SOIL REPORT OF HUNAN PROVINCE

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ISRIC

INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

PREFACE

This abbreviated version of the Soil Report of Hunan province is made for the "Red Soils Development in Hunan province" project. The maps, accompanying text and tables comprise a summary of the Hunan's land resources.

The report will form the base for a rapid field reconnaissance survey of the project team. The fieldwork aims on the verification of the representativity of six sites, proposed for the implementation of pilot demonstration plots.

The report concentrates on the major soil types of the hilly and mountainous landscapes, such as the Red, Yellow Red, Yellow, Limestone and Purplish soils. Hydromorphic soils (paddy, valley bottom soils etc.) and soils with a very small acreage are not considered. The translation could not be verified by soil scientists of Hunan province, because of limited time. A scrutiny of the text is therefore recommended, especially when further reference will be made to this document.

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1. FORMATION AND DEVELOPMENT OF SOILS

Hunan province is located in the middle and lower reaches of Yangtze river with latitudes of 108°47' and 114°15'E, and longitudes of 24°39' and 30°08'N. With a width of 667 km from east to west and of 774 km from south to north. About 57 million people live in Hunan Province, 21,1800 square kilometre area. The province is composed of 80% hilly and mountainous area, 13.8% plains and 6.4% water surface.

The region is surrounded by mountains in the east, west and south. In the north are lakes and plains. The central part is mainly dominated by a rolling hilly landscape and terraces along the rivers.

The main mountaineous ridges in the east part have a NE-SW orientation with Luoxiao mountains being the highest (2115 m.a.s.l.), forming the drainage division of Xianjiang and Ganjiang rivers. The five mountain ridges, normally called South ridges or Nanling mountains, stretches from west to east forming the division of Yangtze and Pearl river basins.

Most mountains peaks are above 1000 m, the highest peak (Bamian Mt.) is 2042 m above sea level. To the west, Xuefeng mountains stretches from SSE to NNE, disappearing at the Dongting lake plain. In the northwest is the Wuling mountain with direction of NE and SW. In the central part, the highest mountain is Hengshang, which is surrounded by hills and low mountains, mostly lower than 500 m.a.s.l. Four main rivers flow into the Dongting lake, which is the second largest one in the country. The lake is surrounded by alluvial and lacustrine deposite plains. The plains are normally lower than 50 meter with the lowest point of 23 m.a.s.l. in Guhuazhou.

The main parent materials in the mountainous region are coarse and loose weathering residues of various acid rocks such as granite (occupying 8.5% of the whole area of the province). The residues from sedimentary rocks, such as shale and slate (occupying 19% of the whole area of the province) are generally more clayey. The weathering products derived from sandstone (occupying 18.3%) are comparatively coarse and those from limestone are clayey. Other parent materials are quaternary earth (4%) and purplish sandstone and shale (14%) which are widely spread in various hinterland basins. The purplish shale and sandstone is easily weathered under the summer monsoon climate. The young deposited alluvial materials by river and lake are mainly distributed along the four main river (Xiang-Li-Yuan-Zi) occupying of 5% of the whole areas. They are mainly the basis of paddy soils and hydromorphic soils in flat and basin areas.

Parent materials have a strong impact on physical and chemical properties of the soils derived from them (Table 1-1,2). Most of soils developed upon Quaternary red earth and limestone are loamy clay or clay and those on granite and sandstone are normally light loam or sandy in texture. Soil nutrients are also determined by parent material.

CLIMATE

Located in the middle and north subtropical areas of South China, the climate of Hunan is characterized by warm, moist and rainy conditions with abundant radiation. The average annual temperature ranges from 10 to 18°C. The mean temperature of January is 4 to 7°C with a minimum of minus 6°C. The temperature of July is 26.5 to 30°C. The number of days with temperatures warmer than 10°C is around 250-260 days and the accumulated temperature of > = 10°C is around 5000-5800°C. With a frostless period of more than 260 days, many crops can grow in this province almost throughout the year (Table 8,9,10,11).

The annual precipitation is 1200-1700 mm, with the mountainous areas receiving more than 1500 and the flat areas around the lake less than 1300 mm. A general decreasing trend of precipitation exists from south to north and from high to low altitude areas. The distribution of precipitation is seasonal with a rainy season (from April to June) and a drier season (from July to September).

The annual evaporation is between 1000-1700 mm (Table 9). Compared with the annual rainfall, three types of water balances can be distinguished. In the central part, precipitation is similar to evaporation, with evaporation surpassing precipitation for 2 month in later summer (July to August). In the south part, the evaporation is normally 150 mm or more than precipitation. Because of the low temperature, precipitation is always larger than evaporation in the mountainous areas of west and east. The large differences of temperature in mountain and lowland area and its combination with precipitation has a strong influence on the soil formation and properties (Table 13-16).

Table Regional differentiation of climate conditions in Hunan Province

Area	Mean temp.			> =10°C		Annual	
	Year	Jan	Jul	Days	Accum. Temp.	Rain	Evaporation
N	16.7	4.3	28.8	240	5306	1295	1256
E	17.7	5.5	29.4	248	6583	1442	1445
SE	16.5	5.7	26.1	241	5082	1508	1316
S	18.1	5.7	27.9	254	5672	1475	1498
SW	16.5	5.1	26.8	241	5127	1327	1253
NW	16.3	4.7	27.3	247	5188	1394	1154
C	17.4	5.1	29.3	244	5481	1510	1424

Vegetation

The zonal vegetation of the study area is evergreen broad-leaved forest, with a vertical altitude differentiation. The low mountain and hilly areas are covered by evergreen broad-leaved forest. At higher altitudes the mixed forest zone is composed of evergreen and deciduous species, followed by the broad-leaved deciduous forest (between 1600-1900 m.a.s.l.). On the top of the mountains higher the 1500 m is a dwarf forest (shrub) with abundant bryophy and tuffed grasses. Due to the long history of cultivation, most of natural vegetation were turned into secondary or planted forest. Only in the remote mountainous areas exists some original forests. Most of low and hilly areas are dominated by Masson pine and China fir with some cypresses in limestone areas and an increasing area of bamboo. Tea-oil forest is common in southwest and central Hunan, the plantation of fruit trees such as mandarin orange, tung tree has also increased recently.

More than 48% of red soils occurs on the weathering products of slate and shale and 22% on residues of sandstone, 14% on limestone, 8% on granite, and 8% Quaternary red earth.

The vegetation in the red soil areas is dominated by secondary or artificial forests composed mainly of Masson pine, China fir and tea-oil trees.
Red soils are formed under subtropical bio-climatic conditions, characterized by a warm temperature and adequate rainfall. However, the precipitation is unevenly distributed, the greater part is concentrated in March to June and comes often in the form of storms, which usually results in soil erosion. Drought periods may occur in July and August.

The primary vegetation is subtropical evergreen broad-leaved forests predominated by genera of beech family including evergreen chinkapins (Castnopsis spach), Tan oaks (Lithocarpus) and etc. The annual dry weight of litters under evergreen broad-leaved forest amounts to 3750-4500 kg/per hectare. Tree crops can be harvested annually, and many subtropical cash crops can also be planted in addition to cereal crops.

The most significant feature of the climate in the red soils area in Hunan is the alternation of dry/sub-humid and moist seasons. The annual temperature is 16-18°C. Average temperature of January is 4-7°C and that of July is 26-30°C. The Accumulated temperatures of > = 10°C are 5000-5700 °C. The annual precipitation is 1300-1700 mm with a clear rainy (April through June) and dry/sub-humid (July through September) season (Table 5-21).

2.2 RED EARTH [RED SOILS]

Red Earth is the taxonomic name of red soils in the official Chinese classification (1980). However, in this document in stead of Red Earth the term 'red soils' will be used, because this terminology is frequently used in the project document as well as by non-soil specialists.

RED SOILS

Red soils are the most widely distributed soils in Hunan occupying 51.0% of the whole area of the province. But vertically, they occur in the areas that lower than 600 m in the central and east, 700 m in the south and 500 in the north. The upper limit of their distribution in vertical zones is a little bit higher on the south (sunny) slopes than on the north (shadowy) slopes.

