Soil Brief CN 9

# PEOPLE'S REPUBLIC OF CHINA

## Reference soil of Chaoyang County, typical of the formerly wooded, hilly areas in the SW of Liaoning Province

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# Reference soil of Chaoyang County, typical of the formerly wooded, hilly areas in the SW of Liaoning Province

| *Number* | *Chinese classification* | *FAO-Unesco* | *Soil Taxonomy* |
|---|---|---|---|
| CN 34 | Haplic Cinnamon Soil | Chromic Cambisol | Typic Ustochrept |

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ABSTRACT

A representative soil from the Chaoyang area (Liaoning province) was studied as a contribution to the establishment of a Chinese soil reference collection and pedon database. Description and sampling were 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 Chaoyang area is characterized by extensive soil erosion. The climatic conditions are those of a typical continental monsoon region: strongly varying temperatures, a relatively short frost free period and a semi-arid climate with about 500 mm of rain, mainly falling in summer. These arid conditions are only moderately favourable for rainfed agriculture: the long and dry winter and sometimes the delayed summer rains present serious limitations for crops.

The soil studied was developed in thick colluvial materials that are present in form of extensive deposits resulting from severe erosion that followed the complete cutting of the forest vegetation about 100 years ago.

The soil is a deep, reddish brown, well drained silt loam. It is classified as a Haplic Cinnamon Soil (CSTC, 1991) or Chromic Cambisol (FAO, 1988).

The soil is used mainly for rainfed maize and sorghum. It has a neutral reaction and good fertility. The moisture storage capacity of the soil is high but it is only partly used since recharge of the soil water in winter is very limited. Thus the main limiting factor for agricultural production is the soil moisture content.

## 摘 要

为建立中国土壤样品参比库和土壤剖面数据库，一个典型土壤剖面采自辽宁省朝阳地区。该项目在欧共体STD2项目资助下，由中国科学院南京土壤所和荷兰国际土壤信息参比中心合作实施。

朝阳地区大面积土壤遭受侵蚀。气候属于典型大陆型季风气候：即温差变异大，相对短的无霜冻期和半干旱气候（降雨约５００mm多集中在夏季）。由于长且旱的东季和有时晚夏的雨季在一定程度上对雨养农业带来不利的影响。

所采集的土壤剖面发育于厚层的坡积物上，由于１００多年前森林被砍伐造成强烈的土壤侵蚀，目前地表光秃。

土层深厚呈红棕色，排水良好，粉砂壤土。该土壤分类为普通褐土（ＣＳＴＣ，１９９２）或者艳色雏形土（ＦＡＯ，１９９０）。

土壤利用主要是雨养玉米和高粱，具有适中的酸度和较高的肥力。土壤持水能力强，但因冬季土壤水分有限。限制农业生产的条件仍然是土壤水分含量。

# FOREWORD

The objective of a soil brief is to provide a description of one or more reference soils in an ecological setting.
It is composed of a text accompanied by a number of data annexes.

The illustrated text includes a description of the ecological setting of the reference soil(s), a description and a discussion of the major characteristics of the soil(s), followed by classification and an evaluation of soil and land qualities.
The annexes provide data on the soil(s) and the environment, available from field studies, laboratory analyses and the literature.

The Soil Brief is written for both soil-specialists and laymen. For the latter, the comprehensive information in the annexes often is too detailed and therefore requires some textual explanation. For the soil scientist, the textual part is of use since it summarizes important land and soil qualities, relevant aspects of soil management and considerations of soil formation. Furthermore it provides access to additional information that cannot be stored in a computerized database.

This report is one in a series that is the result of a joint research programme of ISSAS and ISRIC in the framework of the Science and Technology for Development Programme (STD2) of the European Community, contract No. TS2*-CT91-0336. The "Establishment of a soil reference collection and pedon-database for the classification and assessment of soil/land" forms part of this project. Additional support for field missions was provided by the Royal Dutch Academy of Arts and Sciences.

In 1983, '85, '92 and '93 the Institute of Soil Science of the Academia Sinica (ISSAS), in collaboration with the International Soil Reference and Information Centre (ISRIC) studied, described and sampled 51 reference soils for the National Soil Collection of the People's Republic of China. A duplicate set of soil profiles was collected for ISRIC's world soils collection. The reference soils are chosen to be characteristic of China's major ecological regions.

This Soil Brief considers a representative soil from Chaoyang (Liaoning Province), an area in Northeast China characterized by the consequences of large scale deforestation about 100 years ago.

