Soil Brief *China 4*

PEOPLE'S REPUBLIC OF CHINA

Purple upland and lowland reference soils of subtropical Sichuan Province

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Purple upland and lowland reference soils of subtropical Sichuan Province

ISRIC Soil Monoliths:

Number	*FAO-Unesco*	*Soil Taxonomy*	*Chinese Classification*
CN 50	Calcaric Cambisol	Lithic Eutrochrept	Calcic Purple Soil
CN 51	Calcaric Cambisol	Oxyaquic Eutrochrept	Calcic Purple Soil

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CONTENTS

ABSTRACT

Two representative soils, located in the Central Hills Area of the subtropical Sichuan Basin were studied for the establishment of a Chinese soil reference collection and pedon database. Description and sampling was carried out in the framework of a 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 Central Hills Area has a sub-tropical, moist and seasonal windy climate. Despite the favourable climatic features yield and quality of crops are low. The low amount of sunshine and the radiation values limit photosynthesis. Consequently, crop varieties should be looked for, which use the light efficiently.
The parent materials are mostly Cretaceous or Tertiary purple shale, sandy shale and sandstone. The deep purple colour of the soils originating from the violet clay shales is a result of the presence of large quantities of iron and manganese oxides in specific mineralogical forms.
On the Ziyang Agricultural Environment Protection Station near Songtao, a shallow, somewhat excessively drained, dark yellowish brown to purplish silt loam upland soil derived from sandstone and shale was studied. The soil is classified as a Calcic Purple Soil or a Calcaric Cambisol. Intercropping of wheat, sweet potatoes, green pepper, peanuts and watermelon is typical for the area.
The low water holding capacity of the soil and the proximity of slowly permeable rock near the surface as well as the intensive cultivation of the land and the concentrated rainfall may cause severe soil erosion. Terracing and improvements in the vegetation cover to control run-off are promoted. The shallow, permeable soils on the slopes of the hills have a low water holding capacity and are susceptible to drought stress. Measures to improve the soil moisture retention capacity have been taking form in increasing the soil depth and decreasing the slope angle. In addition, water use and storage techniques to intercept run-off and improve drought resistance are developed. Drought tolerant plants have also been introduced. Wherever irrigation is possible, the soils produce fairly well, but the topography is generally unfavourable for irrigation.
The soil is well structured and well drained. The natural fertility is in general moderate and it is affected by farming practices. The production of wheat, which has a good market price, can be increased by proper use of fertilizers. Leguminous or green manure crops should be included in the rotation system.
The purple shale breaks down readily. Mechanical weathering and incipient soil formation are dominant, but erosion prevents the development of a deep soil. Farmer's experience show that already after one year the weathered purple shale can be used to grow crops. The partly weathered rock easily releases nutrients which contribute to the fertility but the soils are susceptible to erosion.

A second, deep (very) poorly drained, reddish brown, silty clay to silt loam soil developed from alluvial and colluvial deposits from purple shales, was studied in a nearby valley. The land is flooded for rice cultivation, and intercropped with soybeans. Reduction features and a puddled A horizon are observed in the profile. Also this soil is classified as a Calcic Purple Soil or Calcic Cambisol, anthraquic phase.
Radiation is high enough for two rice crops in one year. In practice the rice is only planted once. Rice only flowers if temperatures exceeds 23°C, and this is only reached in the summer months. The capacity of the lowland soil to store water is high. There is sufficient precipitation to ensure that the water demands of the rice crop are met in the summer season but uneven distribution and hot dry spells can have adverse effects. Additional irrigation water is sometimes needed, but it is not always available due to an insufficient water supply from elsewhere. The soil has a moderate nutrient availability and the nutrient retention capacity is high. In general, this soil type shows deficiencies of micro-elements (Zn, Fe and B) due to high alkalinity. Fertilizers needs to be applied to correct these deficiencies.

摘 要

爲建立中國土壤樣品參比庫和土壤剖面數據庫，兩個典型土壤剖面采自位于亞熱帶的四川盆地中部丘陵區。該項目在歐共體STD2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。

四川盆地中部丘陵區屬濕潤季風氣候區。盡管氣候條件優越，但受低太陽輻射和短日照時數的影響，作物的質量和產量都不高。因此，培育光能利用效率高的作物品種有重要意義。

母岩大多是白堊紀或第三紀的紫色頁岩、砂頁岩和砂岩。發育于自色粘質頁岩上的土壤，由于富含特定形態礦質鐵錳氧化物，顏色呈深紫。

在資陽農業環境保護站的旱地上，采集了一個砂頁岩上發育的土壤，它的土淺，排水稍顯過暢，深黃棕色到紫色粉砂壤質土。該土壤分類爲鈣積紫色土（中國土壤系統分類，1990）即石灰性雛形土（FAO土壤分類，1989）。現行土地利用方式主要是小麥，土豆，青椒，花生和西瓜間作。

土壤持水力低，岩石接近地表，過度開墾以及降雨過于集中，造成了嚴重的水土流失。營造梯田、恢復自然植被來降低地表徑流應被鼓勵。在波狀丘陵的山腰，土層潜，保水差，易受旱災。當地除了增加土層深度和降低地形坡度措施外，還開發了攔截地表徑流和抵御干旱的節水和儲水技術，同時引種耐旱作物。灌溉固然有利，但地形起伏不適于建立灌溉系統。

土壤結構和排水良好，肥力中等并與耕作措施有關。增施化肥，能提高有較高經濟價值的小麥產量。豆科或綠肥應包括在輪作制度中。紫色砂頁岩分解快，土壤土壤發育以機械風化爲主，但土壤侵蝕嚴重，成熟的土壤剖面難以發育。農人的經驗表明，紫色砂頁岩風化一年后，就能釋放足够的礦質養分供莊稼生長，但易遭受土壤侵蝕。

采集的第二個土壤剖面發育于紫色砂頁岩冲積物和坡積物上，土層深，但排水不暢，紅棕色粉粘到粉砂壤土，土壤剖面上有還原特征和淤積A層。該土壤分類爲鈣積紫色土（中國土壤系統分類，1990）即鈣積雛形土（FAO土壤分類，1989）。

從可利用能量資源看，當地水稻能一年兩熟，但由于溫度超過23度時，水稻僅能開花，實際上，一年只能種一季。低窪地土壤持水性好，降雨能確保水稻生長的需要，但降雨不均和干熱季節會帶來負面影響。灌溉會受到水源不足的限制。土壤肥力中等，但保肥力强。可能由于土壤呈碱性，造成土壤中缺乏Zn，Fe，B等微量元素，可以通過施化肥來矯正。

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 purple soils situated in the subtropical Sichuan 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 in more detail.

In this Soil Brief, the text part includes a general characterization of the Sichuan Basin presenting climate, geology and geomorphology (Chapter 1). Also a more specific description is given of the subregion 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" (ISSAS), 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 ISSAS. Duplicates of these soils were collected for ISRIC's world soil collection. In this Soil Brief two of these reference soils are presented.

Valuable comments on draft versions of this report were received from ISSAS and ISRIC staff, from Dr. T. de Meester and Mr. A.E. Hartemink. 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).