According to their genesis processes and properties, the red soils can be subdivide into 4 subgroups: they are typic red soils, yellow red soils, brow red soils and young red soils. Generally, the typic subgroup are distributed at the south and toward north is the brow subgroup. The yellow subgroup is situated at a higher altitude than typic red soil. Upwards are the typic yellow soils and young yellow soils. The total area of red soil group is 129.558.000 Mu (= 8.637.200 ha) [15 mu = 1 ha] (Table 5-7).

AREAS OF DIFFERENT SUBGROUPS OF RED SOILS (based on table 5-7)

Soil type	Area	% of the group
Typic red soils	7887	60.88
Yellow red soils	3451	26.64
Brow red soils	222	1.12
Young red soils	1394	10.76
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Total	12955	100

TYPIC RED SOIL

The greater part of the typic red soil subgroup is reclaimed for cultivation of crops, and partly for plantation of forests. The region of the typic red soils forms an important base of agricultural and forest products in Hunan province.

To overcome the threat of droughts and erosion of the soils, facilities of water conservation and measures of reasonable cultivation such as building water reservoirs on mountainous land, early sowing, dense planting, straw mulching and contour farming are generally adopted by local farmers in these soil areas.

The surface soil of typic red soils has generally an organic matter content of 1.5 to 2.5%. The total phosphorus is about 0.04-0.20, and the available potassium content is low. The pH value ranges from 4.5 to 6.0. In cultivated soils, the depth of ploughing layer is generally 17-18 cm, with an organic matter content of more than 2.5%. However, the infertile red soils have only an Organic Matter (OM) content of 1% or even less, having a heavy and compact solum, difficult for cultivation. Some of these soils are sandy in texture with very low water and nutrient retention ability. All these red soils should be improved (table 5-15).

Main characteristics of typic red soils

Morphologically, typic red soils have a layer with brow red (2.5 YR4/6) as common colour. The profile has an A-B-C or A1-A-B-C type structure. The litter and humic layer is commonly encountered in areas covered with good vegetation (forest or dense shrub). The A horizon has a dark colour with granular or granular blocky structure, loose and having many roots. The B horizon has more clay and a higher compactness, blocky or prismatic blocky structure, red or brow red, often covered by films of Fe-Mn and clay. Sometimes iron or Fe-Mn nudules can be found in this horizon. The C horizon has more Fe-Mn nodules and mottles (Table 5-11).

Red soils are strongly influenced by the type of parent materials. The red soils derived from Quaternary red earth has a thick solum, sometimes with a thickness of more than 5 meters, having a greyish brown surface soil and an orange red subsoil, which contains more clay and a remarkable illuviation of clay. The soil is poor in permeability and aeration due to its heavy texture (Table 5-12).

Red soils derived from granite have a reddish white and yellow colour. Soils developed on granite, shale and slate, and Quaternary red clay have generally a 1-1.5 m deep profile. On sandstone soil depth is much shallower (60-80 cm). Soils on limestone have different depths, on ridges from 60-80 cm and on steep mountain footslopes from 80-100 cm.

Red soils derived from sandstone have generally a purplish red colour and a thinner solum of only 50- 60 cm with more gravel and sand. The soil has a low phosphorus content, but a higher potassium content. It has a poor capability of water and nutrient retention due to the lighter texture.

Red soils derived from granite and gneiss are mainly distributed in the regions of rolling hills and low mountains with a relative height of 150-300 m. The soils have a grey-brown surface layer, a higher content of potassium and more quartz sand and gravel in the solum. These soils are often eroded owning to higher relief, greater slope and lighter texture. Those derived from limestone are generally more clayey.

Physical characteristics

Most of the typic red soils developed on Quaternary red clay, limestone, and shale have a clay texture with a clay content (particles finer than 0.01 mm) of more than 55% (Table 5-12).

Apart from SiO2, Al2O3, and FE203, many other oxides can be detected. The soil texture becomes heavy especially in the illuviation horizon. The degree of compactness of a B horizon of a red soil in Huafeng is as high as 32.7 kg/cm3, the C horizon of 42.7 and the A of only 3.1 kg/cm3. In the soils developed on Quaternary red clay, exchangeable aluminium is the dominant form of exchangeable acidity. The pH values of most red soils (water extracted) range from 4.5-6.5. The pH value of soils is influenced by parent materials. Soils formed in limestone are normally higher than 5.5, but those from shale and slate lower than 5.0. (Table 5-13).

The exchangeable cations of red soils are characterized by a high proportion of Aluminium. The CEC ranges from 5 to 15 cmol/100g soil. The exchangeable bases are less than 5 cmol (with an exception of soil developed on limestone). So the base saturation is commonly lower than 30% and does not exceed 40%. Mineralogically, red soils are desilicated and relatively enriched with iron and aluminium (Table 5-14).

Another feature of red soils is that they normally have a low content of nutrients, this is mainly caused by their strong acidity and low organic matter content due to the destruction of primary vegetation. The organic matter content is mostly less than 2% with generally an inadequate macro-nutrient level for good crop production. Also due to the deficiency of some micro-nutrient (e.g. Zn and B in soils developed on Quaternary red clay and granite), soil fertility is not high. However, most of the cultivated red soils have a much higher available micro-nutrient content (Table 5-15, 16).

With a dominant allitic process, the silica-alumina ratio of the clay fraction in typic red soils is 1.8-2.2; with clay minerals being dominated by kaolinite.

Based on parent materials, the typic red soils can be sub-divided in 5 families.
The soils developed on Quaternary red clay located in flat plains and basins have a deep profile, and clayey soil texture (Iron and Manganese coatings can be present).
Soils on granite in hilly or low and middle mountainous areas are characterized by loose and coarse texture (light loam to sandy loam or sandy), so they are much sensitive to water erosion.

Soils on slate and shale have a shallower profile and sometimes semi-weathered fragments are present at the soil surface.
Soils on sandstone have more sand (to 70%), moderately deep sand or sandy soil with light sometimes yellow colour, lumpy or powder-like structure.
Soils on limestone have a high value of pH (5.5-6.0), heavy texture and blocky structure.

Soil fertility can only be improved if careful utilization is considered.

YELLOW RED SOILS

Yellow red soils are mainly distributed in mountainous areas at the belts between 500-700 m.a.s.l. In a altitudinal sequence the yellow red soils are positioned in between the lower altitude red and the higher altitude yellow soils. Most of yellow red soils occurs on weathering residues of sandstone, slate & shale, granite and limestone. Climatically, the yellow red soil areas are little cooler than that of red soil region, with mean annual temperature of 15-16°C. Accumulative temperature of > 10°C ranges from 4500 to 5000°C. Although the precipitation is similar to the rainfall in the red soil region, the yellow red soil area is more moist (higher relative humidity). A distinction of a drier and moist season is present. The yellow red soil area has generally a better forest coverage in comparison to the red soil area.

Basic properties

Typic yellow red soils have a colour of yellow in the upper part of solum. The absolutely difference of ignited water loss of typic red soil and yellow red soil is 0.88-0.91% (Table 5-19). Weathering, leaching and allitic processes are slightly weaker compared with typic red soils.

Yellow red soil has more organic matter than typic red soil subgroup and is generally lighter in texture. Soil pH is little higher than the typic red soil. The soil CEC is dominated by exchangeable Aluminium (75-100% of BEC).

The organic matter in the surface soil of yellow red soils ranges from 1.15 to 4.29. The total N is 0.071 - 0.160 and total P is 0.082 to 0.206 and K from 2.15 to 3.69. However the differences of soil fertility among the subgroups are closely related to soil parent materials such as, families derived from granite, slate and shale, sandstone, and limestone (Table 5-27).

Brown red soils are the transition type between red soils and yellow brown soils. No further attention will be given because the total area of brown red soils in Hunan province is very small.

YELLOW SOILS

Yellow soils are also important in Hunan province with a total area of 31.595.800 mu. (2.106.400 ha). These soils are formed at a higher altitude of hills and mountains. The thermal condition of yellow soil region is slightly lower than that of red soils at the same latitude. There are 50% more foggy days in the region and the sunshine rate is 30%, which is much less than that in the red soil area. The yellow soil region is characterized by a high air humidity, even in drier season.