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

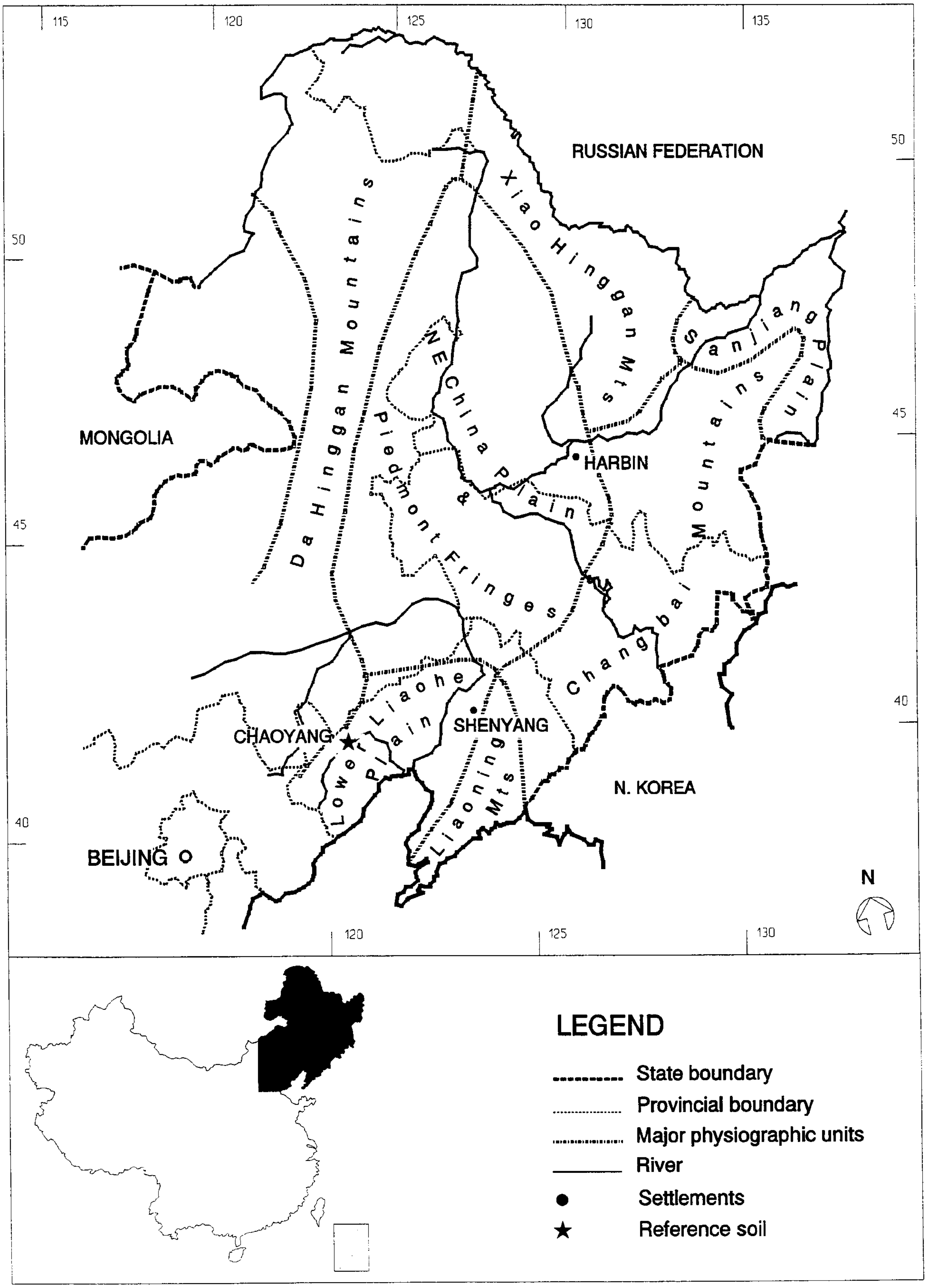



**Figure 1** Major physiographic zones of northeast China; location of CN 34 at Chaoyang.

# 1 ECOLOGICAL CHARACTERIZATION OF NORTHEAST CHINA

## 1.1 Introduction

Northeast China comprises the administrative provinces of Heilongjiang, Jilin and Liaoning and the eastern part of the Inner Mongolia Autonomous Region. This Soil Brief is limited to the three provinces. They occupy 1.3 million $km^2$, of which some 50 percent consists of mountainous areas, about 10 percent has a hilly character and some 40 percent can be described as plains. The mountainous and hilly areas surround the plain of Northeast China and its piedmont fringes on the western, northern and eastern sides (figure 1).

## 1.2 Climate

The main climatic characteristic of large parts of China is the widespread occurrence of a monsoon climate in combination with a marked continentality. Most of Northeast China is under a temperate monsoon climate, except for the high, northernmost Da Hinggan Mountains that belong to the frigid temperate zone and the Liaodong peninsula which has a warm temperate monsoon climate. The main climatic features of Northeast China can be summarized as follows (Zhao, 1986; Guo *et al.*,1990): mean annual temperatures reach from below 5°C in the north to about 9 °C in the south. The variation between mean summer and winter temperatures is important: in the northern part mean temperatures are about 17 to 20 °C for July and about -28 to -35 °C for January. The south shows a much smaller amplitude: resp. 25 °C and about -4 to -8 °C.

Very cold winters are experienced in the north of Heilongjiang province which has the lowest temperature recorded in China (Mohe, -52 °C). This is illustrated by the soil freezing to a depth of about 2.5 m. Summers may be hot: an absolute maximum of 38 °C has been recorded at Dedu.

Precipitation clearly reflects the monsoon character of the climate. Winters are dry and the maximum amount of precipitation occurs between early summer and autumn. Mean annual amounts of precipitation vary from less than 400 mm $yr^{-1}$ in the north to over 1000 mm $yr^{-1}$ in the south and in mountainous areas. Figures 2 and 3 illustrate the distribution and magnitude of precipitation and temperature for Northeast China. These figures were generated by means of SOLGRAPH (Brunt *et al.*, in press).

Winds in Northeast China blow from the northwest in autumn and winter. Summer shows more variable wind directions. Typhoons, common further south, only exceptionally affect northeast China.

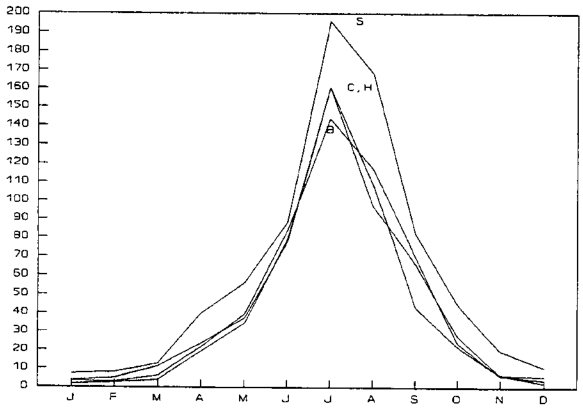



**Figure 2** Precipitation in mm for Northeast China.
C: Chaoyang, H: Harbin, B: Beijan, S: Shenyang.

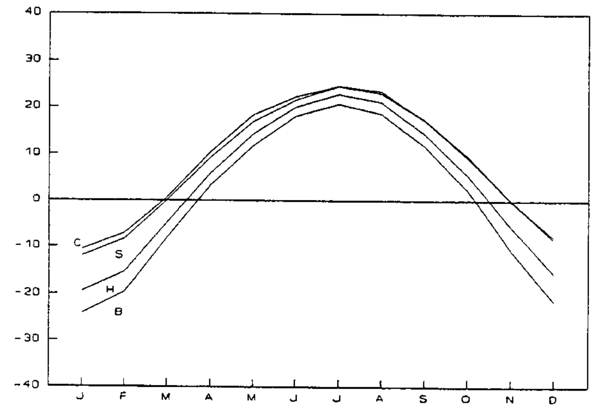



**Figure 3** Average temperatures in °C for Northeast China.
C: Chaoyang, H: Harbin, B: Beijan, S: Shenyang.

## 1.3 Geology and geomorphology

China comprises three major geomorphological divisions: the *Qinghai-Xizang Plateau* ("Roof of the World") with an elevation of 3000 - 5000 m a.s.l., the *Middle China Plateaus and Basins* (1000 - 2000 m base level) and the extensive *Low plains of East China* which continue in the continental shelf beneath the Yellow Sea. Northeast China belongs partly to the Low Plains of East China and partly to the Middle China Plateau (Da Hinggan Mountains).

Two hundred million years ago a large geosyncline occupied this region, in the base of which metamorphism occurred. Subsequent uplift in Hercynian times was accompanied by emplacement of large granitic complexes. Under the influence of the Mesozoic Yanshan orogeny, the central part of NE China subsided to form the NE trending Song-Liao basin. In the eastern and western adjacent zones, large masses of igneous rock were extruded, mainly of basaltic character, but with some granites. Continuing into Recent times, volcanic activity is present as the Pacific tectonic plate subducts below the Eurasian continent.

Since the beginning of the Cenozoic era, the Song-Liao basin gradually has been infilled with predominantly fluviatile deposits, finally leading to the extensive Dongbei plain. This is made up of two parts, the Liaohe plain in the south and the Songnen plain in the north, separated by a low divide between both plains. The Dongbei plain, which is the largest plain of China, is sandwiched between two mountain ranges: the NNE trending Da Hinggan Mountains in the west and the NE trending Changbai and Quinshan Mountains to the east. Two main tectonic events determine this tripartite division: at depth a major lithosphere fault delimits the eastern boundary of the Da Hinggan Mountains and a crustal fault is the western boundary of the Changbai-Quinshan Mountains (Zhao, 1986; Terman, 1973).

## 1.4 Hydrology

Drainage of large parts of northeast China is towards the Dongbei plain. The northern part of the plain drains to the Heilongjiang and its tributaries; the southern part through the river Liaohe.
In summer, amounts of run-off are large because most precipitation occurs in summer. Run-off is very low in winter, since both soils and rivers are frozen and only small quantities of precipitation occur, mostly as snow. The spring run-off, as a result of melting snow causes floods and amounts to about a quarter of the annual total. As far as groundwater is concerned, both the Liaohe plain in the south and the Songnen plain in the north of northeast China possess important fresh water aquifers. Locally artesian waters occur.