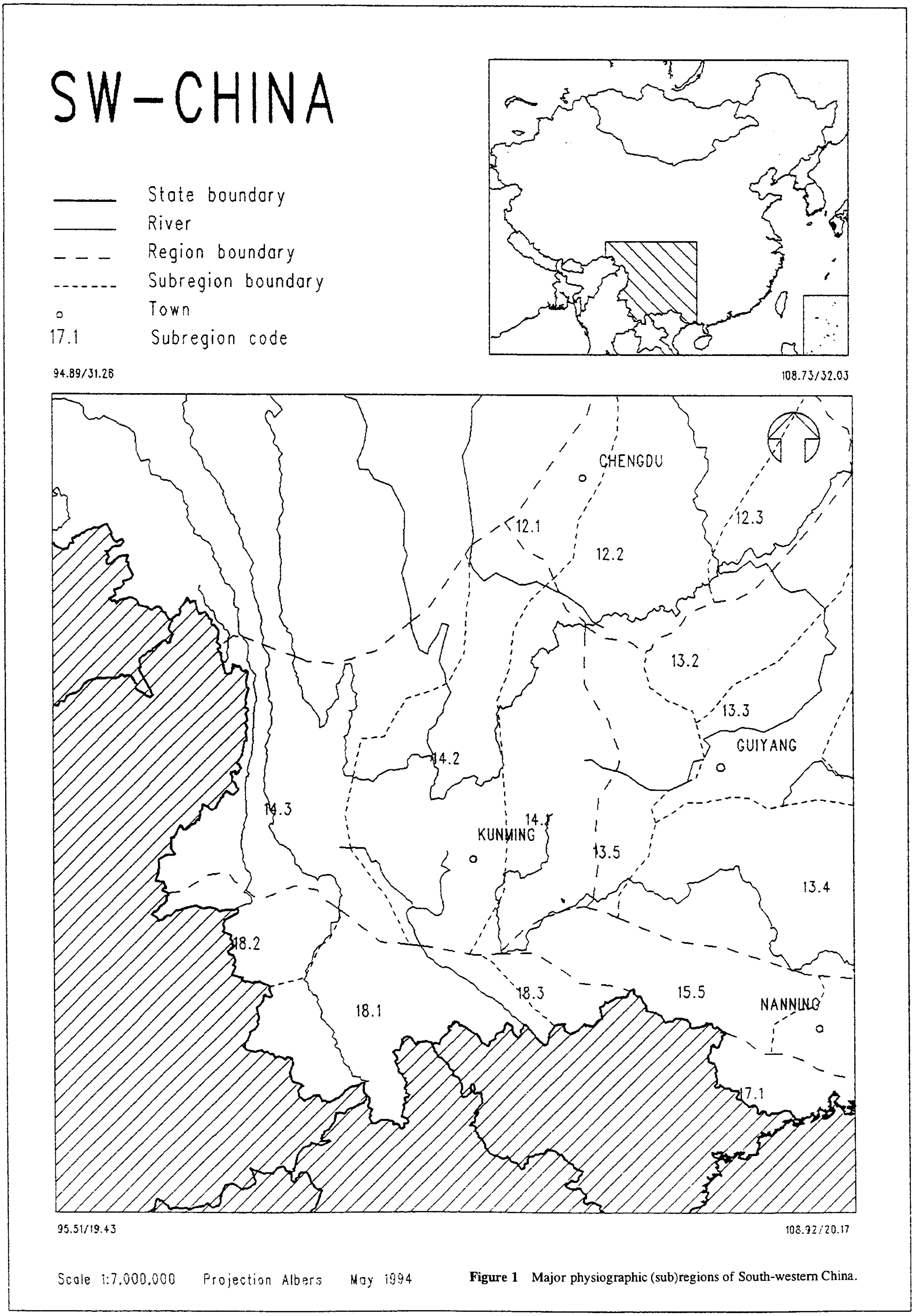


Figure 1 Major physiographic (sub)regions of South-western China.

1 THE SICHUAN BASIN

1.1 Introduction

The Sichuan Basin (260,000 km^2), is one of the largest inland basins in China. It occupies about 46% of the extensive Sichuan Province, which has a population of nearly 100 million, and is one of the highest populated agricultural regions in the world.

The basin, demarcated roughly by the 700 to 750 m contour line, is uninterruptedly encircled by a series of high mountains. The basin itself has an elevation of 250 to 700 m a.s.l. and is covered with rolling hills. It stretches 395 to 455 km from west to east, and 330 to 335 km from north to south. Mountains occupy almost 50% of the total land area, hills about 42%, and plains only 8%. In the northeastern part of the basin, the Chengdu plain is located. The central part is occupied by the low Fan Shan upland. In the east, gently sloping broad folds in the relief form a system of low parallel ranges.

1.2 Climate

Due to the protection provided by the surrounding mountains, the mean air temperature in January decreases to 5 to 8°C. Summer is long and hot, with a mean temperature in July of 27°C. The average annual temperature is 17°C. The summer season lasts four months; more than 250- 320 days belong to the frostless season and ground temperatures are always above 5°C (Luo Xiao Chuan).

Annual precipitation ranges from 1500 to 1800 mm in the surrounding mountains to 900 to 1300 mm in the basin. The precipitation decreases from southeast to northwest. About 50 to 60% of the precipitation falls in summer time and in the winter period only 10% of the rainfall is recorded. The area has droughts in winter and spring, and flood hazards during the summer (Luo Ji Tian *et al.*). The relative humidity is high throughout the year (80 to 85%). In western Sichuan Basin, there are more than 300 foggy days (Zhao Songqiao, 1986; Li Zhong-ming *et al.*, 1986).

According to the Köppen classification system, the Sichuan Basin belongs to the area with a Humid Subtropical Climate, characterised by a humid warm summer and a dry winter (Caw).

1.3 Geology and geomorphology

The basin has a typical rhombic shape that was formed in the Indo-China Tectonic Movement during the Mesozoic period. It corresponds to the part of the South China platform which was separated from the main platform during Hercynian-Mesozoic times (350 millions years ago). Continuous subsidence of the basin led to the accumulation of red sandstones and clays and purple shales of Jurassic and Cretaceous periods. It is sometimes called the Red Basin. Subsequent incision by the river network transformed the major part of the flat bottom into a disorderly complex of flat-topped hills.

1.4 Vegetation and land use

The vegetation of the basin is evergreen broad-leaf forest, low mountainous evergreen coniferous forest, groves of bamboo and subtropical thick growth of grass (Li Zhong-ming *et al.*, 1986). Most of the original vegetation has been cleared for farmland.

The basin has been intensively cultivated for more than 2000 years and practically all plains and hills are used for agriculture. There is more than 6 million ha of cropland of which 56% is used for paddy cultivation. Agriculture is depending on rainfall and seriously threatened by environmental degradation caused by the population growth (Zhao Songqiao, 1986). The agricultural history of Sichuan Province shows that in the winter season peas and sweet potatoes are cultivated, while in the summer season rice is the main crop (Yang Wen Yuan and Li Da Xiang). Citrus plantations are of more recent date, yielding the best quality fruits of China.

2 THE CENTRAL HILLS AREA OF SICHUAN BASIN

2.1 Introduction

In Fig. 1 the subregion is indicated with the code 12.2 and is located in the central part of the Sichuan basin (the central hills area has an elevation of 250 to 600 m a.s.l.). The central hill area is 121,000 km^2, which accounts for 21% of the Sichuan area. The cultivated land of this area is about 366.000 ha, which is 57% of the cultivated land in the Sichuan basin.

2.2 Climate

The area has a sub-tropical, moist and seasonal wind climate. The temperature is moderately high throughout the year with a few extremely hot summers. Daily average air temperatures are above 0°C and the average annual temperature is 17°C. The radiative energy of the sun is 3344- 4180 mJ/m^2. There are 280 days without frost and the annual precipitation fluctuates from 800 to 1200 mm. Climatic extremes as low temperatures, hailstorms and gales can have adverse effects on crop production.
Fig. 2 shows monthly data of the maximum, average and minimum temperature, of the meteorological station Ziyang, located 10 km from site CN 50 and CN 51. Fig. 3 presents mean monthly data for precipitation and evaporation measured in Ziyang. As is indicated in Fig. 3, the complete inter-cropping scheme, as practised on site CN 50, is related to the annual rainfall distribution. Both figures were made with SOLGRAPH (Brunt & Kauffman, 1995).