Uncultivated yellow soils are generally covered by subtropical broad-leaved forests and evergreen deciduous broad-leaved mixed forest. In the forest, 'fish-scale' bamboo and bryophytes can flourish. Although it has a better permanent coverage of vegetation than that of the red soils, very little primary vegetation remains on the yellow soils. Most of the plants on these soils form a secondary vegetation dominated by masson pine, silvergrass (Miscanlhus spp.), common Eulalia, and others.
Mineralogically, the iron oxides in yellow soils are dominated by hydrated iron oxides such as goethite and hyposiderite with a larger amount of gibbsite, while the iron oxides in red soils are dominated by haematite with very little gibbsite. Owning to a very distinctive chelation-eluviation in soil, the yellow soils have a lower value of pH, a higher exchangeable aluminium content and hydrolysis coefficient (difference between hydrolysable acidity and exchangeable acidity) than red soils. The ignition loss of water of yellow and red soils differs too, which indicates that yellow soils are developed under a moister condition. So throughout the profile especially in the illuviation horizon a yellow or yellowish colour can be observed.

Like the red soils, yellow soils are also determined by the parent rocks. Soils developed on granite and sandstone usually have a thicker solum, are sandier, have a higher permeability for water and a more distinctive eluviation. Soils derived from shale have a loam or clayey texture, a good permeability and distinctive desilication. The altitude where yellow soils is higher going from east to west. The upper limit of the vertical distribution of yellow soils also varies from east to west and from south to north. In addition, the vertical distribution of yellow soils on the slopes facing the monsoon is commonly lower than that on the other sides of the mountains.

Yellow soils are also significant for the development of agriculture and forestry. The yellow soils on the higher mountains are commonly used for forestation and growing of medicinal herbs. The soils on the lower part are used for the development of forestry in combination with agriculture. The yellow soil in hilly areas with a gentle slope are generally used for grain crops or for some cash crops.

Yellow brown soils occur only in the southwestern part of the province and mostly appear in the vertical sequence of mountains. One of its most distinctive morphological features is its brown subsoil. It usually presents an angular blocky or blocky structure covered by coatings of brown to dark brown colour, or with iron and manganese concretions, though its colour varies with parent materials. It is clayey in texture and sometimes even becomes a clay pan due to the accumulation of clay. The surface layer of cultivated yellow brown soils is a plough layer, while those uncultivated consist of a litter and a humus horizon. The thickness of litter layer depends on the vegetation. It is about 1 cm thick under the arbour forest. The humus horizon is dark greyish brown in colour and its thickness ranges from 10 to 20 cm. The litter layer under coniferous forest is thinner than that under deciduous forest. The surface layer is of granular or crumby structure, loose and porous, with abundant roots.

LIMESTONE AND PURPLISH SOILS

Limestone and purplish soils are the main regolic soils in this province, which generally remain in a young stage of soil development, having higher base saturation and abundant carbonate. Since no distinct allitic features can be found in soil profiles, these soils are azonal types but with different degrees of zonal impacts of bio-climatic condition. They are found in mountainous areas composed by carboneous rocks.

These soils cover totally an area of 620 000 ha with two thirds of them in the west of the province (see 2.7).

The unique feature of limestone soils is that they are normally neutral or alkaline in reaction due to their parent materials. The vegetation on those soils is mostly calciphilous xeromorphic species, with representative ones are *Cyclobalanopsis glauca, Carpinus spp.,* and others. The formation process and the properties of limestone soils are closely related to the weathering of parent materials and leaching of carbonate. With the dissolution of carbonate being the main characteristics in the weathering process, the weathering process usually brings about a clear boundary between the solum and the parent rocks, especially limestone, without any fragments or semi-weathered layer. Due to the severe erosion caused by run-off, the soils are always in a young stage. The solum of limestone soils is very shallow, generally less than 40 cm on mountains or steep slopes, with an exception when situated in the valleys or cracks(?) of parent rocks, being as deep as 1 meter (Table 7-3, 7-9, 7-15).
In these soils, biological enrichment of calcium by calciphilous plants is an important process of carbonate accumulation in the soils (besides that derived from parent materials). In summary, there coexist the process of decalcification and recalcification or the migration and accumulation of calcium in limestone soils. The soil content of calcium and magnesium are much more higher than those in red and yellow soils occurring within the same bioclimatic zone (Table 7-11, 7-26).

Types of limestone soils are classified according to their main soil forming processes. With black limestone soils has a stronger recalcification process than decalcification, and much free carbonate in soils, while red limestone soils are more dominated by decalcification with some desilication and allitic processes. The brown limestone soils are in between.

Black limestone soils are normally rich in organic matter and carbonates. The Organic Matter content ranges from 3% to 5% with an apparent humus horizon, and that of carbonate is around 1-5% and sometimes even up to 10% with different forms of pseudomycelia, whitish powder or concretions in profiles (calcium nodules are found in Loudi prefecture). Soil reaction is slightly alkaline with a pH value of >7.5 (Table 7-4).

The yellow limestone soils are the major subgroups of black limestone soils (2/3 of the whole coverage). Their distribution position is generally below that of the typic black subgroup in the mountains, scattering on the limestone mountains within the belt of 500 to 1000 m above sea level. Owning to more adequate rainfall and warmer condition, much of the soil carbonate is leached, making these soils being neutral or slightly acidic, with a pH value of 6.0-7.0 (Table 7-16). In comparison to typic black limestone soils, the yellow ones have an A-B-D type solum with a thinner humus layer (shallower than 8 cm). In the B or BC horizon, the matrix has yellow brown or light yellow red colours, with blocky or prismatic blocky structure. Also a distinct accumulation of iron and manganese can be observed in the field. The clay content in B horizon is clearly higher than that of the A horizon (Table 7-14).

3. BASIC PROPERTIES OF THE SOILS OF HUNAN

Soil particles and texture

The soils in Hunan province are mainly developed on Quaternary red clay, granite, limestone, sandstone and shale. Due to parent materials the particle composition of the soils differs greatly (Table 9-1).

Soils developed on granite generally have a thick solum, while developed on purplish shale usually have a thinner solum, mostly with rock fragments in profile. Red soils derived from sandstone shale commonly have a fine clay content of 40-45%, which is higher than that of the red soils derived from sandstone. Red soils derived from granite have a sand content of 35%, that is higher than that of the red soils derived from sandstone and shale.

Generally, the clay (particles less than 0.01 mm) content of soils derived from slate and shale, limestone and Quaternary clay is from 42-57%. Soils derived from sandstone and purplish sandstones have a lower content of clay of around 40%. Soils derived from granite have the least of clay (around 30%), accordingly, soil texture being sandy-loam or loam. Soils derived from sedimentary materials in flat or low-lying areas have a wide range of clay content according to their origins.

The particle composition of different soils is as follows. Red soil has more clay (22%), dark brown soil has less (15%), yellow soil in between (17%). The differences among different subgroups of red soils are also clear, with clay content of 22% in typic subgroup, 19% in yellow red soils and 15% in young subgroup. This phenomena also exists between red limestone soils and black limestone soils with the former one is 23%, the later 19%. Slightly differences can be found among the three subgroups of purplish soils too. A decreasing trend of sand content in A horizon exists downward from top of mountains (Table 9-1,2).

Owning to the local difference of hydro-thermal situation, soils in the south part of the province often have a higher clay content. Another factor causing the variation of particle composition are soil management practices ('mellowing' of soils). The silt content is mostly constant throughout profiles.

Soil specific gravity, bulk density and porosity

Soil specific gravity varies from 2.22 to 2.94 g/cm3 with an average one of 2.58 g/cm3, which depends mainly on parent materials, organic matter content and cultivation. Soil derived from granite and sandstone is much lighter than that derived from slate and shale. Those developed on shale, limestone and Quaternary red earth is in the middle. The bulk density of soils in hilly and mountainous areas decreases from red soils (1.35 g/cm3) to yellow soils (1.09) and to dark yellow-brown soils (0.97). That of purplish and hydromorphic soil is much higher (Table 9-5,6). The coefficiency between bulk density of upland soils and soil organic matter are relatively high with $r>0.8$ (pp.57).

