 46 cm

WATER TABLE : no watertable observed
DRAINAGE : moderately well
PERMEABILITY : moderate Slowly permeable layer from 28 to 46 cm
FLOODING Frequency : nil Run off : very rapid
MOISTURE CONDITIONS PROFILE : 0 - 10 cm moist 10 - 140 cm dry

LAND USE : afforestation; improvements : terracing
Landuse/vegetation remarks : Leucaena planted in 1991

CLIMATE : Köppen: Caw
Station: YUANMOU 25 44 N/101 52 E 1118 m a.s.l. 1 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	20	263	326	478	544	530	353	299	235	28	205	195	202	3848
relative humidity %	20	45	36	32	35	45	62	66	72	69	68	63	56	54
precipitation mm	20	3	3	4	10	41	115	135	141	89	63	23	6	634
no. of raindays	24	1	2	2	3	8	15	17	16	12	10	5	2	91
tot.glob.rad. MJ/m2		13.9	15.9	19.5	21.3	20.2	17.0	16.7	17.1	14.6	13.4	13.3	12.7	16.3
T mean °C	20	15.0	18.1	21.8	25.2	27.0	26.2	26.3	25.2	24.1	21.3	17.3	14.5	21.5
T max °C	20	23.5	25.9	29.9	32.8	33.6	32.2	31.9	30.9	30.2	27.5	25.0	23.1	28.4
T min °C	20	8.2	10.0	14.3	18.9	21.6	22.2	22.4	21.5	20.3	17.1	11.9	8.2	16.5
windspeed(at 2m) m/s	20	2.2	2.7	2.8	2.9	2.6	2.0	1.7	1.1	1.4	1.4	1.5	1.7	2.0
bright sunshine h/d	20	8.3	8.8	8.9	8.8	8.0	5.7	5.9	6.2	5.9	6.1	7.0	7.7	7.3
bright sunshine %	24	78	76	74	70	59	43	43	48	50	52	67	74	60

ISIS 4.0 data sheet of monolith CN 46 Country : PEOPLE'S REPUBLIC OF CHINA Print date (dd/mm/yy) : 27/05/94

PROFILE DESCRIPTION :
Deep, moderately well drained, reddish brown sandy clay loam to silty clay derived from sandstone. The soil has between 28 and 46 cm depth a slowly permeable layer as reflected by common low chroma mottles. It is uncertain if the topsoil is original or aggradated.

Ah	0 - 10 cm	Reddish brown (5YR 5/4, moist) sandy clay loam; weak to moderate fine granular structure; common very fine exped-inped pores; moderately porous; many very fine to coarse roots throughout; very few fine fresh sandstone fragments; clear smooth boundary to
AB	10 - 28 cm	Reddish brown (5YR 5/4, dry) clay loam; moderate medium angular blocky structure; hard; common very fine exped-inped pores; moderately porous; common fine and medium roots throughout; very few fine fresh sandstone fragments; clear wavy boundary to
Btg	28 - 46 cm	Reddish brown (2.5YR 5/4, dry) clay; strong medium angular blocky to strong fine to medium columnar structure; very hard; common heterogeneous distinct clear gray (10YR 5/1) mottles; patchy thin unspecified cutans on pedfaces; common very fine exped-inped pores; moderately porous; common fine roots throughout; few powdery soft segregations; gradual wavy boundary to
BC	46 - 119 cm	Reddish brown (2.5YR 5/4, dry) silty clay; very strong fine angular blocky parting to very strong coarse to very coarse columnar structure; extremely hard; few powdery soft segregations; gradual wavy boundary to
2C	118 - 150 cm	Brownish yellow (10YR 6/6, dry) weathered sandstone

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	10	-	1	2	5	30	20	58	8	9	18	25	18.0	1.62	38	38	38	34	31	29	19	17
2	10	28	-	2	2	4	19	14	40	9	18	27	33	23.0	-	-	-	-	-	-	-	-	-
3	28	46	-	2	2	2	4	4	13	4	28	32	55	36.5	1.47	46	45	41	39	37	35	32	30
4	46	119	-	1	2	2	4	4	12	13	32	45	43	25.0	1.53	43	42	40	39	37	36	32	31