## 1.5 Vegetation

The original natural vegetation of northeast China was a warm temperate, mixed needle- and broad-leaved forest, with cool-temperate needle-leaved taiga forest in the northern regions (Zhao, 1986, Zhonghua, 1982). The well-drained, rolling plains, as well as the hilly and mountainous areas of northeast China, once carried these kinds of forests.
Significant parts of Northeast China consist of low-lying areas with moderately high to high levels of groundwater (Liaohe, Songnen and Sanjiang plains). These areas, partly annually flooded, are characterized by various meadow and swamp vegetation types, locally with a salt-tolerant character.
A vertical zonality of vegetation is obvious in all mountainous areas and this is especially well developed in the Changbai Mountains.
Today, outside the mountainous areas, most of the natural vegetation has been cleared.

## 1.6 Agricultural landuse and forestry

Northeast China is a very important agricultural area within the People's Republic of China, and although large parts of it are cultivated, many places have a relatively short agricultural tradition.
Some sources claim there are still hundreds of thousands of hectares of virgin lands which could be changed into productive agricultural land (Zhao, 1986). The main problems in developing agriculture in northeast China are spring drought alone or in combination with summer floods, sometimes in combination with low soil fertility and secondary salinization (Xin *et al.*, 1988).
Until relatively recent times, northeast China was not heavily populated and as a consequence agricultural landuse was not intensive. For instance, up to a century ago, large areas in the west of the Liaoning province were covered with (imperial) woods; it was only since then that the trees were felled and the land put into agricultural use. In some places, severe erosion of these lands has resulted as can be seen in the Chaoyang area. Other areas have been brought into cultivation very gradually since the turn of the century (Heilongjiang province - 710.000 $km^2$ - had only 25.000 inhabitants and 5.300 ha of cropland in 1897). Considerable extension of the cultivated land took place under duress during the Japanese occupation in the Second World War. Finally, great achievements in the agricultural development of the area have been accomplished since the foundation of the People's Republic of China; a necessity since the population of the area has tripled since 1949. Frequently, this expansion has been at the cost of large areas of natural vegetation which now is limited to the higher, usually inaccessible mountainous country.
China's large needs for timber required the commercial exploitation of these (mainly natural) forests in the northeast of the country; sometimes with important losses from an environmental point of view.

## 1.7 Human impact

Scarcely populated until recently (4.2 million in the 16th century, 30 million in 1949), today Northeast China has a population of about 100 million, living in both large industrial centres like Shenyang, Harbin, Qiqihar, Daqin, Changchun or Dalian, as well as in numerous towns and villages in the country.
The important industrial potential of the region, results from the presence of natural resources such as gas, oil, coal, iron and non ferrous ores, the easily accessible sea-ports, and a good infrastructure, as well as the agricultural activities have made this area one of China's busiest regions.

# 2 THE CHAOYANG AREA

## 2.1 Introduction

The Chaoyang county is situated in the hilly southwestern part the Liaoning province. It consists of rolling and hilly terrains between 200 and 1000 m above sea level, being part of the North China Mountains. It occupies about 22.000 km$^2$. The most important centre is the town of Chaoyang; its name meaning "exposed to the sun".

## 2.2 Climate

The monsoon climate of the area can be characterized as follows: it has an annual radiation of about 5500 to 6000 MJm$^{-2}$ yr$^{-1}$, with a mean annual temperature of 8 °C, in combination with mean temperatures for January of -10 to -13 °C and mean temperatures for July of 22 to 25 °C. Mean annual precipitation is between 440 and 580 mm. Summarizing, this results in a cumulative annual temperature over 10 °C of about 3450 °C, a frost free period of 145 to 165 days and an aridity coefficient of 1 to 1.3 (Zhao, 1986).

The meteorological station of Chaoyang provides some representative data for the reference soil; the climatic diagrams (figures 4 and 5) illustrate the monthly precipitation, evapotranspiration and temperature. The data used for the construction of these diagrams, as well as other characteristics (Soil Survey Group, 1987), are presented in Annex 1.
The mean annual precipitation amounts to 486 mm. Only a small amount of precipitation occurs in the cool season: 40 mm in 6 months (October through March); 60 percent of the annual precipitation is in June, July and August. An important part of the summer rainfall is in the form of heavy showers.

The calculated evapotranspiration (Penman-Monteith; FAO, 1991) amounts to 1183 mm (measured evapotranspiration for Chaoyang 2109 mm). Leaching rainfall occurs rarely during the heavy showers in summer. Mean annual relative humidity is 52 percent; aridity coefficient 1.1.
Air temperatures for Chaoyang show a mean annual figure of 8.4 °C, with a mean summer temperature of 23.3 °C and an absolute maximum temperature of 41.1 °C. Mean winter temperatures (December, January, February) are moderately low: -8.3 °C; with an absolute minimum temperature of -31.1 °C.
The average number of frost free days for Chaoyang is 149 days, with a growing season of 135 days.
Radiation amounts to 5950 MJ m$^2$ yr$^{-1}$. Although the amount of radiation in summer is markedly higher than in winter, the relative amount of daily sunshine in summer is lower.
An outline of climatic conditions in Liaoning province is given by Ja *et al.* (1992).

### 2.2.1 Soil climate

Recorded soil temperatures show that the mean annual soil temperature is 10.2 °C; the mean soil temperature for May is 20.4 °C, for July 25 - 28 °C and for January about -10 °C. The average depth of freezing is between 0.8 and 1 m (maximum 1.3 m). The soil temperature regime according to Soil Survey Staff (1992) qualifies as mesic.
Data on the soil moisture regime are not available. Based upon the atmospheric climate, an ustic soil moisture regime is presumed.

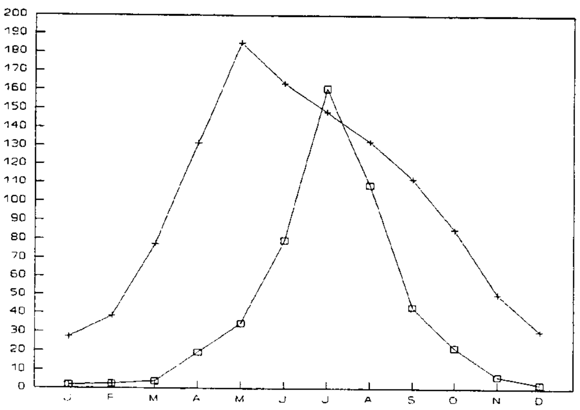



**Figure 4** Mean monthly precipitation (□) and evapotranspiration (+) in mm at Chaoyang.

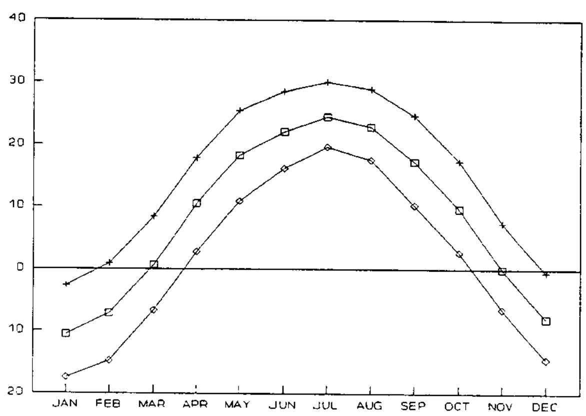



**Figure 5** Mean monthly maximum (+), average (□) and minimum (◊) temperatures in °C at Chaoyang.

## 2.3 Parent materials and hydrology

The Chaoyang area is situated at the eastern end of the Yan Shan uplift (Terman, 1973).
Parent materials in the Chaoyang district mainly consist of late Pleistocene loess and loess-like deposits. They have a thickness of over 10 m at the site of the reference soil. The upper part consists of a recent colluvium of considerable thickness, as a result of severe erosion and re-deposition during the last one hundred years (Geological Map of Liaoning province 1:500.000).
The loess-like deposits are underlain by middle Pleistocene red clays and upper Jurassic (Shangtong) sandstones and shales. However, these formations are not exposed near to the site.