Soil organic matter (OM)

Soil content of organic matter in surface layer ranges from 1.5% to 7.7%. The general order of OM content in the surface of cultivated soils is mountain meadow soils > dark yellow brown soils > yellow soils > black limestone soils >red soils >purplish soils. The C/N ratio has a similar sequence.

Red soils have generally an organic matter content of 1.8-2.7% in surface layer. Within the yellow red soils have more Organic Matter (average 3.2%), the young red soils (2.6%), and the typic red soil (2.3%), and brow red soils the least (1.82%) (Page 282:Table 10-11). Also a variation between soils derived from different parent material can be seen. Red soils developed on slate, shale, sandstone have more OM than those originated from limestones.

The OM content of soils in mountainous areas has a distinctive altitudinal variation. Soils situated at the upper part of the mountains have a higher content than those developed at the lower altitudes. The OM content of limestone soils ranges from 2.8 to 3.5%, that of purplish soils is much lower (from 1.4 to 2.7), with acidic subgroup the least, and the neutral one the highest (Table 10-15).

The impact of cultivation of soil on soil organic matter can be described in two ways. Those with high amount of soil OM decrease rapidly after exploitation; those seriously eroded can be improved by fertilization and mellowing. The maintainance of high soil OM and its upgrading can be realized if the following measures will be taken, e.g. green and application of other organic fertilizers, rational cultivation and rotation to regulate the accumulation and decomposition of soil organic matter.

The quality of soil humus, characterized by humic and fulvic acids (HA/FA) and light transmittance in solution (E4) also differs in soils distributed in different altitudes of mountainous areas (Table 10-19).

The CEC of red, yellow and dark yellow and dark yellow brown soils are given in Table (10-45), from which we can see that of red soils range from 6.9 to 27.1 cmol/100 g soil with an average value of 12.8. These soils derived from limestone and Quaternary red clay generally have a higher CEC value than those derived from sandstone and granite. The CEC of the yellow subgroup of red soils is slightly higher than that of typic red soils derived on the same parent materials which have a range of 8.6 to 18.5 cmol/100g soil and an average of 12.9 cmol/100g soil. That of the young red soils is generally lower, averagely 11.3 cmol/100g soil due to the severe erosion.

The CEC of yellow soils, ranging from 7.3 to 32.8 cmol/100g soil with an average value of 15.5, which is much higher than that of red soils. Within this group, the young yellow soils have a slightly higher one than that of the typic yellow soils. The decreasing order of CEC of soils developed on different rocks are: shale and slate > sandstone, limestone >granite.

Tables 10-45 and 10-47 gives the soil CEC of different soils.

Owning to the strong accumulation of soil OM, the CEC of mountain meadow soils is normally larger than 20 me/100g soil and sometimes even up to 50.

The CEC of azonal soils (limestone and purplish soils) is usually higher than the zonal ones. Limestone soils have a CEC value of 13-40 me/100g soil, with the highest values for black limestone (approximately 30 cmol). Yellow and red limestone soils less than 20 cmol/100g soil. The CEC of purplish soils are much lower than that of limestone soils and it normally falls with in 5-25 me/100g, with the acidic subgroup around 14.3, neutral one of 13.5 and calcic one of 18.3. The sandy families of those subgroups usually have a CEC value of 20, which is less than the loam or clay soils in the same subgroups.

In summary, the CEC of soils in Hunan province depends mainly on their soil development stage, the organic matter content and the oxides in soil. Therefore a general trend of CEC exists from red soils, yellow soils, yellow brown soils to mountain meadow soils. The ratio of exchangeable cations to soil CEC ranges from 40-90%, with a higher value in typic red soils and lower one in yellow red soils because of the high activity of oxides in the later.

The exchangeable bases and their composition

Generally speaking, the zonal soils have a lower base exchangeable capacity (BEC) and base saturation than the azonal soils in the province. The BEC of red soils is less than 3 cmol/100g soil and the base saturation (BS) is lower than 30%. Soils derived from limestone and Quaternary red clay have a higher BEC and BS than those from acidic rocks. The BEC of yellow soils ranges from 2.61 to 6.91 me/100g soils, and the BS is also higher than the one of red soils. However, the BEC of young yellow soils are distinctively low (less than 2 me/100g soil)

The most significant feature of base composition of soil in hunan province is the strong influence of parent materials, with exchangeable Ca being 60-90% of the total BEC in azonal soils and 46-65% in zonal soils Table 10-50 and 10-51).

Soil nutrients

The total nitrogen of upland soils in Hunan province ranges from 0.9% to 0.17%, it is closely correlated with organic matter content of soils, both of them have the same sequence from high to low. The OM contents of young dark yellow brown soils, young yellow soils, typic yellow soils, yellow red soils, young red soils, typic red soils are 7.8%, 5.9%, 4.4%, 3.2%, 2.8% and 2.3% respectively, and that of total nitrogen are 0.21%, 0.24%, 0.19%, 0.15%, 0.15%, 0.14% and 0.12%. The second feature is that natural soils have a higher value of soil N than the cultivated ones of the same types (Table 12-15).

The available nitrogen in upland soils ranges from 64.5 to 27.5 ppm. With most of soils fall in the fourth class of nitrogen levels (according to the national classification standards of soil N, having six classes). The necessary application of N-containing fertilizers should be emphasized not only on its application amount, but also on its spatial and temporal distribution and operational techniques.

The total phosphorus (P2O5) of upland soils is 0.01-0.55%. The differentiation of soil P is closely connected with parent materials. The total P of soils developed in alluvial materials is higher than the soils derived of granite, slate and shale, purplish sandstone and shale, sandstone, limestone and Quaternary red clay. With more than half of the upland soils short of P (85% of soils in mountainous areas), Phosphorus fertilization is very important for the agriculture production of Hunan province. The second feature of soil P in this province is that the average content of soil P in non-cutivated soils is much less than that of the cultivated soils. And especially cultivated soils have more available P than non-cultivated soils. In view of the decreasing intensity of soil P-providing, the most urgent thing is to raise the availability of P. The availability of soil P is controlled by several factors, therefore a comprehensive investigation is still needed.

The improvement of soil Potassium (K), especially in soils derived from Quaternary red clay, can only be realized by the application of farmyard and green manure.

Ca or Mg fertilizers is only used for soils with strong or moderate acidity.

Micronutrient status of soils depends on parent materials, with soils derived from granite short of B and those from purplish sandstone and shale short of Zn and Mo.

The availability of soil micro-nutrients is closely related with soil pH. Application of micro-fertilizer can give good results, however generally only attention is paid to the soils of the paddy fields.

4. AMELIORATION AND UTILIZATION (RED AND YELLOW SOILS)

Low productive red soils are widely distributed in the low mountain and hilly basins of east, central and south Hunan. Low productive yellow soils only exist in western Hunan. And the obstacles to high yield in these soils are the shallow, strong soil acidity, clayey(?) and drought-sensitive nature of red soils.

The main measures to upgrade soil fertility of high yield land are rational deep ploughing and soil harrowing ('mellowing') to establish a good pedon structure; increasing the application of organic fertilizers to maintain soil fertility; planting according to soil conditions and optimum rotation and combination of different crops, constructing a good ecological condition to enable the sustainable production.

The main problems in fertilization are:
1. Imbalance of N, P, and K application. Presently, the ratio of N : P2O5 : K2O is 1: 0.35 : 0.49. The improvement of productivity of production is strongly inhibited by lower levels of P and K. According to the crop requirement of different nutrients, the ratio of N:P2O5:K2O should be regulated to 1 : 0.5 : 1.

2. Imbalance of organic and in organic fertilizer Since the output of nutrient by harvesting is the combination of several nutrient elements, the long term application of chemical fertilizers will unavoidably results in the inadequacy of some elements. Apart from the application of specific mineral fertilizers, organic fertilizer is one of the solutions. Rational rotation of crops, sometimes with green manure and straw-burying also can contribute to the improvement of soil fertility.