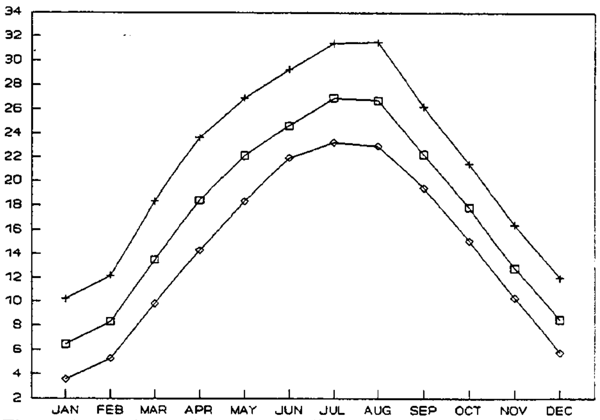


Figure 2 Maximum (+), average (□) and minimum (◊) temperature in °C at Ziyang meteorological station.

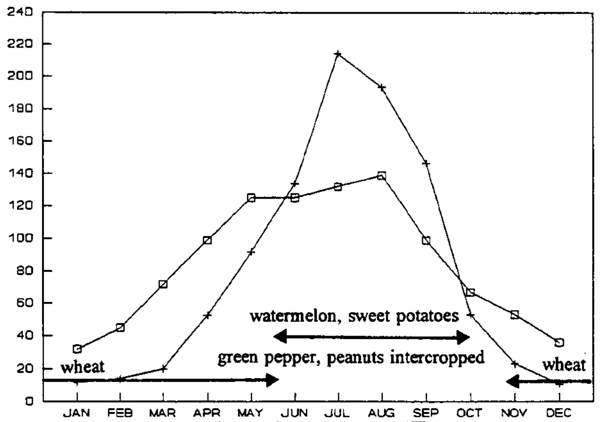


Figure 3 Precipitation (+) and evaporation (□) in mm at Ziyang meteorological station.

2.3 Geology and geomorphology

The hills are mainly composed of reddish sandstone and purple shale, with nearly horizontal strata. They were deposited in the Cretaceous, Jurassic and Triassic period. Since the late Tertiary period they have been deeply dissected, resulting in steep slopes and flat crests creating the so-called mesa topography. Valley floors vary in width from 15 to 100 m (Luo Ji Tian).
The soils are influenced by the parent rocks which are mostly Cretaceous or Tertiary purple shale, sandy shale and sandstone. The deep purple colour of the soils originating from the violet clay shales, is a result of the presence of large quantities of iron and manganese oxides in specific mineralogical forms (FAO-Unesco, 1978). Different lithological characters, rock formations and stratigraphic structures as well as the age of the rock, greatly affect the properties and fertility of the purple soils.

2.4 Vegetation and land use

Since ancient times the central hills have been a well-developed agricultural area with grain, cotton and sugar-cane as major crops. More recently other crops like water melon, tobacco, mulberry (for silkworm cocoons) and oranges were introduced in response to a more liberal price policy set by the central government and the distribution of fertilisers. The cultivated land of this area is 366,000 ha, which makes up 57% of the total cultivated land in Sichuan. The population density is over 250 per km^2 and the cultivated land per person is 0.06 ha. The cultivation index is over 30%, but in areas with forest only 3 to 5%. The population growth, the shortage of land and the deterioration of the environment causes difficulties for sustainable agricultural production.

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 50 and CN 51 is discussed. Both soils belong to the group of purple soils within the Chinese soil classification system and are located close to each other. CN 50 is an upland soil and CN 51 a lowland soil.
Detailed description, sampling and the taking of monoliths of both reference soils was carried out in 1993 by scientists the Chinese Institute of Soil Science and ISRIC. Field and laboratory data are given in Annex 1A and 1B: Soil and environmental data were stored in ISRIC Soil Information System (Van Waveren & Bos, 1988).

3.2 Location

The population pressure causes that the cultivated land per capita is declining and that the environmental conditions become less favourable for agricultural production. The combination of high population densities, extensive deforestation, inappropriate cultivation methods and intense rainfall have resulted in serious soil erosion. Therefore the Sichuan Academy of Agricultural Science (SAAS) created the "Ziyang Agricultural Environment Protection Station" near Songtao, Ziyang County (Fig. 4), where soil and water conservation research is realized. Both soils are situated within a 4.5 km^2 catchment area.
Reference soil CN 50 is located at 20 m distance from the meteorological station of the Ziyang Agricultural Environment Protection Station. Reference soil CN 51 is located at 1 km distance from CN 50.
Both soils are classified as purple soils. They occupy in Sichuan Province about 160,000 km^2, and 68% of these soils are cultivated (Chen Zhicheng *et al.*, 1990).

3.3 Landscape, geology, vegetation and land use

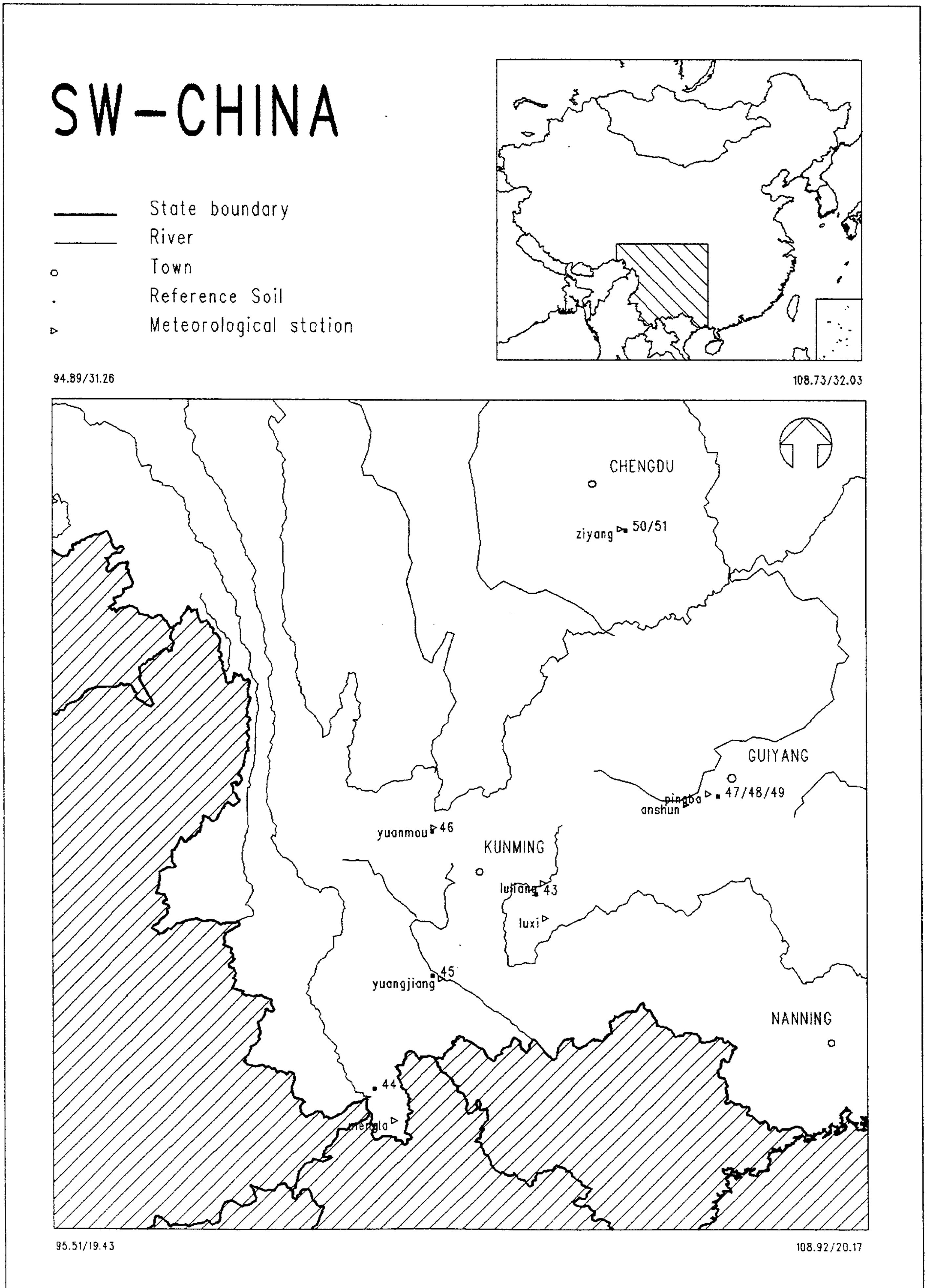
As part of a small catchment area in which the fieldstation of SAAS is situated, different physiographic units are distinguished. Low flat-topped hills with a hilly topography are predominant. Soil CN 50 is located on the crest of such a hill and is derived from shale and sandstone. Soil CN 51 is situated in a valley-bottom. The topography is almost flat due to man-made terraces. The parent material is alluvial and colluvial sediments.
The increased use of fertilizers and the introduction of the so-called three pond system has lead to an increase in the possibilities for planting crops on the higher parts, and the development of intercropping systems. Typical is the system of intercropping on the site where soil CN 50 was studied: wheat, sweet potatoes, green pepper, peanuts and watermelon. Additional farmer's income is obtained by selling watermelon (Yang Wen Yuan & Li Da Xiang). On the site watermelon and peanuts show evidence of drought stress.
In the lowlands, the winter and spring flooded paddy fields, which cover 80% of the total paddy field area, are only used for a single rice crop. This means that limited use is made of the radiation energy. Two rice harvests, however, require additional water supplies because of rainfall shortage. On the site where soil CN 51 was studied, the rice did not develop very well and gives probably a poor yield. The farmer had not enough resources to finance additional irrigation as was done in some neighbouring plots. Therefore, the decision was taken to sow soybeans in the rice as an emergency crop.