Drainage of the Chaoyang area is by the Daling He river directly into the Bohai Sea. The regime of the river clearly reflects the continental and monsoon character of the climate with run-off nearly absent in winter, some run-off in spring, but the major part of the run-off occurs in summer. Total annual run-off for the area corresponds to about 25 mm which is about 5 percent of the annual precipitation.

## 2.4 Vegetation and agriculture

The original natural vegetation was a warm temperate deciduous forest in the lower undulating country, and a mixed needle- and broad-leaved forest in the higher parts of the area.

Rigorous cutting of the forests destroyed the natural vegetation completely about one hundred years ago. In recent years a re-afforestation programme has been set up. Chinese characters saying "Plant trees and create a green Chaoyang" are frequently encountered in the area. Valley bottoms carry small stands of poplar.

Although most of the area is considered an arid environment (section 2.2), the annual amount of precipitation is sufficient for a non-mechanized, terraced contour cropping system of rainfed agriculture on the uplands. The soil water content is only partly recharged during the dry winters, but the relatively short, humid and warm summer rains offer good possibilities for recharge. Usually a family cultivates soils both on the upland and in the valley; a per capita average of about 1 mu rainfed and 1 mu irrigated land is cultivated. Government regulations demand 1 mu of irrigated wheat per capita.
Maize is grown in a rotation with sorghum or millet. Yields vary from 300 to 400 kg $mu^{1}$ (4.5 to 6 Mg $ha^{-1}$).
Rainfed sorghum yields about 100 kg $mu^{-1}$. Irrigated sorghum in the valley yields 300 kg $mu^{-1}$.
Wheat is grown only on the valley floor. It is grown on government contracts, and yields about 400 kg $mu^{-1}$ when irrigated and about 200 kg $mu^{-1}$ when rainfed.
Cotton is grown as an irrigated crop in the valley only. The high amount of sunshine makes the Chaoyang district an important cotton producing area in the Liaoning province.
Relatively small quantities of beans, melons, eggplants etc. are grown in the valley for sale in local markets.
Some apples are grown in the valley.

# 3 REFERENCE SOIL CN 34

## 3.1 Introduction

The first nationwide soil survey of China started in 1958, so the distribution of soils in the area is well known. The results of this survey served to identify the broad distribution of soils in the country and lead to a soil map of China at a scale of 1:10.000.000 (Nanking Institute of Soil Science, 1980); followed by a translation into Japanese (1983) and an English version in combination with the book *Soils of China* (ISSAS, 1990), and the Chinese contribution to the *FAO-Unesco Soil Map of the World 1:5.000.000* (FAO, 1978).
Since 1958, more detailed information about soil distribution and soil characteristics has become available. In many counties and districts of northeast China (semi-) detailed soil surveys have been carried out within the framework of the second national soil survey of China, usually resulting in county and district soil survey reports. In most cases, these reports have lead to provincial monographs. Some of these detailed reports have been included in the list of references. All this information has contributed to the compilation of a new version of the soil map of China, now being prepared by the Institute of Soil Science of the Academia Sinica at Nanjing. Publication is expected in a few years.
Special attention to the distribution of soils in the Chaoyang area is given in publications by the Soil Survey Group (1987) and Ja (1990, 1992).
The most important soils, classified according to the FAO/Unesco nomenclature and other classification systems, are presented in Table 1.

Reference soil CN 34 is located 10 km south of Chaoyang, next to the brick-works east of the main road to Janchiang. The total area represented by this soil type in the Liaoning province is approximately 20.000 km$^2$.

**Table 1** Major soils of the Chaoyang area after the *FAO-Unesco Soil Map of the World 1:5.000.000* (FAO, 1978) and Zhao (1986).

| FAO-Unesco (1988) 1974 | 1990 | 1984 Chinese soil classification (ISSAS, 1990) | Chinese Soil Taxonomic Classification (CSTC,1991) | USDA Soil Taxonomy (1992) |
|---|---|---|---|---|
| Chromic and Haplic Luvisols Lc,Lo | LVx, LVh | Semiluvic soils: Cinnamon soils | Ustic Siallisols: Luvic Cinnamon soils | Haplustalfs, Paleustalfs |
| Chromic, Calcaric and Eutric Cambisols Bc, Bk, Be | CMx, CMc, CMe | Burozems | Ustic Siallisols: Haplic and Calcic Cinnamon soils | Calcic Ustochrepts Eutric Ustochrepts |
| Rendzic Leptosols E | LPk | Black Limestone soils: Rendzinas | Lithic Primarosols: Rendzinic Leptisols | Rendolls |
| Mollic Gleysols G | GLm | Semi-aquic soils: Meadow soils | Orthic Aquisols: Umbrihumic Chao soils | Aquolls |

N.B. Correlation of soils is approximate.

## 3.2 Landscape and soil

This reference soil is a Haplic Cinnamon soil (CSTC,1991) or Chromic Cambisol (FAO, 1988). It is characteristic of the low mountainous areas around Chaoyang and clearly reflects the environmental conditions. As a consequence of the total deforestation, important erosion and accumulation features can be observed in the relief features. The soil under consideration is situated on a terrace in a zone of accumulation of loess-like sediments and is representative of this situation. The reference soil presented in this paper has close relationships and occurs in close association with other cambisols (Calcaric, Eutric) as well as Luvisols (Chromic) where the slope wash deposits are thin.
A comparable soil has been described by Wen (Soil Survey Group, 1987).

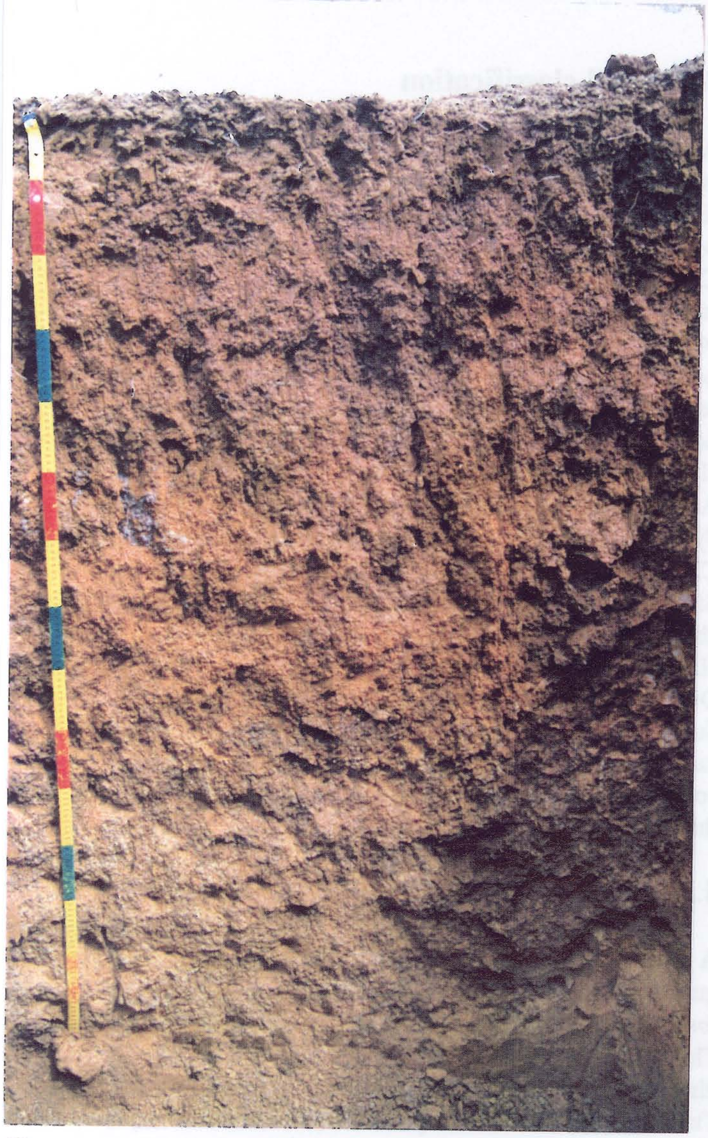
**Brief field description of CN 34**
CN 34 is a reddish brown, deep, well drained silt loam, developed in moderately thick slope wash materials over a truncated subrecent soil at 65 cm depth. The topsoil has a very weakly developed crumb structure and a plough pan can be observed. It has a low organic carbon content. The subsoil structure is dominantly prismatic and angular blocky. The soil has a slightly alkaline to alkaline reaction, sometimes carbonates are present. The upper surface of the (buried) truncated soil is the top of an argic B horizon.