Soil erosion — its prevention and control

According to the investigation, there is 41958 km2 of Hunan province effected by soil erosion, which is 20.8% of the total area (Table 16-1). Soil erosion mainly occurs on red soils of hilly areas in central hunan and red and yellow soils in the mountains of northwest Hunan. The rest are located patchwise in the hilly or mountains of east and west Hunan.

According to the type, nature and intensity of soil erosion, 6 soil erosion regions are distinguished (Map 19, Table 16-1)

Table Soil erosion status in Hunan

Erosion types			Area by land use			Area by degrees of erosion			
Sheet	Gully	Collapse	Agric.	Forest	Grass/ barren	Light	Moderate	Strong	Severe
41958	1673	368	6954	27312	9733	2083	14240	7942	986

Table Soil erosion in different regions of Hunan

Regions	Total area	Erosion area (ha)	%
I	4988.1	13000	26
II	52793.3	14815.5	28.1
III	27259.8	5267.8	19.3
IV	23304	4973.7	21
V	40428.5	5100	12.6
VI	18162.3	842.7	4.6
Total	211829	44000.6	20.8%

According to research data, each year totally 170 million ton soil is washed from the soil surface of the province, that corresponds to a ploughing layer of 53000 ha, or equals 2.5 million ton of organic matter.

Region I is dominated by surface erosion of cultivated sloping land which is caused mainly by slash and burn cultivation of steep slopes (>30°). Another cause is the intercropping of cereals and tung-oil trees on steep slopes of high mountains where almost 90% of areas are eroded with a quantity of 13000-19000 ton/km2 year. The yield of tung oil per hectare lowered by 50%, due to the serious washing of soils.

Region II is basically the hilly-red soil area. Soil erosion depends mainly on parent materials. Gully erosion and 'collapse' (land slide) erosion prevails in the granite area. Coarse weathering residues of purplish rocks are much sensitive to drought and difficult to revegetate, resulting sometimes in vast red 'deserts'. Erosion in limestone area is mainly of the sheet erosion type.

Region III is characterized by patchwise moderate erosion of forest land and some grassland; The erosion of region IV is caused by large-scale destroy of primary forest and mining activities.

Apart from the large-scale losses of surface soil and corresponding soil nutrients, soil erosion brings some other negative results too. These are: the decreasing yield of agricultural land, the inverse succession of vegetation in forest areas, the silt up of reservoirs and small reservoirs, the increase of drought and flood frequency.

Owning to the continuing silt deposition, the water area of Dongting lake has reduced to 2740 km2 from 4350 in 1949, the water holding capacity also decreased from 29300 m3 [x 10^6 ?] to 17800 m3, which makes silt deposition the most serious problem in agriculture in this area of 'house of rice and fish'.

The main causes of soil erosion

Degree of slope; the percentages of areas with slope degree of more than 15° and 25° are 70 and 83% respectively. The erosion index of a 25° slope is 4.5 times larger than that of slopes of 11°.
There are many storm days in the rainy season (May, June, July).

The weak erosion resistance of soils (high soil erodibility) derived from loose weathering products of granite and sandstones is the second factor.
The serious destroy of forest vegetation is the third major basic cause of soil erosion.

The prevention and control of soil erosion

More integrated measures should be taken to prevent and control the present soil erosion. These measures consist of agricultural techniques, field engineering, forest improvement and afforestation, and water conservation techniques (contour ploughing, ditch and ridge planting, intercropping, less or no ploughing, addition of clay to sandy soil and terracing).

Table Effects of terracing and forest reservation of the run-off and soil erosion

time	precipitation (mm)	rain intensity (mm/s)	runoff (m3/ha)			soil erosion quantity		
			slope	for.res.	Ter.	Slope	For.res.	Ter.
29-30 May	29.3	1.2	5.046	2.395	2.901	7.10	0.092	0.417
10 Aug	29.4	48.0	44.61	18.675	17.385	138.3	12.10	84.5

(Based on Table 1-25)

Suggestions for the rational utilization of the red soil hilly area.

Presently, most of the red soils in hilly areas are used for forestry with Masson pine and China fir as the dominant species, and tea plantation. The main problems of limestone soils are soil and water erosion.

Firstly to adjust the cropping system. With higher input multiple cropping of several cash crops, grains, oil crops and combinations of multiple grain crops with each one from the three kinds of crop rotation. The multiple cropping index can reach 210-220% in southern and central Hunan. With the improvement of soil fertility maintenance and use of improved crops species, the productivity of red soils can be further raised.

Recommended is the establishment of dominant cash crop production areas:

1. Tea production
Areas with deep, strong acidic soils developed on Quaternary red clays are the best locations for tea plantations. Since the main obstacles are high temperature and strong direct sunshine, the best method to improve the quality of the tea produced in this area are: tea intercropped with other trees, sprinkler irrigation, tree alleys in tea gardens, which will result in the reduce of direct sunshine, the increase of dispersing sunshine, the lowering of air convection and water evaporation, the increase of air humidity, etc.

2. Citrus production
The coincidence of concave micro relief of some soils derived from sandstone makes it possible to buffer low temperature and drought which are the main limiting factor for citrus production. The main gardening techniques are the build up of soil fertility and the improvement of tree rooting possibilities.

3. Further improvement of the tea-oil forest
With more than two-thirds of camellia growing on red soils, these soils having the greatest potential for tea-oil production. However, due to the ageing and damaging of trees, the poor soil, the lay waste (poor management) of the plantation, the yield of tea-oil is less than 40 kg/ha. The specific measures to raise tea-oil production are: to rejuvenate old trees, to put emphasis on limestone soils and soils derived from purplish sandstone and to strength tending and management.

4. Greening the desolated mountains with proper tree species
According to research, soils derived from Quaternary red clay are suitable for Masson pine, Torch pine, Chinese sweet gum (Liquid-amber taiwaniana), Camphor tree, White oak, Locust, China fir and Paulownia in deeper and moister locations. Red soils from sandstone are suitable for timber (granite areas for solarphilous species).

Regolic soils

Limestone soils and purplish soils are the most seriously eroded soils. To utilize these soils the first step is to control erosion with mainly biological measures. Throughout the investigation, we found that Locust is the best pioneer species for forestation on purplish soils and Honey Suckle on limestone soils.

Soils in mountainous areas (yellow soils and dark yellow brown ones) are used mainly for forestry. Apart from the development of local special products, forests with different function (water and soil conservation, fast-growth timber production) are urgently needed. The main specialities of this area are Pine Foggy tea, Yangtao (Actinidia chinensis), Job's tears, Hawthorn, medicinal herbs and famous flowers, etc.