3.4 Soil characterisation

3.4.1 Brief field descriptions

CN 50 is a moderately deep to shallow, somewhat excessively drained, dark yellowish brown to purple, silt loam soil which is moderately to strongly structured and highly porous. Shale particles are found throughout the profile. Ridges are made by the farmers to cultivate sweet potatoes. Depth to parent material is highly fluctuating. On nearby flat-topped hills the thin solum had disappeared due to erosion and the parent material is outcropping.

Reference soil CN 51 is a deep, (very) poorly drained, reddish brown, silty clay to silt loam soil with a puddled topsoil and a moderate to strong prismatic structure in the subsoil. Pores in the topsoil are few and the subsoil is moderately porous. There are no distinct differences between soil horizons and it is difficult to observe the thin, compacted, slowly permeable plough sole. Due to reduction processes, translocation and precipitation of iron and manganese compounds in the subsoil, hard concretions are found below the plough sole.



Scale 1:7,000,000 Projection Albers May 1994

Figure 4 Location and numbers of the reference soils.

3.4.2 Brief analytical characterisation of CN 50 and CN 51

Soil samples were analyzed at ISRIC's soil laboratory according to the procedures described by Van Reeuwijk (1992). All analytical data are presented in Annex 1A and 1B, and a summary is given in Table 1.
Some important soil data were selected and presented in a graphical way, using SOLGRAPH (Brunt & Kauffman, 1995).
Fig. 5 and 6 show the textural composition of the two soils with depth. Soil CN 50 does not show any sand, silt and clay content changes with depth. The particle size distribution of CN 51 shows that clay, silt and sand contents are highly variable with depth.
Fig. 7 and 8 present chemical properties with depth. The organic C content, sum of the exchangeable bases (Ca, Mg, K and Na), and soil acidity (pH-H_2O and pH-KCl). The sum of the exchangeable bases of soil CN 50 and soil CN 51 is very high throughout the profile, and constant with depth. Also the pH of both soils does not vary very much with depth and is slightly alkaline or neutral. The organic C content of soil CN 50 is low. The topsoil of CN 51 has a medium organic C content, but it is decreasing with depth.
Fig. 9 and 10 present the moisture retention curves. The intersection point with the x-axis, gives the water content of the soils under saturated conditións, which indicates the 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) is the quantity of moisture between pF 2 (field capacity) and pF 4.2 (permanent wilting point). The available moisture in the topsoil of CN 50 is medium and it is slightly decreasing with depth. Large pores are found in the subsoil and the overall porosity of the soil is medium. Soil CN 51 of which only one horizon was sampled, has a high amount of available moisture (19%). Only few large pores exist, but the overall porosity of the horizon is moderately high.

Table 1 Key properties of soils CN 50 and CN 51

	CN 50	CN 51
Texture	silt loam throughout the profile	silty clay in the topsoil to silt loam in the subsoil
Organic carbon	very low (0.3%) throughout the profile	medium (1%) in the topsoil to low (0.5%) in the subsoil
pH-H_2O	slightly alkaline (pH-H_2O 8.2) throughout the profile	neutral (pH-H_2O 7.1) throughout the profile
Sum of bases	very high (± 50 $cmol_c$ kg^{-1} soil) throughout the profile	very high (± 47 $cmol_c$ kg^{-1} soil) throughout the profile
Cation Exchange Capacity	high (22 $cmol_c$ kg^{-1} soil) throughout the profile	high (23 $cmol_c$ kg^{-1} soil) in the topsoil to medium (± 17 $cmol_c$ kg^{-1} soil in the subsoil
Phosphorus	medium (8 mg kg^{-1}) in the topsoil and low (2 mg kg^{-1}) in the subsoil	high (22 mg kg^{-1}) in the topsoil and medium (7 mg kg^{-1}) in the subsoil
Nitrogen	very low (0.06%) throughout the profile	low (0.12%) in the topsoil to very low (0.05%) in the subsoil
Clay mineralogy	smectite, mica/illite	smectite, mica/illite
Air capacity	low (8%) in the topsoil to medium (14%) in the subsoil	extremely low (2%) in the topsoil
Available soil moisture	medium (11%) in the topsoil to low (9%) in the subsoil	high (19%) in the topsoil
Bulk density	high (1.4 kg dm^{-3}) throughout the profile	high (1.4 kg dm^{-3}) in the topsoil

3.5 Soil classification

3.5.1 Soil classification of CN 50

FAO-Unesco (1988)
The soil classifies as a Calcaric Cambisol, because the soil has an ochric A horizon (too light in colour, too little organic matter, and too thin to be a mollic or umbric epipedon) overlying a cambic horizon, and containing more than 2% $CaCO_3$ between 20 and 50 cm from the surface. The occurrence of continuous, coherent hard rock within 50 cm of the surface causes that the soil has a lithic phase.
The soil is too deep (> 30 cm) to be classified as a Leptosol and is also not a Regosol because it has a cambic horizon.

USDA Soil Taxonomy (1992)
The soil classifies as a Lithic Eutrochrept, because it has an ochric epipedon, a base saturation of more than 60% in the subsoil, and a lithic contact within 50 cm of the mineral soil surface.

Chinese Soil Classification System (Soil Taxonomic Classification Research Group, 1993)
The soil keys out as a Calcic Purple Soil, because as a Regosic Primarosol it has the lithologic characteristics of purple sandstones and shales. The soil has calcaric properties (≥ 1% $CaCO_3$) and a base saturation over 50% below a depth of 20 cm.

3.5.2 Soil classification of CN 51

FAO-Unesco (1988)
The soil classifies as an Calcaric Cambisol, because the soil has an ochric A horizon (too light in colour, and too thin to be a mollic or umbric epipedon) overlying a cambic horizon with a recognizable soil structure. The base saturation is ≥ 50% between 20 and 50 cm from the surface and the soil is calcareous (> 2% $CaCO_3$) at that depth.
In this probably originally well drained soil, surface waterlogging (related to long continued irrigation or inundation) has given rise to stagnic properties within 50 cm of the surface. This is expressed in the classification by the anthraquic phase of the Cambisols. Gleyic soil properties are strictly associated with movement of the groundwater table; mottled, oxidized horizons occur on top of a fully reduced subsoil. Because the soil has reduction resulting from irrigation, it is not classified as a Gleysol.