A detailed description of the soil and its horizons according to FAO guidelines (FAO *et al.*, 1990), is given as an ISIS database presentation sheet in Annex 1.

1

1. Severe erosion of the loess terrace on which CN 34 is situated
2. Agricultural land use of the loess terrace

2



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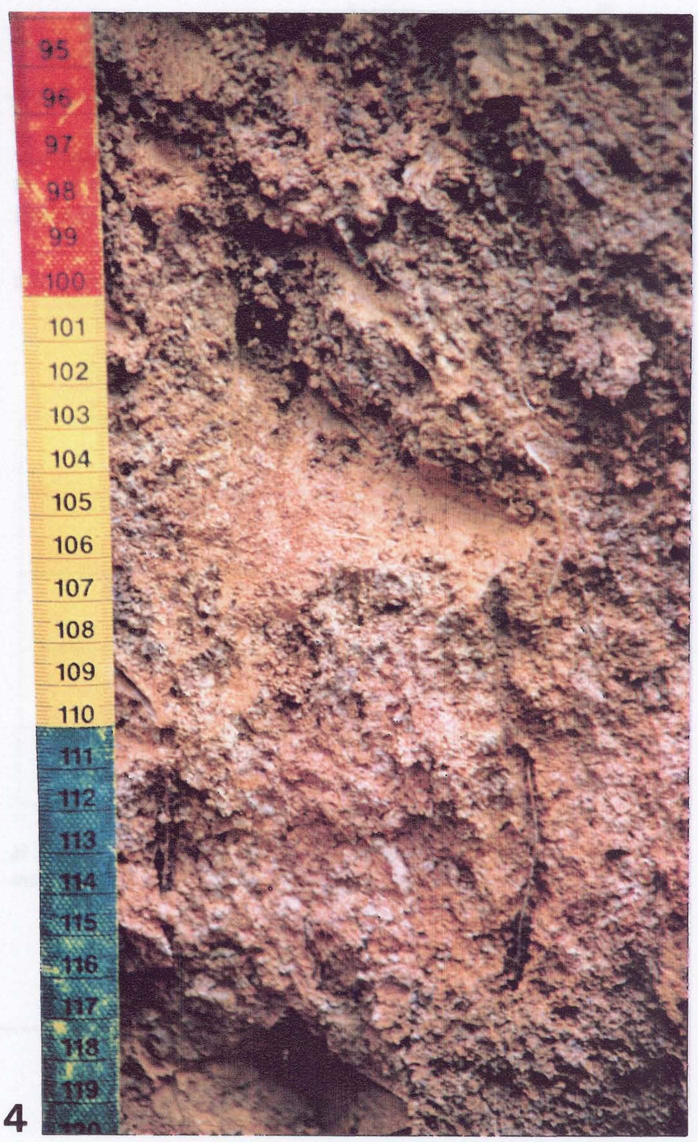


4

3. Reference soil CN 34
4. CN 34: detail of Bt horizon at 100 cm depth

## 3.3 Brief analytical characterization of CN 34

Soil samples have been analyzed at ISRIC's soil laboratory according to its procedures (Van Reeuwijk (1993). A number of key characteristics is given below (Table 2) and a full account of the analytical data is given in Annex 1.

**Table 2** Selected physical and chemical characteristics

| | CN 34 |
|---|---|
| Texture | silty clay loam throughout the profile |
| Organic carbon % | low in the topsoil (0.7) to very low in the subsoil (≤0.3) |
| Acidity | neutral in topsoil to alkaline in subsoil |
| Sum of bases cmol$_c$ kg$^{-1}$ soil | very high throughout the profile (over 20) |
| CEC cmol$_c$ kg$^{-1}$ soil | medium throughout the profile (18 to 20) |
| Phosphorus | medium in upper part to high in depth |
| Total N % | very low throughout the profile (0.08 or less) |
| Clay mineralogy | mixed |
| Air capacity % | medium to high (about 15 throughout) |
| Available moisture % | high (20) in topsoil to medium (14) in subsoil |
| Bulk density Mg m$^{-3}$ | medium (increasing from 1.3 in topsoil to 1.4 in deep subsoil) |

Soil moisture retention curves are presented in figure 6. The calculated available moisture content is 140 mm/100 cm. The soil is not always fully recharged with water after the rainy season.
Other chemical and physical characteristics are graphically presented in figures 7 and 8.

## 3.4 Soil classification

According to FAO/Unesco (FAO *et al.*, 1988), the soil is classified as a Chromic Cambisol. It lacks diagnostic features other than an ochric A and a cambic B horizon, which determine its place in the major soil group of Cambisols. The low content of carbonates, as well as the strong brown to reddish colour, locates it in the soil unit of Chromic Cambisols. The presence of an argic B horizon at more than 65 cm below the surface is not relevant to high level classification (where the argic B horizon is present close to the surface, the soil must be classified as a Chromic Luvisol).
According to the *Chinese Soil Taxonomic Classification System* (CSTC, 1991) the soil belongs to the suborder of Cinnamon soils (which is the ustic suborder of the Siallisols). Strict application of the criteria reveals the absence of calcaric properties which makes the soil a Haplic cinnamon Soil.
Diagnostic criteria as used in USDA *Soil Taxonomy* (Soil Survey Staff, 1992), include an ochric epipedon and a cambic horizon. The mesic soil temperature regime, in combination with the ustic soil moisture regime, places this soil in the Typic Ustochrepts.

## 3.5 Soil and land suitability

A general qualitative evaluation of the relevant land qualities according to the *Guidelines for Land Evaluation for Rainfed Agriculture* (FAO, 1983) was carried out. The results of the evaluation are presented in Annex 2, directly showing major constraints for agricultural use.
The available soil moisture potential (140 mm/100 cm) is a major limiting factor for crop growth, especially in combination with the usually incomplete recharge of water after the dry winter, the risk of dryness during germination and sometimes late frosts. Apart from the available moisture, germination conditions and nutrient retention capacity are not optimal.