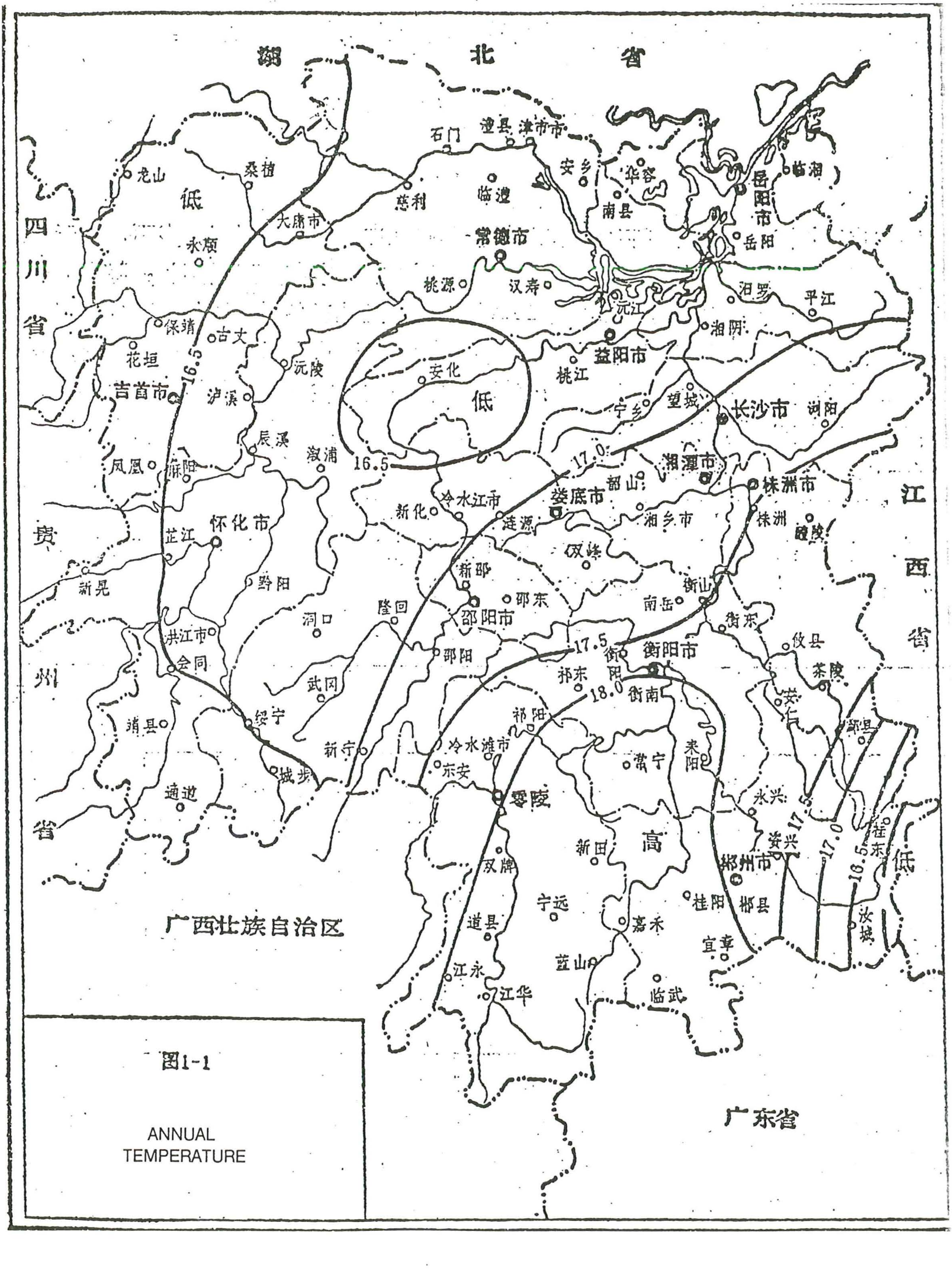

图1-1

ANNUAL TEMPERATURE

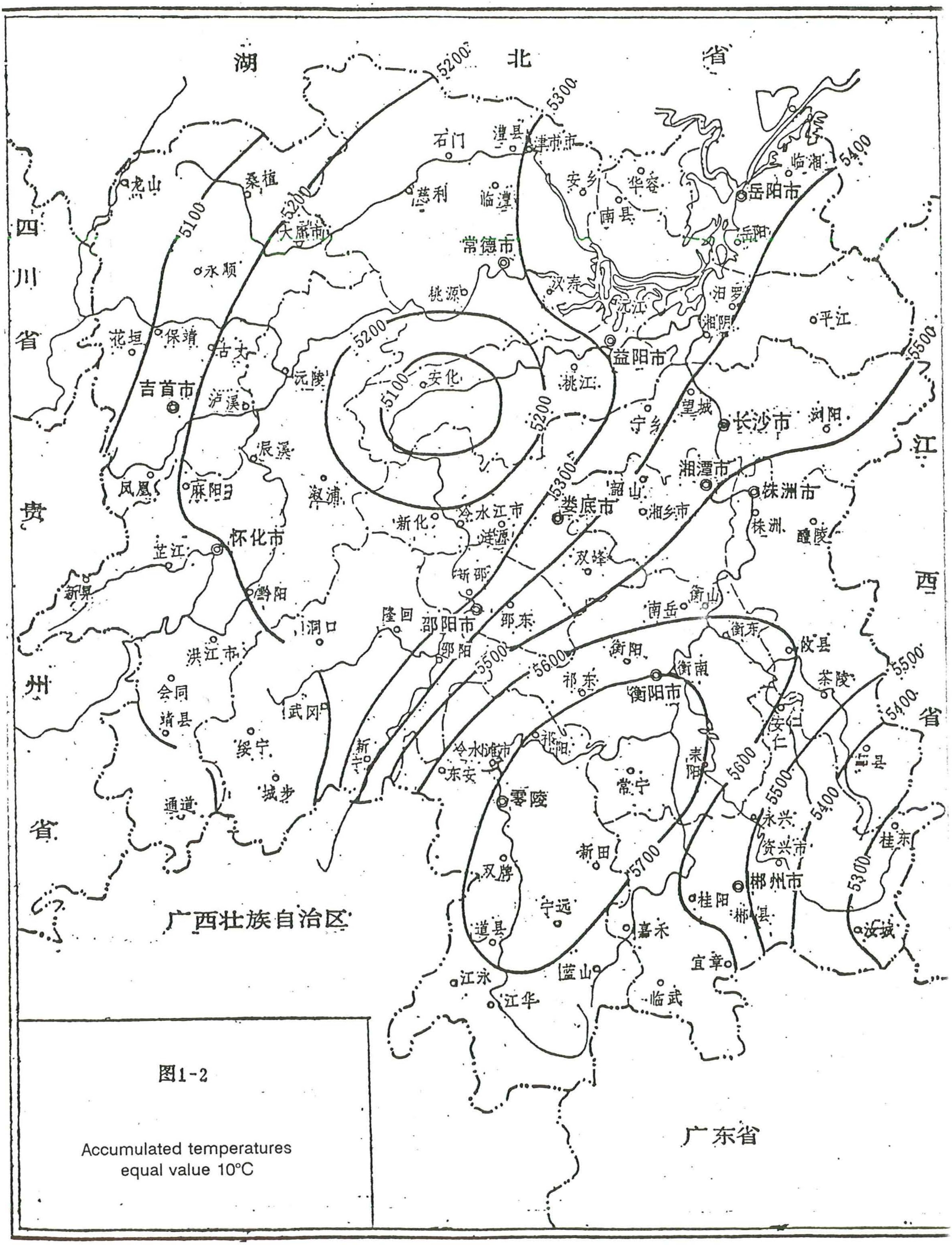

图1-2

Accumulated temperatures equal value 10°C

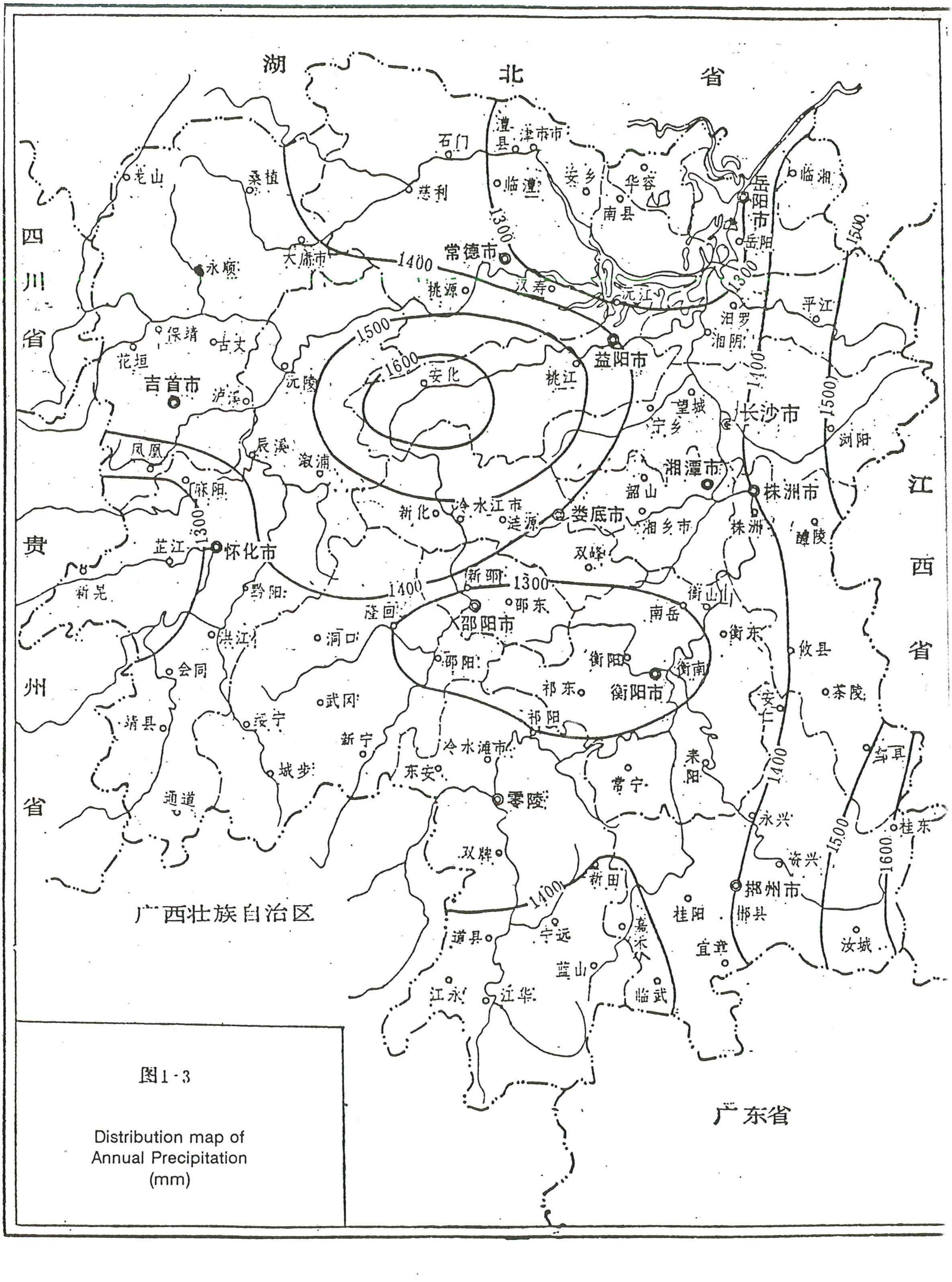

图1-3

Distribution map of Annual Precipitation (mm)

Table 1.9

Regional differentiation of precipitation (month, season and annual)

(1951～1980年)

区域	Meteo-stations	Month (mm)													Season (%)			
		1	2	3	4	5	6	7	8	9	10	11	12	全年	春	夏	秋	冬
North	澧县、安乡、常德、益阳、岳阳、华容	41.9	62.8	111.9	169.3	197.4	198.3	114.0	137.3	70.0	86.3	64.0	41.7	1294.9	16.7	43.7	24.8	14.8
East	醴陵、浏阳、茶陵、攸县	60.5	93.5	145.9	203.6	233.9	201.1	117.4	130.6	53.5	78.1	71.8	52.6	1442.5	20.8	44.3	20.9	14.0
Southeast	桂东、资兴、汝城、酃县	57.3	78.0	129.9	191.7	207.3	228.2	130.1	191.2	100.4	82.8	61.7	49.2	1507.8	17.6	41.6	28.0	12.8
South	江华、江永、蓝山、临武、宜章、道县	58.8	70.8	121.3	208.8	232.9	230.8	119.0	156.9	75.6	85.0	61.3	52.9	1475.1	17.0	45.6	23.9	13.5
Southwest	通道、靖县、绥宁、城步、会同	53.3	54.1	88.6	170.7	222.5	195.4	136.0	122.9	68.7	93.0	76.3	46.0	1327.5	14.8	44.3	24.7	16.2
Northwest	龙山、桑植、大庸、永顺	24.7	36.8	73.5	145.5	208.4	237.3	196.4	159.7	111.8	107.0	61.9	31.2	1394.2	9.7	42.4	33.6	14.3
Central	湘潭、衡阳、双峰、邵阳	57.3	78.0	129.9	194.2	207.3	288.2	130.1	191.2	100.4	82.8	61.7	49.2	1510.3	17.6	41.7	27.9	12.8

表1-10 Regional differentiation of monthly, seasonally and annual evaporation

(1951～1980年)

区域	Meteo-stations	Month (mm)													Season (%)			
		1	2	3	4	5	6	7	8	9	10	11	12	全年	春	夏	秋	冬
North	澧县、安乡、常德、益阳、岳阳、华容	43.1	44.8	67.4	97.3	119.8	143.4	214.9	185.2	129.6	97.8	64.4	48.8	1256.5	12.3	28.7	42.2	16.8