USDA Soil Taxonomy (1992)
The soil classifies as an Oxyaquic Eutrochrept because the soil has an ochric epipedon which is underlain at a depth of 50 cm by a cambic horizon. The soil has a base saturation in the subsoil of more than 60% and is saturated with water in one or more layers within 100 cm of the mineral soil surface, for one month or more per year in 6 or more out of 10 years.
The soil does not have an aquic soil moisture regime because the ochric epipedon is not underlain by a horizon with a chroma of ≤ 2.

Chinese Soil Classification System (Soil Taxonomic Classification Research Group, 1993)
The soil is classified as a Calcic purple soils, because it has the lithologic characteristics of purple sandstones and shales and calcaric properties and a base saturation of 50% or more, below a depth of 20 to 50 cm. The soil has a hydragric epipedon formed under the conditions of a submerged cultivation. It has a subsurface horizon with features which indicate redox processes (manganiferous concretions). An agric horizon is absent so it does not key out as an Anthrosol.

3.6 Soil suitability and environment assessment

A qualitative evaluation of relevant land qualities according to the Framework for Land Evaluation (FAO, 1983) was carried out. Soil CN 50 was evaluated for wheat, a traditional crop of great importance in this part of China and soil CN 51 for paddy rice.
Crop growth criteria were taken from Purseglove (1972), 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 wheat

Wheat (*Triticum spp.*) needs at least 250 mm of well-distributed rainfall. Optimum temperatures are 15-20°C. Mean minimum temperature should not be below 10°C, mean maximum not above about 25°C, especially when this coincides with high humidity. A cold period is required for flowering during early growth and a dry period is needed for ripening.
It is a deep rooting crop (> 90 cm), high nutrient demanding and with an optimum pH of 6 - 7. Excessive nitrogen applications result in lodging of the crop, and promote rust. The tolerance to periods with water saturation of the soil and/or to periods with drought is medium. The soil, preferably of fine to medium texture must be well structured, permeable and well drained. A low to moderate Available Water Capacity (AWC) of the soil is important, taking into account that 50-60% of the water uptake takes place in the first 30 cm.

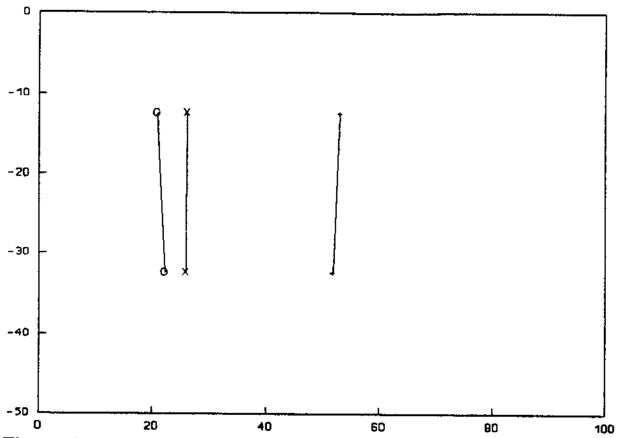


Figure 5 Percentages clay (×), silt (+) and sand (o) versus depth (cm) in profile CN 50.

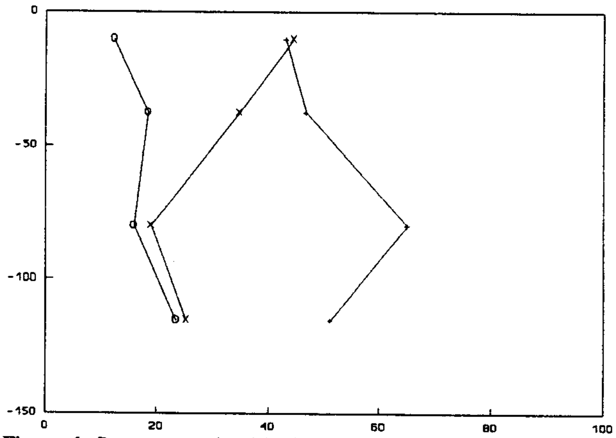


Figure 6 Percentages clay (×), silt (+) and sand (o) versus depth (cm) in profile CN 51.

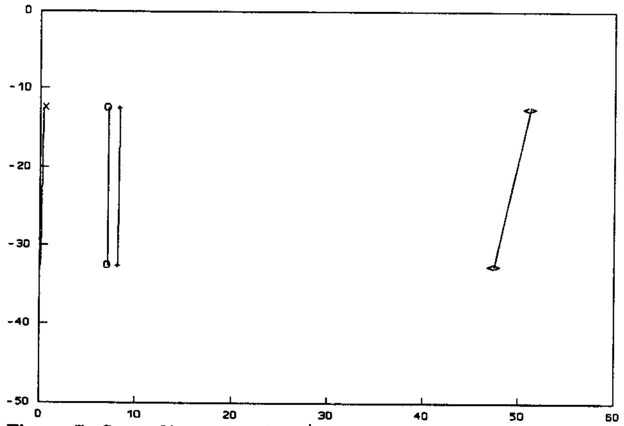


Figure 7 Sum of bases ($cmol_c$ kg^{-1} soil) (<>), pH-H_2O (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile CN 50.

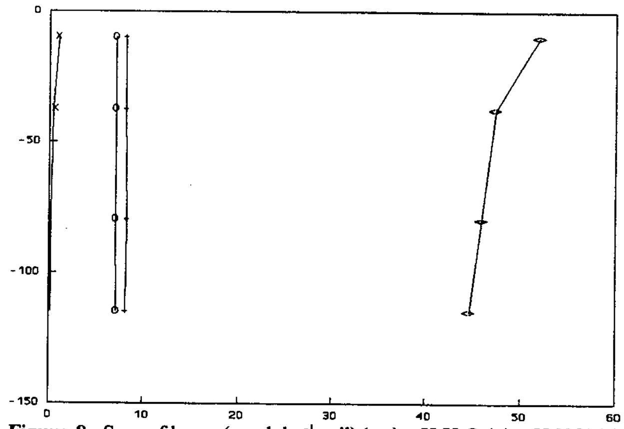


Figure 8 Sum of bases ($cmol_c$ kg^{-1} soil) (<>), pH-H_2O (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile CN 51.

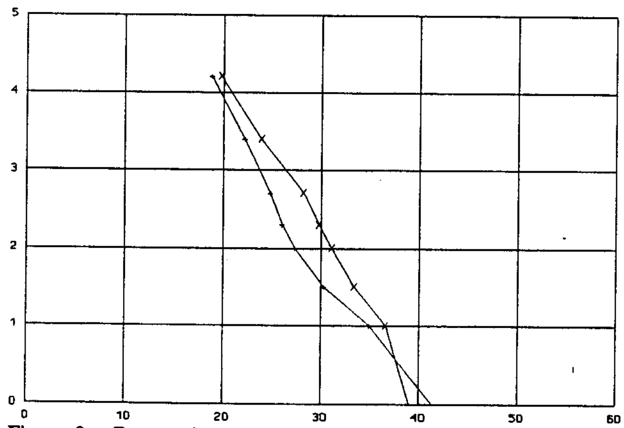


Figure 9 pF or moisture retention curves (water content in vol % versus suction) at depth 0-25 cm (×), 25-40 cm (+) in profile CN 50.