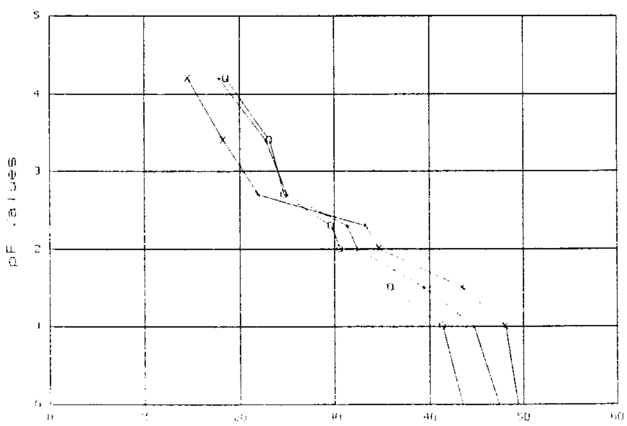

**Figure 6** Soil moisture retention curves (water content in vol % versus suction (pF)) at depths of 0-15 cm (x), 40-60 cm (+), 70-100 cm (o) of CN 34.

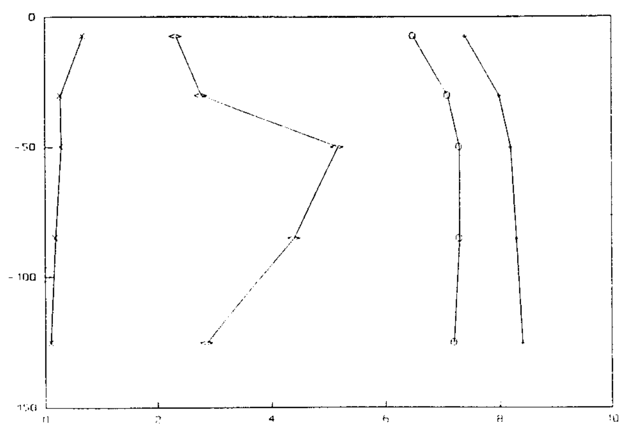

**Figure 7** Sum of bases (cmol$_c$ kg$^{-1}$ soil) (◇), pH-$H_2O$ (+), pH-KCl (o) and organic carbon (x) versus depth (cm) of CN 34.

Some erosion hazard by water is present but it is limited by the use of contour ploughing and planting. Where these precautions are omitted severe erosion occurs and very deep gullies develop.

The soil is evaluated for rainfed maize, a very common crop in the area.

Maize (*Zea mais*) is a nutrient-demanding crop (especially N) that requires a significant amount of precipitation during the growing period (optimum 450 - 800 mm). Daily temperatures must be between 22 and 27 °C. The crop is sensitive to frost. It prefers deep, well aerated, fine to loamy textured soils with a neutral pH; waterlogging is not tolerated. Maize is only slightly salt-tolerant (up to 1.7 mS $cm^{-1}$).

Growth conditions with regard to climate are somewhat comparable to conditions in the Great Plains of North America, since northeast China has a comparable continental climate (Unger *et al.*, 1990).

Optimal crop growth criteria with regard to soil conditions were obtained from the Institute of Soil Science of the Academia Sinica (pers. comm., 1994) which favours the following soil conditions for maize growing in northeast China: soil depth 1.25 m; a loamy soil texture; a bulk density between 1.00 and 1.20, a pH between 6.5 and 7; an organic matter content of more than 1.5 % and available amounts of N, P and K of >30, >30 and >150 mg $kg^{-1}$ respectively.

The use of varieties adapted to the climate overcome to a great extent the limitations set by the environmental conditions indicated in Annex 2. Application of measures to improve soil qualities (Wang *et al.*, 1990; Chen *et al.*, 1988) would diminish limitations imposed by the soil.

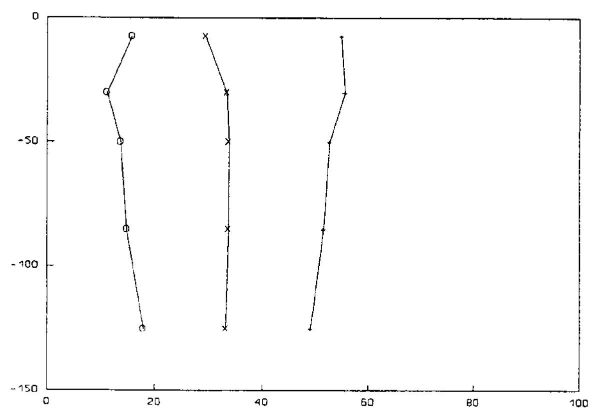


**Figure 8** Percentages clay (x), silt (+) and sand (o) versus depth (cm) of CN 34.

## 3.6 Soil genesis

Given the almost ubiquitous presence of loess-like parent materials, the moderate relief and the almost total absence of natural vegetation (woods) in the area, soil genesis is governed mainly by climatic conditions and slope processes. On slopes over 3 ° erosion can be an important hazard. In the higher areas, bordering the mountains, bare hard rock is often present.

The well drained soils reflect the influence of the monsoon climate as a determinant of the soil forming processes. The production of organic matter starts in late spring when temperature rises quickly and precipitation increases. The warm, relatively humid summer leads to both production of organic matter and a rapid turn-over. Consequently, when the cold season starts at the end of October, a relatively small amount of organic matter is present at the surface to be incorporated in the soil by animal activity. The soil is frozen for several months during the winter when floral and faunal activity are absent.

This generalized picture of soil evolution is strongly influenced by precipitation and evapotranspiration. The effect of modest amounts of precipitation in combination with a (usually) larger total of evapotranspiration during the year leads to a non-leaching regime. Thus, carbonates usually are not removed entirely from the soil, leading to the occurrence of secondary carbonate accumulation at some depth in the soil.

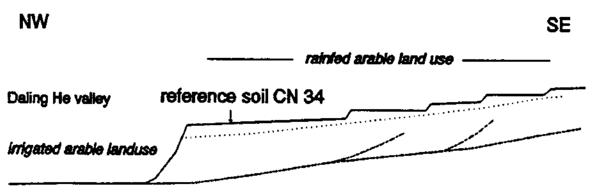


**Figure 9** Situation of reference soil CN 34, situated on the terrace of the river Daling He.
— bottom of gullies ...... bottom of colluvial materials.

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## Annex 1 ISIS Data Sheet CN 34

ISIS 4.0 data sheet of reference soil CN 34 Country : PEOPLE'S REPUBLIC OF CHINA Print date (dd/mm/yy) : 19/12/94

FAO/UNESCO (1988) : Silti-Chromic Cambisol (Eutric) (1974 : Chromic Cambisol)
USDA/SCS SOIL TAXONOMY (1992) : Typic Ustochrept, fine-silty, mixed, mesic (1975 : Typic Ustochrept)
CSTC (1991) : Haplic cinnamon soil

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

LOCATION : Liaoning Province, Chaoyang
Latitude : 41°27' N Longitude : 120°28' E Altitude : 200 m a.s.l.
AUTHOR(S) : Boerma, J.A.K. Date (mm/yy) : 6/93

GENERAL LANDFORM : hill Topography : rolling
PHYSIOGRAPHIC UNIT : dissected slope
SLOPE Gradient : 10% Aspect : W Form : straight
POSITION OF SITE : middle slope
MICRO RELIEF Kind : level
SURFACE CHAR. Rock outcrop : nil Stoniness : nil
Cracking : nil Slaking/crusting : partly slaked
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : slight sheet and severe gully Aggradation : present
Slope stability : stable

PARENT MATERIAL : slope wash derived from eolian deposits overlying truncated soil derived from same eolian deposits
Texture : silty

EFFECTIVE SOIL DEPTH : 150 cm

WATER TABLE : no watertable observed
DRAINAGE : well
PERMEABILITY : moderate; no slowly permeable layer(s)
FLOODING Frequency : nil Run off : medium
MOISTURE CONDITIONS PROFILE : 0 - 150 cm dry

LAND USE : low level arable farming; crops : maize; no irrigation; rotation : continuous crop rotation; improvements : terracing
Land use/vegetation remarks : see additional remarks

ADDITIONAL REMARKS :
PARENT ROCK: profile consists of a characteristic deposit of about 100 year old colluvia on top of the truncated loess. HYDROLOGY: run off is zero during less important showers due to small ridges perpendicular to the slope; heavy showers may result in important run off. As a consequence aggradation occurs only in combination with heavy showers. LAND USE: crops also include sorghum. VEGETATION: original vegetation was cut completely about 100 years ago. It consisted of broad leave forest.