East	醴陵、浏阳、茶陵、攸县	45.3	46.3	68.8	101.9	129.2	162.7	257.3	220.3	165.5	118.7	75.2	53.9	1445.1	11.1	27.3	44.5	17.1
Southeast	桂东、资兴、汝城、酃县	53.3	53.7	74.4	99.4	124.2	140.5	199.3	170.8	139.6	116.4	83.3	61.5	1316.4	13.8	27.7	38.7	19.8
South	江华、江永、蓝山、临武、宜章、道县	60.0	58.6	80.0	105.2	139.2	160.9	229.4	200.7	166.7	134.4	93.9	68.7	1497.7	13.3	27.1	39.8	19.8
Southwest	通道、靖县、绥宁、城步、会同	43.3	46.2	73.5	104.2	117.8	134.7	198.9	174.2	144.0	100.3	65.1	51.0	1253.2	13.0	28.5	41.2	17.3
Northwest	龙山、桑植、大庸、永顺	40.7	45.0	69.4	93.9	110.4	129.0	174.7	178.6	128.2	86.5	55.1	42.0	1153.5	13.5	28.9	41.7	15.9
Central	湘潭、衡阳、双峰、邵阳	42.9	43.2	67.2	101.7	123.1	158.8	258.6	222.4	168.4	114.7	70.5	52.9	1424.4	10.8	26.9	45.6	16.7

表1-11 湖南省区域性山地气候

(1951～1980年)

Region	Location	Elevation (m)	Average temperature (°C) Jan.	July	Annual	≥10℃ Accum. temp.	Frostless period (day)	Annual rainf. (mm)	Annual evapor. (mm)	Rel. humid. (%)
East	桂东	835.9	5.2	24.2	15.4	4644.8	232.8	1663.1	1302.6	82
	平江	77.1	4.5	28.6	16.9	5338.7	241.6	1457.2		81
West	通道	397.5	5.2	26.2	16.3	5058.9	240.8	1403.5	1172.2	83
	安化	128.3	4.3	27.9	16.2	5089.5	239.3	1691.2	1125.3	81
	龙山	486.4	4.4	26.5	15.8	5001.8	242.4	1386.7	1042.0	81
South	汝城	608.3	6.2	25.5	16.6	5097.4	243.7	1547.6	1382.0	82
	江华	338.3	7.4	26.5	17.8	5537.9	307.8	1512.5	1269.8	83

从上述三个气候要素中，可以把我省气候特点制成湘中、湘南和西部山区几个代表性图式。

P precipitation
E evaporation
Q temperature
S surplus
R alternation between surplus and deficit
D deficit

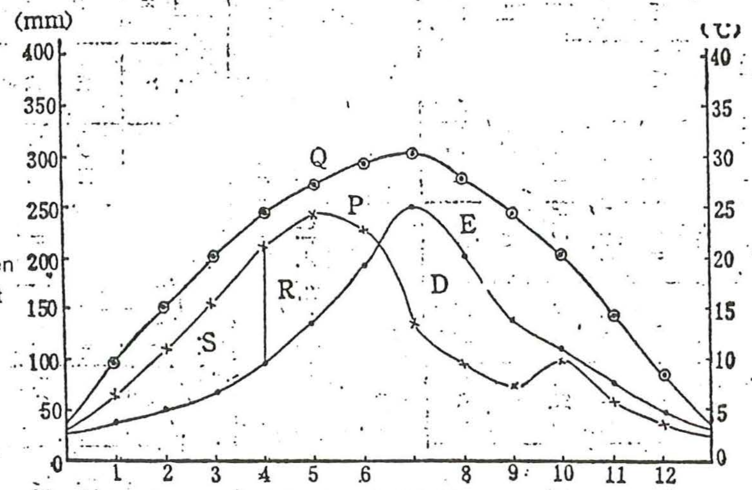

图1-4 水分平衡型

Changsha (30 yr average): Annual precipitation 1389.8 mm; Annual evaporation 1382.2 mm; Annual average temperature 17.2°C.