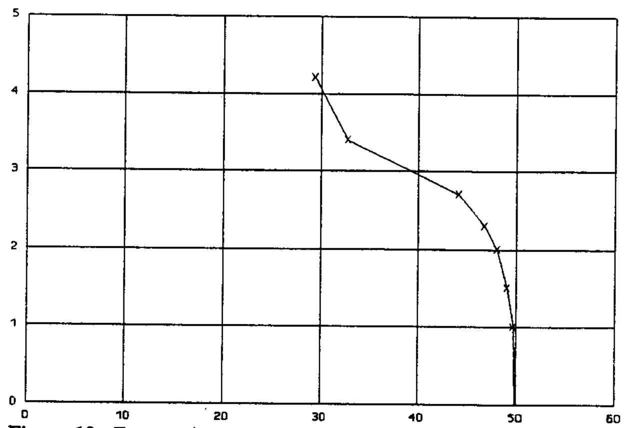
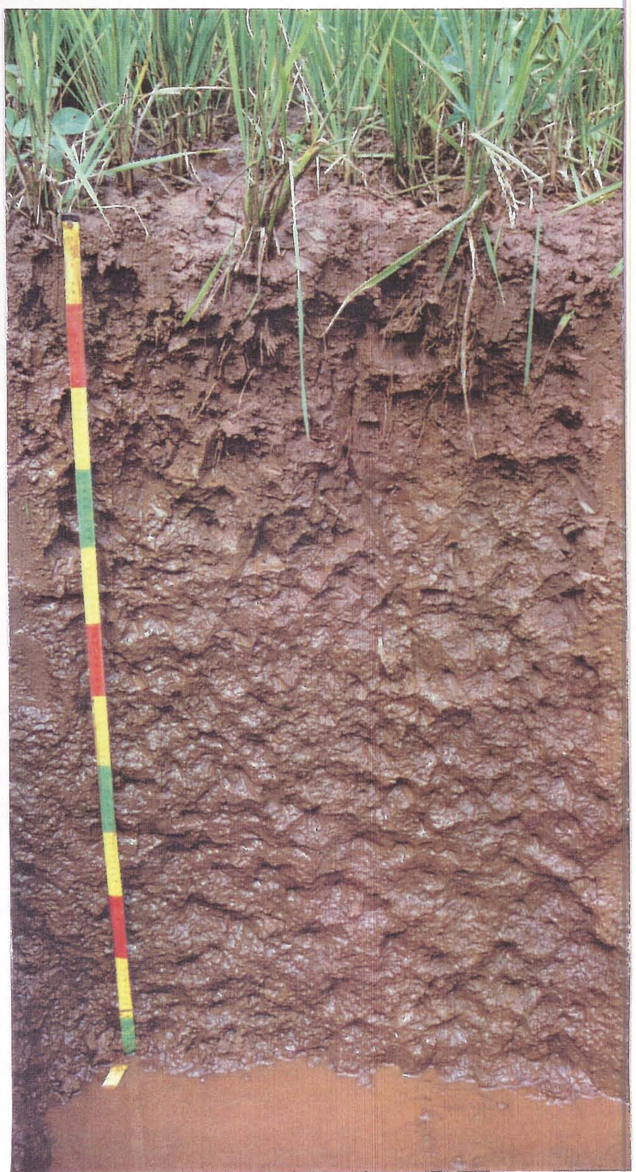


Figure 10 pF or moisture retention curves (water content in vol % versus suction) at depth 20-55 cm (×) in profile CN 51.


1


2

1. Landscape CN 51
2. Profile CN 51
3. Transport monolith CN 51


3

1

2

1. Landscape CN 50
2. Profile CN 50
3. Runoff plots near CN 50

3

3.6.2 Evaluation of CN 50

The favourable climate permits crop growth the whole year around. However, yield and quality of wheat are low. The low sunshine hours (27% of the potential) and the radiation values, limit photosynthesis. As a result, the potential to use the light resource more efficiently, to increase crop yields is important. It is recommended to look for crop varieties which maximise the light potential in terms of short growth, close planting, high light efficiency conversion, adaptive intercropping and rapid post-harvest crop establishment by transplanting (Zhang Jian Hua).
The soils are well-structured with strong micro-aggregates, and are well-drained (FAO-Unesco, 1978). The natural fertility is mediocre (very low C and N contents) but it is greatly affected by farming practices. Wheat production can be increased by proper use of fertilizers. Organic manure should be applied to increase the organic matter and nitrogen contents of the soils (Chen Zhicheng *et al.*, 1990). Leguminous or green manure crops could be included in the rotation system in order to increase the productivity of the soils. However, the population growth has lead to an increased demand for wheat, and because of the high economic benefits, reduction in the area cropped with wheat is unlikely (Yang Wen Yuan & Li Da Xiang).
The environment has been degraded by soil erosion. Over 50% of the annual precipitation falls in the summer period and intensity may be high. The main forms of erosion are sheet and gully with a characteristic criss-cross pattern. Erosion affects 63% of the purple hilly area and has reached 3,035 t km^{-2} y^{-1}, with an annual soil loss of 11,610 tons (Luo Xiao Chuan). The average annual run-off is 305, mm which accounts for more than 30% of the annual precipitation. Conservation measures as land terracing and improvements in the natural vegetation cover including the development of wood/grassland systems to control run-off and increase their production, are recommended.
Due to the limited soil depth as a result of the severe erosion, a high permeability coefficient and low water holding capacity, the soils on the slopes may suffer from drought. Therefore, the productivity of the soils depends on the rainfall, which is not very reliable and often limited. Dry winters, spring droughts and severe droughts occur every 10 years, moderate droughts every 5 years and two minor droughts in every 3 years.
Measures to improve the soil moisture retention capacity include increasing the soil depth and decreasing the slope angle. In addition, water use and storage techniques to intercept run-off (by contour ridges) and improve drought resistance (such as the three pond system: water pond, silt pond and manure pond) are developed as possible solutions (Chen Zhicheng *et al.*, 1990). Also drought tolerant plants have been introduced. Wherever irrigation is possible, fair yields are obtained, but the topography is generally unfavourable for irrigation.
The purple shale breaks down readily because of its heavy texture and high expansion and contraction coefficient. Therefore soil erosion is followed by a phase of dominantly mechanical weathering and incipient soil formation, but erosion prevents the development of a deep profile (Lu Xixi & Shi Deming, 1991). According to field investigations, once the rocks are outcropping, they may weather into soil in approximately ten years (Li Zhong *et al.*, 1986). Farmers experience shows that already after one year's weathering of exposed purple shales, a crop can be grown. The partly weathered rock easily releases nutrients which contribute to the fertility. The loose weathered materials are, however, susceptible to erosion.

3.6.3 Requirements and limitations for irrigated rice

Irrigated rice (*Oryza sativa*) needs 1200 to 1800 mm of water, rainfall plus irrigation, including water for land preparation. Dry weather during ripening and harvesting is essential for an even maturation of the crop. Availability of irrigation water is probably more important than rainfall. The average temperature should be between 18 and 35°C. Low temperature during early growth retards seedling development and in general temperatures should not fall below 10°C. Variations between day and night temperatures of 10°C are conducive to high yields. Long periods of sunshine, a slight wind and a fairly low relative air humidity are required for high yields.
It is a moderately high nutrient demanding crop, especially nitrogen; pH 4 - 8, optimum pH 5.0 - 6.5. The soil, preferably of fine texture should have an impermeable subsoil and should be poorly drained to reduce losses of water and nutrients. A high Available Water Capacity (AWC) of the soil is important. The tolerance to periods with water shortage is low, while the tolerance to periods with water saturation or even logging of the soil is high.

3.6.4 Evaluation of CN 51

The solar energy is sufficient for two rice crops in one year. In practice the rice is only planted once. This depends more on the temperature and less on the amount of available water, because the rice will only flower if the temperature is more than 23°C. This temperature is only reached in the summer months.
The capacity of the soil to store water is high (Available Water Capacity is 187 mm/100 cm soil). There is sufficient precipitation to ensure that the water demands of the rice crop are met in the summer season but uneven distribution and hot dry spells can have adverse effects. Additional irrigation water is sometimes needed, but is not always available.

The soil has a moderate availability of nutrients (low N content, high to medium P content), and the nutrient retention capacity is high. In general, this soil type has deficiencies of micro-elements for Zn (available Zn is 1 ppm), Fe and B. A reason might be the slight alkalinity of the soil (pH 8.2). Fertilizers should be applied to correct theses deficiencies.