CLIMATE : Köppen: Dwx
Station: CHAOYANG 41 33 N/120 27 E 169 m a.s.l. 11 km N of site Relevance: good

| | No. years of record | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETo (PenMon) mm | 29 | 27 | 38 | 78 | 131 | 185 | 164 | 149 | 132 | 112 | 85 | 50 | 31 | 1183 |
| pan evaporation mm | 29 | 42 | 65 | 145 | 279 | 389 | 300 | 233 | 194 | 178 | 151 | 86 | 46 | 2109 |
| precipitation mm | 29 | 2 | 3 | 4 | 19 | 35 | 80 | 161 | 109 | 43 | 22 | 7 | 3 | 486 |
| no. of raindays | 29 | 2 | 2 | 2 | 5 | 7 | 12 | 14 | 11 | 7 | 4 | 2 | 1 | 69 |
| tot.glob.rad. MJ/m2 | 28 | 435.4 | 447.9 | 519.1 | 523.3 | 594.5 | 540.0 | 506.6 | 502.4 | 523.4 | 498.2 | 435.4 | 418.6 | 5941.2 |
| T mean °C | 29 | -10.6 | -7.2 | 0.7 | 10.5 | 18.3 | 22.2 | 24.6 | 23.0 | 17.3 | 9.7 | 0.0 | -8.0 | 8.4 |
| T max °C | 29 | -2.7 | 0.9 | 8.4 | 17.9 | 25.5 | 28.6 | 30.1 | 29.0 | 24.8 | 17.4 | 7.5 | -0.5 | 15.6 |
| T min °C | 29 | -17.4 | -14.7 | -6.7 | 2.8 | 10.9 | 16.2 | 19.7 | 17.6 | 10.3 | 2.7 | -6.5 | -14.4 | 1.7 |
| relative humidity % | 29 | 44 | 40 | 38 | 38 | 41 | 60 | 73 | 74 | 64 | 55 | 50 | 46 | 52 |
| windspeed(at 2m) m/s | 29 | 2.2 | 2.5 | 3.0 | 3.5 | 3.4 | 2.6 | 2.1 | 1.6 | 1.8 | 2.2 | 2.4 | 2.1 | 2.4 |
| bright sunshine h/d | 29 | 6.8 | 7.8 | 8.2 | 8.4 | 9.1 | 8.5 | 7.7 | 7.9 | 8.5 | 7.8 | 6.9 | 6.5 | 7.8 |

Remarks: other climate stations available in ISIS with reference to this soil are: JINGZHOU (41 8 N/121 7 E; altitude 66 m a.s.l.; 65 km SE of site; relevance: moderate) and JIANPING YEBAISOU (41 23 N/119 42 E; altitude 422 m a.s.l,; 65 km WSW of site; relevance: moderate).

PROFILE DESCRIPTION :

Deep, well drained, (dark) reddish brown silt loam derived from slope wash materials overlying at 65 cm depth a truncated soil developed in loess deposits. The topsoil has very weakly developed crumb structures and a plough pan can be observed. Its organic carbon content is low. The subsoil dominantly shows prismatic and angular blocky structures. Soil reaction is slightly alkaline to alkaline and some calcium carbonate is present.

Ap 0 - 15 cm Strong brown (7.5YR 4/6, dry) silt loam; very weak medium crumb structure; sticky, slightly plastic, very friable, slightly hard; no mottles; no cutans; many micro pores and many fine to coarse pores; common very fine and fine roots; very few very fine weathered fragments of various nature; plough pan present; few worm channels; non calcareous (10% HCl); abrupt smooth boundary to

B 15 - 65 cm Dark reddish brown (5YR 3/4, moist) and strong brown to yellowish red (6.2YR 5/8, dry) silt loam; weak very coarse prismatic parting to moderate coarse subangular blocky structure; sticky, slightly plastic, friable, slightly hard; no mottles; patchy thin clay and sesquioxide cutans; many very fine inped tubular pores; common very fine and fine roots; locally strongly calcareous (10% HCl); gradual smooth boundary to

2Bt 65 - 150 cm Yellowish red (5YR 4/8, moist) and dark brown (7.5YR 4/6, dry) silt loam; weak to moderate coarse angular blocky parting to strong fine to very fine angular blocky structure; sticky, slightly plastic, very friable, slightly hard; common fine distinct sharp yellowish brown (10YR 5/6) and very few fine prominent sharp black (N 2/0) mottles; continuous moderately thick clay and sesquioxide cutans on pedfaces and few uncoated silt and very fine sand coatings; many very fine to fine inped tubular pores and few medium vertical continuous tubular pores; common very fine roots; few worm channels; locally slightly calcareous (10% HCl)

ANALYTICAL DATA :

| Hor. | Top - Bot | >2 mm | 2000-1000 µm | 1000-500 µm | 500-250 µm | 250-100 µm | 100-50 µm | TOT SAND | 50-20 µm | 20-2 µm | TOT SILT | <2 µm | DISP CLAY % | BULK DENS | pF 0.0 | pF 1.0 | pF 1.5 | pF 2.0 | pF 2.3 | pF 2.7 | pF 3.4 | pF 4.2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ap | 0 - 15 | - | 0 | 1 | 1 | 2 | 12 | 16 | 35 | 20 | 55 | 30 | - | 1.29 | 49 | 48 | 44 | 35 | 33 | 22 | 18 | 15 |
| B | 15 - 40 | - | 0 | 0 | 0 | 1 | 10 | 11 | 32 | 23 | 56 | 33 | - | - | - | - | - | - | - | - | - | - |
| | 40 - 65 | - | 0 | 0 | 0 | 1 | 12 | 14 | 31 | 21 | 53 | 34 | - | 1.30 | 47 | 45 | 39 | 32 | 31 | 25 | 23 | 18 |
| 2Bt | 65 - 105 | - | 0 | 0 | 0 | 1 | 14 | 15 | 32 | 19 | 52 | 34 | - | 1.38 | 44 | 41 | 36 | 31 | 30 | 25 | 23 | 19 |
| | 105 - 140 | - | 0 | 0 | 0 | 1 | 17 | 18 | 30 | 19 | 49 | 33 | - | - | - | - | - | - | - | - | - | - |

| Hor. | pH H2O | pH KCl | CaCO3 % | ORG C % | ORG N % | Ca | Mg | K | Na | sum | EXCH AC H+Al | EXCH AC Al | CEC soil | CEC clay | CEC OrgC | ECEC | BASE SAT % | Al SAT % | EC 2.5 mS $cm^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | cmol$_c$ kg$^{-1}$ | | | | | | | | | | | | | |
| Ap | 7.4 | 6.5 | 1.0 | 0.68 | 0.08 | 20.3 | 2.4 | 0.6 | 0.1 | 23.4 | - | - | 19.2 | 65 | 2.4 | 23.4 | 122 | - | 0.26 |
| B | 8.0 | 7.1 | 0.8 | 0.28 | 0.05 | 25.2 | 2.1 | 0.4 | 0.1 | 27.8 | - | - | 19.7 | 59 | 1.0 | 27.8 | 141 | - | 0.20 |
| | 8.2 | 7.3 | 2.5 | 0.29 | 0.05 | 48.8 | 2.4 | 0.4 | 0.2 | 51.8 | - | - | 18.4 | 54 | 1.0 | 51.8 | 282 | - | 0.16 |
| 2Bt | 8.3 | 7.3 | 1.5 | 0.19 | 0.04 | 41.0 | 2.4 | 0.4 | 0.3 | 44.1 | - | - | 19.2 | 57 | 0.7 | 44.1 | 230 | - | 0.18 |
| | 8.4 | 7.2 | 1.1 | 0.10 | 0.03 | 25.6 | 2.4 | 0.3 | 0.4 | 28.7 | - | - | 18.4 | 55 | 0.4 | 28.7 | 156 | - | 0.16 |