Hor. no.	pH- H2O	KCl	CaCO3 %	ORG- C %	MAT. N %	EXCH Ca	CAT. Mg	K	Na	sum	EXCH H+Al	AC. Al	CEC soil	clay	OrgC	ECEC	BASE SAT %	ESP	EC 2.5 mS/cm
						cmol$_c$ kg^{-1}													
1	8.3	7.3	3.9	0.35	0.05	18.1	2.0	0.3	0.2	20.6	-	-	9.0	36	1.2	20.6	229	2	0.12
2	8.5	7.2	1.0	0.28	0.05	18.1	3.7	0.3	0.5	22.6	-	-	13.3	40	1.0	22.6	170	4	0.14
3	8.2	6.9	1.6	0.18	0.05	17.6	6.6	0.3	1.0	25.5	-	-	22.5	41	0.6	25.5	113	4	0.17
4	7.9	6.4	0.7	0.10	0.04	12.0	7.2	0.3	1.5	21.0	-	-	19.2	45	0.4	21.0	109	8	0.25

CLAY MINERALOGY (1 very weak, ..., 8 very strong) / AVAILABLE P (Bray & Olsen)

Hor. no.	MICA /ILL	SMEC	KAOL	MIX	QUAR	GOET	AVAIL. P mg/kg Bray	Olsen
1	4	6	4	2	2	2	6.1	4.1
2	4	6	4	2	2	2	2.2	5.7
3	4	6	4	2	2	2	15.4	3.4
4	4	6	4	2	2	1	0.7	1.6

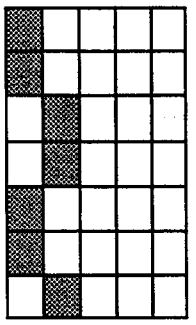
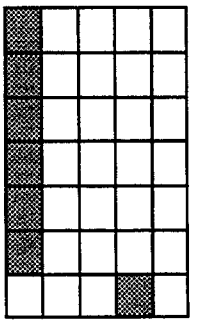
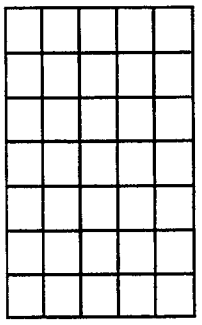
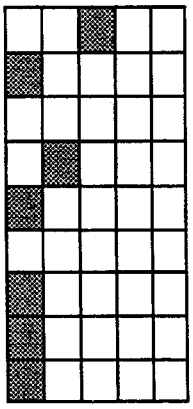
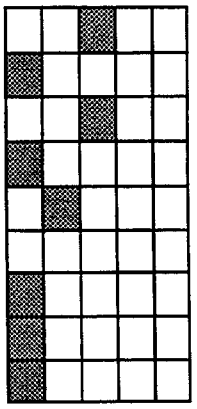
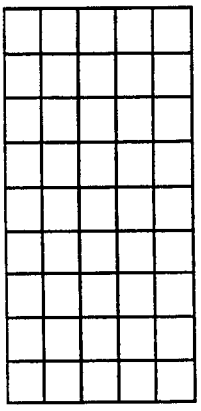
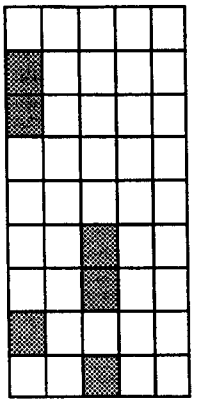
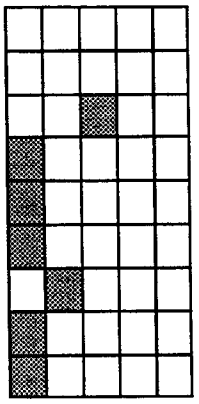
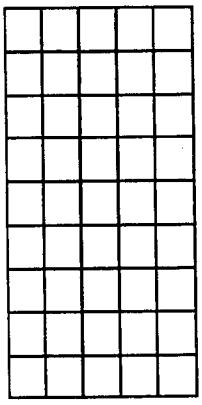
Annex 2 Evaluation of Soil/Land Qualities

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 43	CN 45	CN 46
CLIMATE					
Radiation regime	- total radiation	1			
	- day length	1			
Temperature regime		1			
Climatic hazards (hailstorm, wind, frost)		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 Methods of Soil Analysis

Preparation Each sample is air-dried, cleaned, crushed (not ground), passed through 2 mm sieve, homogenized. Moisture content is determined at 105° C.

pH H_2O (1:2.5): 20 g of soil is shaken with 50 ml of deionised water for 2 hours, electrode in upper part of suspension.

pH-KCl likewise but shaken with 1 *M* KCl.

EC (1:2.5): Conductivity of pH-H_2O suspension.