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Annex 1A ISIS Data Sheet CN 50

ISIS 4.0 data sheet of monolith CN 50 Country : PEOPLE'S REPUBLIC OF CHINA Print date (dd/mm/yy) : 31/05/94

FAO/UNESCO (1988) : Silti-Calcaric Cambisol (Chromic), lithic phase (1974 : Calcic Cambisol, lithic phase)
USDA/SCS SOIL TAXONOMY (1992) : Lithic Eutrochrept, fine-silty, mixed, thermic (1975 : Lithic Eutrochrept)
CSTC (1991) : Calcic purple soil

DIAGNOSTIC CRITERIA FAO (1988) : ochric A, cambic B horizon; calcareous
USDA/SCS (1992) : ochric epipedon, cambic horizon; lithic contact
Soil moisture regime : udic

LOCATION : 20 m from weather station of SAAS fieldstation, Songtao, Ziyang County
Latitude : 30° 6′ 0′′ N Longitude : 104°45′ 0′′ E Altitude : 415 m a.s.l.
AUTHOR(S) : Vogel, A.W., Wang Mingzhu, Huang Xiaoqing Date (mm/yy) : 8/93

GENERAL LANDFORM : low hill Topography : hilly
PHYSIOGRAPHIC UNIT : low hill landscape of Sichuan Basin
SLOPE Gradient : 2% Aspect : N Form : straight
POSITION OF SITE : crest
MICRO RELIEF Kind : ripples Pattern : linear Height : 30 cm
SURFACE CHAR. Rock outcrop : nil Stoniness : very stony
Form : angular irregular Average size : 2 cm
Cracking : nil Slaking/crusting : nil
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : moderate sheet and moderate rill Aggradation : nil
Slope stability : stable

PARENT MATERIAL : sandstone/shale
Texture : sandy clay
Weathering degree : partial or moderate
Depth lithological boundary : 40 cm

EFFECTIVE SOIL DEPTH : 55 cm

WATER TABLE : no watertable observed
DRAINAGE : somewhat excessive
PERMEABILITY : no slowly permeable layer(s)
FLOODING Frequency : nil Run off : medium
MOISTURE CONDITIONS PROFILE : 0 - 40 cm moist

LAND USE : low level arable farming; crops : wheat; no irrigation; rotation : not relevant; improvements : none
Landuse/vegetation remarks : intercropping of five crops

CLIMATE : Köppen: Caw
Station: ZIYANG 30 7 N/104 39 E 357 m a.s.l. 10 km W of site Relevance: good

	No. years of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
EP Penman mm	29	32	45	72	99	125	125	132	139	99	67	53	36	719
relative humidity %	29	81	80	74	73	73	78	82	81	84	84	83	83	80
precipitation mm	29	12	14	20	53	92	134	214	193	147	53	23	11	965
no. of raindays	29	7	9	10	12	15	17	15	14	17	16	11	7	149
tot.glob.rad. MJ m^{-2}		6.2	7.2	9.9	12.0	13.4	14.0	16.6	16.1	10.5	7.3	6.1	5.4	10.4
T mean °C	24	6.5	8.3	13.5	18.4	22.1	24.6	26.9	26.7	22.2	17.8	12.8	8.5	17.4
T max °C	24	10.2	12.2	18.3	23.6	26.9	29.2	31.4	31.5	26.2	21.4	16.4	12.0	21.6
T min °C	24	3.6	5.3	9.8	14.3	18.3	21.9	23.2	22.9	19.4	15.1	10.3	5.8	14.1
windspeed(at 2m) m s^{-1}	24	0.6	0.7	1.0	1.1	1.2	1.0	0.9	0.9	0.9	0.7	0.7	0.6	0.9
bright sunshine h d^{-1}	29	1.7	2.1	3.4	4.4	4.3	4.3	5.3	6.0	3.1	2.2	2.0	1.7	3.4
bright sunshine %	24	18	20	30	34	31	32	42	48	27	19	19	17	29

PROFILE DESCRIPTION :

Moderately deep, somewhat excessively drained, weak red to red silt loam derived from sandstone/shale. The effective soil depth is very much influenced by the land use. Ripples are made by man to cultivate sweet potatoes as one of the five crops.

Ap	0 - 25 cm	Weak red (10R 4/4, moist) gravelly silt loam; very strong fine granular to very strong medium granular structure; friable; many fine to coarse exped-inped pores; highly porous; many fine and medium roots throughout; frequent fine and medium weathered lime-sandstone fragments; frequent worm channels; clear smooth boundary to
B	25 - 40 cm	Weak red to red (10R 4/5, moist) stony silt loam; moderate to strong fine to medium subangular blocky structure; firm; many very fine and fine exped-inped pores; highly porous; common fine roots throughout; few medium fresh lime-sandstone fragments; frequent worm channels; abrupt wavy boundary to
R	40 cm +	Reddish brown (2.5YR 4/4, dry) sandstone/shale

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 - 25	-	2	2	2	4	11	21	19	34	53	26	18.8	1.48	39	37	33	31	30	28	24	20
2	25 - 40	-	2	3	4	6	8	22	14	38	52	26	14.3	1.43	41	35	30	27	26	25	22	19

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^{-1}
						$cmol_c\ kg^{-1}$													
1	8.3	7.1	13.6	0.32	0.06	49.8	1.0	0.3	0.1	51.2	-	-	22.2	85	1.1	51.2	231	-	0.16
2	8.2	7.1	15.7	0.13	0.04	46.3	0.7	0.3	0.2	47.5	-	-	22.2	86	0.5	47.5	214	-	0.26

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

Hor. no.	MICA /ILL	VERM	SMEC	KAOL	MIX	QUAR	FELD	GOET	AVAIL. P mg kg^{-1} Bray	Olsen
1	4	2	5	3	3	2	1	2	0.7	8.0
2	4	2	5	3	3	2	1	1	0.0	1.9

Annex 1B ISIS Data Sheet CN 51

ISIS 4.0 data sheet of monolith CN 51 Country : PEOPLE'S REPUBLIC OF CHINA Print date (dd/mm/yy) : 31/05/94

FAO/UNESCO (1988)	: Silti-Calcaric Cambisol (Chromic), inundic phase	(1974 : Calcic Cambisol)
USDA/SCS SOIL TAXONOMY (1992)	: Oxyaquic Eutrochrept, fine-silty, mixed, thermic	(1975 : Typic Eutrochrept)
CSTC (1991)	: Calcic purple soil	

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

LOCATION : Valley bottom near SAAS fieldstation, Songtao, Ziyang County
Latitude : 30° 6' 0'' N Longitude : 104°45' 0'' E Altitude : 392 m a.s.l.
AUTHOR(S) : Vogel, A.W., Wang Mingzhu, Huang Xiaoqing Date (mm/yy) : 8/93

GENERAL LANDFORM : valley Topography : hilly
PHYSIOGRAPHIC UNIT : valley bottom, low hill landscape
SLOPE Gradient : 0%
POSITION OF SITE : flat
MICRO RELIEF Kind : level
SURFACE CHAR. Rock outcrop : nil Stoniness : nil
Cracking : nil Slaking/crusting : nil
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : nil Aggradation : nil
Slope stability : stable

PARENT MATERIAL 1 : alluvium derived from : sandstone/shale
Texture : mixed
2 : colluvium derived from : sandstone/shale
Texture : mixed

EFFECTIVE SOIL DEPTH : 105 cm

WATER TABLE Depth : 10 cm Kind : flooded
DRAINAGE : very poor - poor
PERMEABILITY : slow Slowly permeable layer from 0 to 20 cm
FLOODING Frequency : irregular, fresh water Run off : ponded
MOISTURE CONDITIONS PROFILE : 0 - 120 cm wet

LAND USE : low level arable farming; crops : rice; seasonal irrigated; rotation : not relevant; improvements : terracing
Landuse/vegetation remarks : paddy intercropped with soybeans

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CLIMATE : Köppen: Caw
Station: ZIYANG 30 7 N/104 39 E 357 m a.s.l. 10 km W of site Relevance: good