CLAY MINERALOGY (1 very weak → 8 very strong)

| Hor. | MICA /ILL | VERM | SMEC | KAOL | QUAR | AVAILABLE P mg $kg^{-1}$ |
|---|---|---|---|---|---|---|
| Ap | 3 | 3 | 4 | 3 | 2 | 7.5 |
| B | 3 | 3 | 5 | 3 | 2 | 2.1 |
| | 3 | 3 | 5 | 3 | 2 | 7.2 |
| 2Bt | 3 | 3 | 5 | 3 | 2 | 13.1 |
| | 3 | 3 | 4 | 3 | 2 | 16.8 |

PSD: weight %. BULK DENS: Mg/$m^3$. pF: vol. %. $CaCO_3$, org. C, tot. N: weight %. Exch. bases, CEC: $NH_4OAc$ pH 7. Exch. ac.: 1 *M* KCl. Clay mineralogy: MICA/ILL mica/illite, VERM vermiculite, SMEC smectite, KAOL kaolinite, QUAR quartz. Available P (Olsen): mg/kg.

## Annex 2 Evaluation of Land Qualities of CN 34

| LAND QUALITY | | vh / n | h / w | m / m | l / s | vl / vs |
|---|---|---|---|---|---|---|
| Availability (1) | | vh | h | m | l | vl |
| Hazard / Limitation (2) | | n | w | m | s | vs |

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

**CLIMATE**

| Land quality | | vh / n | h / w | m / m | l / s | vl / vs |
|---|---|---|---|---|---|---|
| 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**

| Land quality | | vh / n | h / w | m / m | l / s | vl / vs |
|---|---|---|---|---|---|---|
| Potential total soil moisture | 1 | | ■ | | | |
| Oxygen availability | 1 | ■ | | | | |
| Nutrient availability | 1 | | ■ | | | |
| Nutrient retention capacity | 1 | | | ■ | | |
| Rooting conditions | 1 | ■ | | | | |
| Conditions affecting germination | 2 | | | ■ | | |
| Excess of salts - salinity | 2 | ■ | | | | |
| - sodicity | 2 | ■ | | | | |
| Soil toxicities (e.g. high Al sat.) | 2 | ■ | | | | |

**LAND MANAGEMENT**

| Land quality | | vh / n | h / w | m / m | l / s | vl / vs |
|---|---|---|---|---|---|---|
| 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 | | | | | |

# Annex 3 Units, Glossary, Classes and Acronyms

## UNITS

**Chinese weights and measures SI equivalent**

| | |
|---|---|
| 1 mu | 0.067 ha |
| 1 jin | 0.5 kg |
| 1 jin/mu | 0.133 kg $ha^{-1}$ |

**Other units**

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

## GLOSSARY

| | |
|---|---|
| Air capacity | Amount of pore space filled with air 2 or 3 days after soil has been wetted. It is calculated from the difference between amount of water under almost saturated conditions (pF 0.0) and moisture retained at "field capacity" (pF 2.0), and expressed as volume percentage. |
| Al saturation | Ratio of exchangeable aluminium to the CEC, expressed as percentage. |
| Available soil moisture | Amount of moisture retained between "field capacity" (pF 2.0) and "wilting point" (pF 4.2), expressed as volume percentage (also called "available water capacity"). It is indicative of the amount of moisture available for plant growth. |
| Base saturation | Ratio of the sum of bases to the CEC, expressed as percentage. |
| Bulk density | Weight of an undisturbed soil sample divided by its volume. |
| CEC | Cation exchange capacity, indicative of the potential nutrient retention capacity of the soil. |
| Clay mineralogy | Type of clay-sized (< $2\mu m$) particles. |
| kaolinite | Clay mineral with a low nutrient retention capacity, common in soils from (sub)tropical regions. |
| smectite | Silica-rich clay mineral with a high nutrient retention capacity and the ability to absorb water, resulting in swelling of the clay particles. |
| illite | Potassium-rich clay mineral with a moderately high nutrient retention capacity, common in soils from temperate regions and in alluvial soils. |
| vermiculite | Clay mineral with a high nutrient retention capacity and strong potassium-fixation. |
| chlorite | Aluminium-rich clay mineral with a moderately high nutrient retention capacity, occurring in variable quantities in soils rich in aluminium. |
| halloysite | Clay mineral with a moderately high nutrient retention capacity, common in soils derived from volcanic ashes. |
| quartz | Residual silica, resistant to weathering. |
| feldspar | Residual primary mineral, unstable in soil environments and, if present, indicative of a slight to moderate degree of weathering. |
| hematite | Reddish coloured iron oxide, common in well drained soils of tropical regions. |
| goethite | Yellowish coloured hydrated iron oxide, common in soils of temperate regions. |
| gibbsite | Aluminium hydroxide, indicative of a high degree of weathering. |
| Consistence | Refers to the degree and kind of cohesion and adhesion of the soil material, or to the resistance to deformation or rupture. |
| ECEC | Effective cation exchange capacity. It is calculated by addition of the sum of bases and exchangeable acidity, and reflects the actual nutrient retention capacity of the soil. |
| ESP | Exchangeable sodium percentage, ratio of exchangeable sodium to the CEC, expressed as percentage. |
| Exchangeable acidity | Sum of exchangeable hydrogen and aluminium. |
| Fine earth fraction | Part of the soil material with a particle-size of 2 mm or less (nearly all analyses are carried out on this soil fraction). |
| Horizon | Layer of soil or soil material approximately parallel to the earth's surface. |
| Land characteristic | Measurable property of land (e.g. texture). |
| Land quality | Set of interacting land characteristics which has a distinct influence on land suitability for a specified use (e.g. erosion hazard, which is a.o. influenced by slope, rainfall intensity, soil cover, infiltration rate, soil surface characteristics, texture). |
| Leaching | Downward or lateral movement of soil materials in solution or suspension. |
| Mottle | Spot or blotch differing in colour from its surroundings, usually indicative of poor soil drainage. |
| Organic carbon | Content of organic carbon as determined in the laboratory (% org. C x 1.72 = % org. matter) |

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

## CLASSES OF SOME ANALYTICAL SOIL PROPERTIES

**Organic Carbon - C (%)**

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

**Acidity pH-$H_2O$**

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

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

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

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

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

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

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

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

**Aluminium saturation (%)**

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

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

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

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

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

## ACRONYMS

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

# Soil Briefs of China

(ISSN: 1381-6950)

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

# Country Reports

(ISSN: 1381-5571)

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