Particle-size distribution Soil is treated with 15% hydrogen peroxide overnight in the cold, then on waterbath at about 80°C. Then boiled on hot plate for 1 hour. Washings until dispersion. Dispersing agent is added (20 ml solution of 4% Na-hexametaphosphate and 1% soda) and suspension shaken overnight. Suspension sieved through 50 μm sieve. Sand fraction remaining on sieve dried and weighed. Clay and silt determined by pipetting from sedimentation cylinder.

Exchangeable bases and CEC Percolation with 1*M* ammonium acetate pH7 using automatic extractor. (If EC>0.5mS pre-leaching with ethanol 80%). Cations are determined in the leachate by AAS. CEC: saturation with sodium acetate 1*M* pH7; washed with ethanol 80% and then leached with ammonium acetate 1*M* pH7. Na determined by FES.

Exchangeable acidity and Aluminium The sample is extracted with *1 M* KCl solution and the exchange acidity (H+Al) titrated with NaOH. Al is measured by AAS.

Carbonate Piper's procedure. Sample is treated with dilute acidand the residual acid is titrated.

Organic carbon Walkley-Black procedure. The sample is treated with a mixture of potassium dichromate and sulphuric acid at about 125°C. The residual dichromate is titrated with ferrous sulphate. The result expressed in % carbon (because of incomplete oxidation a correction factor of 1.3 is applied).

Total nitrogen Micro-Kjeldahl. Digested in H_2SO_4 with Se as catalyst. Then ammonia is distilled, trapped in boric acid and titrated with standard acid.

Extractable Iron, Aluminium, Manganese and Silicon All determinations by AAS.

1 "Free" (Fe, Al, Mn): Holmgren Shaken with sodium citrate (17%) + sodium dithionite (1.7%) solution for 16 hours.

2 "Active" (Fe, Al, Si): Shaken with acid ammonium acetate 0.2 *M* pH 3 for 4 hours in the dark.

3 "Organically bound" (Fe, Al): Shaken with sodium pyrophosphate 0.1 *M* for 16 hours.

Clay mineralogy Clay is separated as indicated for particle-size analysis. about 10-20 mg of clay is brought on porous ceramic tile by suction and analyzed using a Philips diffractometer.

Soluble salts Measuring pH, EC, cations and anions in water extracts.

1 1:5 extract. Shaking 30 g of fine earth + 150 ml of water for 2 hours.

2 saturation extract. Adding to 200-1000 g fine earth just enough water to saturate the sample.

Standing overnight. After filtration Ca, Mg, Na, K are measured by AAS. Cl with the Chlorocounter and SO_4 turbidimetrically.

Gypsum To 10 g of fine earth 100 ml of water is added, shaken overnight and centrifuged. Precipitation by adding acetone. Precipitate redissolved in water and determination of Ca by AAS.

Elemental composition The fine earth is dried, ignited and fused with lithium tetraborate. The formed bead is analyzed by X-ray fluorescence spectroscopy.

Moisture retention Moisture determinations on undisturbed core samples in silt box (pF1.0;1.5;2.0) and kaolinite box (pF2.3;2.7) respectivily and on disturbed samples in high pressure pan (pF3.4;4.2).

Bulk density obtained from dry weight of core sample.

Annex 4 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 $cmol_c\ kg^{-1}$)
μm	micro-metre: $1/1000^{th}$ 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 (< 2μm) 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*
China 1	Red reference soils of the subtropical Yunnan Province	3
China 2	Reference soil ("Latosol") of tropical southern Yunnan Province	1
China 3	Yellow/brown reference soils of subtropical Guizhou Province	3
China 4	Purple upland and lowland reference soils of subtropical Sichuan Province	2
China 5	Reference soils of the subtropical mountains of Jiangxi Province	3
China 6	Reference soils of the subtropical mountains of Guangdong Province	3
China 7	Reference soils of tropical China (Hainan Island)	4
China 8	Reference soils of the Red Basins of Jiangxi Province	5
China 9	Reference soil of Chaoyang County, typical of the formerly wooded hilly areas in the SW of Liaoning Province	1
China 10	Reference soils of the Liaohe plain, Liaoning Province	2
China 11	Reference soil of the Changbai Mountains, Jilin Province	1
China 12	Reference soils of the Songnen plain, Heilongjiang Province	4
China 13	Reference soil of the Wudalianchi volcanic area, Heilongjiang Province	1
China 14	Reference paddy soils of the eastern alluvial lowlands of China (in prep.)	3

Country Reports

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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
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