	No. years of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
EP Penman mm	29	32	45	72	99	125	125	132	139	99	67	53	36	719
relative humidity %	29	81	80	74	73	73	78	82	81	84	84	83	83	80
precipitation mm	29	12	14	20	53	92	134	214	193	147	53	23	11	965
no. of raindays	29	7	9	10	12	15	17	15	14	17	16	11	7	149
tot.glob.rad. MJ m^{-2}		6.2	7.2	9.9	12.0	13.4	14.0	16.6	16.1	10.5	7.3	6.1	5.4	10.4
T mean °C	24	6.5	8.3	13.5	18.4	22.1	24.6	26.9	26.7	22.2	17.8	12.8	8.5	17.4
T max °C	24	10.2	12.2	18.3	23.6	26.9	29.2	31.4	31.5	26.2	21.4	16.4	12.0	21.6
T min °C	24	3.6	5.3	9.8	14.3	18.3	21.9	23.2	22.9	19.4	15.1	10.3	5.8	14.1
windspeed(at 2m) m s^{-1}	24	0.6	0.7	1.0	1.1	1.2	1.0	0.9	0.9	0.9	0.7	0.7	0.6	0.9
bright sunshine h d^{-1}	29	1.7	2.1	3.4	4.4	4.3	4.3	5.3	6.0	3.1	2.2	2.0	1.7	3.4
bright sunshine %	24	18	20	30	34	31	32	42	48	27	19	19	17	29

PROFILE DESCRIPTION :

Deep, very poorly drained, reddish brown silty clay to silt loam developed in alluvial and colluvial deposits derived from sandstone/shale. The profile was at the moment of description completely saturated but shows no mottling or clear hydromorphic properties. Due to the lack of sufficient water the rice cannot be irrigated continuously and soybeans are sown as an emergency crop. The soil has a puddled structureless topsoil and a prismatic structure in the subsurface horizons where also iron and manganese concretions are observed.

Ap	0 - 20 cm	Reddish brown (5YR 4/3, moist) silty clay; strongly coherent structure; slightly sticky, plastic; no macropores; many fine and medium roots throughout; clear smooth boundary to
Bw1	20 - 55 cm	Reddish brown (5YR 4/4, moist) silty clay loam; strong coarse prismatic structure; non sticky, plastic; thin humus cutans in root channels and pores; many very fine and fine inped pores; highly porous; common fine roots between peds; frequent small hard manganiferous concretions and few small soft calcareous concretions; few channels; gradual smooth boundary to
Bw2	55 - 105 cm	Reddish brown (5YR 4/4, moist) silt loam; strong coarse prismatic structure; non sticky, plastic; thin humus cutans in root channels and pores; many very fine and fine inped pores; highly porous; common fine roots between peds; frequent small hard manganiferous concretions and few small soft calcareous concretions; few channels; gradual smooth boundary to
C	105 cm +	Dark reddish brown (5YR 3/4, moist) silt loam; moderate medium wedge-shaped angular blocky structure; slightly sticky, slightly plastic; thin humus cutans in root channels and pores; few very fine inped pores; moderately porous; few small hard manganiferous concretions and few small soft calcareous concretions

ANALYTICAL DATA (air-dry samples) :

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	-	2	2	2	2	5	12	10	33	43	45	19.1	-	-	-	-	-	-	-	-	-
2	20 - 55	-	1	2	2	3	12	19	17	30	47	35	14.4	1.44	50	50	49	48	47	44	33	29
3	55 - 105	-	2	2	2	2	9	16	26	39	65	19	13.5	-	-	-	-	-	-	-	-	-
4	105 - -	-	2	2	2	3	16	23	24	27	51	25	12.5	-	-	-	-	-	-	-	-	-

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^{-1}
						cmol$_c$ kg^{-1}													
1	8.2	7.1	8.9	1.04	0.12	49.0	2.4	0.5	0.1	52.0	-	-	23.0	52	3.6	52.0	226	-	0.24
2	8.2	7.1	8.7	0.44	0.07	45.2	1.7	0.4	0.1	47.4	-	-	19.2	55	1.5	47.4	247	-	0.18
3	8.3	7.1	9.6	0.23	0.05	43.8	1.7	0.3	0.2	46.0	-	-	17.4	92	0.8	46.0	264	-	0.13
4	8.2	7.2	9.4	0.19	0.05	42.6	1.7	0.3	0.1	44.7	-	-	16.8	67	0.7	44.7	266	-	0.13

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

Hor. no.	VERM	SMEC	KAOL	MIX	QUAR	FELD	AVAIL. P mg kg^{-1} Bray	Olsen
1	3	5	3	3	2	2	9.4	22.9
2	3	5	3	3	2	1	7.0	4.8
3	3	5	3	3	2	1	0.0	9.1
4	3	5	3	3	2	1	1.8	0.6

ANALYTICAL DATA (field-moist samples) :

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	-	2	2	2	2	5	12	13	30	43	45	23.9	-	-	-	-	-	-	-	-	-
2	20 - 55	-	2	2	2	2	6	13	14	30	45	43	20.9	-	-	-	-	-	-	-	-	-
3	55 - 105	-	2	2	2	3	17	25	24	27	50	25	14.8	-	-	-	-	-	-	-	-	-
4	105 - -	-	2	2	2	4	15	24	22	26	48	28	18.8	-	-	-	-	-	-	-	-	-

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^{-1}	AVAIL. P mg kg^{-1} Bray	Olsen
						cmol$_c$ kg^{-1}															
1	8.1	6.9	9.4	1.07	0.14	42.0	2.2	0.4	0.2	44.8	-	-	24.6	54	3.7	44.8	182	-	0.36	9.9	20.9
2	8.5	7.1	9.6	0.60	0.10	40.7	1.9	0.3	0.2	43.1	-	-	22.3	52	2.1	43.1	193	-	0.18	0.8	1.9
3	8.7	7.2	9.5	0.33	0.06	36.5	1.6	0.2	0.1	38.4	-	-	16.1	64	1.2	38.4	239	-	0.14	0.7	0.7
4	8.7	7.2	9.8	0.22	0.06	38.3	1.6	0.2	0.2	40.3	-	-	16.8	60	0.8	40.3	240	-	0.12	0.0	0.7

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

CLIMATE

Land quality		Type	CN 50 (1)	CN 50 (2)	CN 50 (3)	CN 50 (4)	CN 50 (5)	CN 51 (1)	CN 51 (2)	CN 51 (3)	CN 51 (4)	CN 51 (5)
Radiation regime	- total radiation	1		X					X			
	- day length	1	X					X				
Temperature regime		1	X							X		
Climatic hazards (hailstorm, wind, frost)		2	X						X			
Conditions for ripening		1	X					X				
Length growing season		1	X					X				
Drought hazard during growing season		2				X					X	

SOIL

Land quality		Type	CN 50 (1)	CN 50 (2)	CN 50 (3)	CN 50 (4)	CN 50 (5)	CN 51 (1)	CN 51 (2)	CN 51 (3)	CN 51 (4)	CN 51 (5)
Potential total soil moisture		1			X				X			
Oxygen availability		1	X									
Nutrient availability		1			X				X			
Nutrient retention capacity		1	X					X				
Rooting conditions		1		X				X				
Conditions affecting germination		1										
Excess of salts	- salinity	2	X					X				
	- sodicity	2	X					X				
Soil toxicities (e.g. high Al sat.)		2	X					X				

LAND MANAGEMENT

Land quality		Type	CN 50 (1)	CN 50 (2)	CN 50 (3)	CN 50 (4)	CN 50 (5)	CN 51 (1)	CN 51 (2)	CN 51 (3)	CN 51 (4)	CN 51 (5)
Initial land preparation		2										
Workability		1			X				X			
Potential for mechanization		1		X				X				
Accessibility	- existing	1	X					X				
	- potential	1		X				X				
Erosion hazard	- wind	2	X					X				
	- water	2				X		X				
Flood hazard		2	X						X			
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 $cmol_c\ kg^{-1}$)
μm	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 (< 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 Agriculture 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)

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China 2	Reference soil ("Latosol") of tropical southern Yunnan Province	1
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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
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13	Zambia	11
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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