P. 降雨；E. 蒸发；Q. 温度；S. 过剩；R. 间断交错；D. 不足。

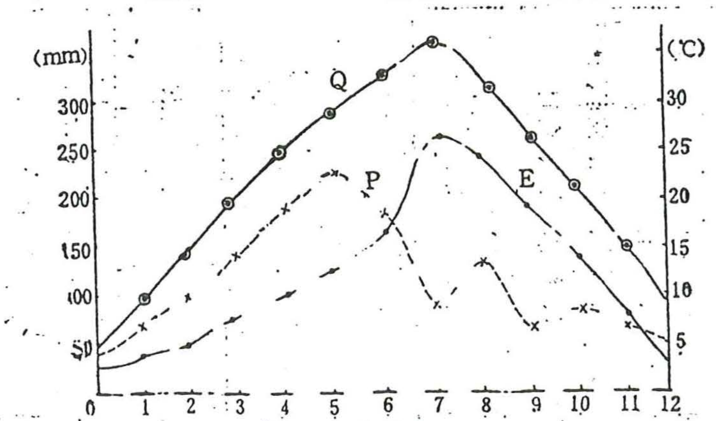

图1-5 水分不足型

Hengyang annual precipitation 1337 mm; Annual evaporation 1463.7 mm; Annual average temperature 17.9°C.

P. 降雨；E. 蒸发；Q. 温度。

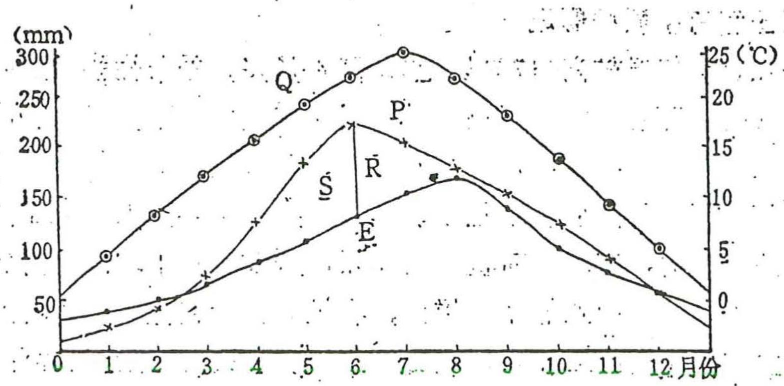

图1-6₁　湿润型

龙山(21年平均)：年降雨 1386.7mm；年蒸发量为 1042mm；年均温15.8℃。
S．过剩；R．间断交错；P．降雨；E．蒸发；Q．温度。

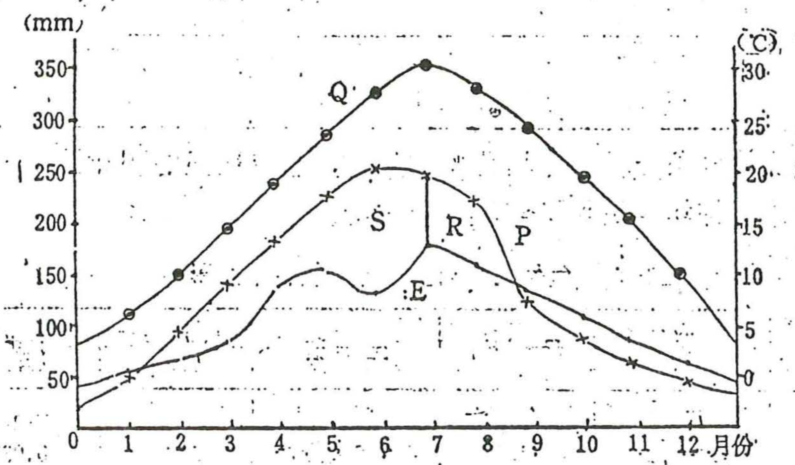

图1-6₂　湿润型

桂东(23年平均)：年降雨1663mm；年蒸发量1302mm；年均温 15.4℃。
S．过剩；R．间断交错；Q．温度；P．降雨；E．蒸发。

根据图1-4、图1-5、图1-6的特点，可以把我省气候划分为以下三个类型。

1．水分平衡型（图1-4）　位于湘北湖区平原和湘中一带，降水量与蒸发量年均差一般在 50mm上下。常年在 7 月前后，因气温高而降雨量减少，蒸发量超过降雨量，水分不足将持续两个月之久，12月至 5 月水分不缺或过剩，6～7 月为水分间歇交错期。

2．水分不足型（图1-5）　位于湘南衡邵盆地，蒸发量大于降水量150mm 或更多，7 月后水分明显不足，将持续两个月以上，12月至 5 月水分不缺，但无过剩现象，因土壤比较干燥，旱季也比湘北来得早。

以上两种类型共同之点为降水与气温同步，气温较高，有明显的湿季和旱季。

3．湿润(或常温)型（图1-6）　位于湘西和湘东南山区，降雨量与气温同步，由于气温较低(15℃左右)，年降雨量超过蒸发量300mm 以上。在气温最高季节(6～8 月)，降雨量也是大于蒸发量，有冷暖之分，无干湿之别。

二、气候对土壤形成的影响

我省的气候条件有助于说明土壤形成和土壤管理的特点。从区域性看，我省属于中亚热带，热量丰富，雨量充沛。从地域性看，则可细分为平原丘陵典型的中亚热带和山地湿润或常湿的亚热带两个亚型。不同的气候类型对土壤的性质发生深刻的影响。

(一)气候对土壤有机质的影响

我省中部平丘区，气温较高(17℃以上)，降水量多，季节性强(集中于4～6月)，干湿季明显。7～10月，蒸发量大于降雨量，在这种气候条件下，微生物活动非常活跃，有机质分解快，积累少，这是我省中部红壤丘岗地区有机质含量少的主要原因；而湘东、湘西、湘南广大中低山区，气温低、雨量多、蒸发量少，全年降水量大于蒸发量，湿度大、气温低，微生物的活动弱，有利于有机质的积累，所以在年平均温度高(一般大于16℃)、土壤以黄、红壤为主的典型中亚热带气候区，有机质含量较低；年平均温度小于16℃，土壤以暗黄棕壤为主的山地湿润亚热带气候区，土壤有机质的含量则较高，两者相差一倍以上(表1-12)。

表1-12 不同气候区与土壤有机质含量的关系

区域	年平均温度	土壤	个数(n)	有机质含量(%)
典型中亚热带	>16℃	红壤为主	2178	2.78
山地湿润亚热带	<16℃	暗黄棕壤为主	189	6.16

从我省几个山头的气象资料和土壤化验结果看，也有明显的规律性。一般有机质含量是：山地草甸土>暗黄棕壤>黄壤>红壤(表1-13)。

表1-13 Relationship between climate and soil organic matter

Location	Ann. temp.* (℃)	Ann. precip. (mm)	Parent rocks	Soil type *	Org. mat. (%)	Total N (%)	C/N
宜章莽山	12.2	2375.5	Granite	1	8.47	0.374	13.1
	14.1	2105.2		2	3.20	0.087	21.3
	14.8	1999.9		3	4.17	—	—
	16.5	1754.2		3	3.98	0.175	13.2
	17.6	1689.4		4	3.67	0.131	16.3
	18.3	1584.1		5	1.97	0.121	9.4
桂东八面山	9.71	2478.6	Granite	1	6.18	0.236	15.2
	11.2	2292.0		2	3.55	0.154	13.4
	11.9	2201.7		2	2.09	0.110	11.0
	12.9	2080.3		3	2.07	0.097	12.4
	13.7	1978.0		3	1.35	0.057	13.7
	15.7	1731.2		4	1.87	0.089	12.2
	16.5	1628.9		5	1.73	0.099	10.1
黔阳雪峰山	10.5	1779.8	Slate and shale	1	3.43	0.158	12.6
	11.8	1697.2		2	2.90	0.115	14.6
	13.0	1622.4		3	2.00	0.085	13.6
	15.9	1443.6		5	0.47	0.072	3.8
南岳衡山	11.3	2074.4	Granite	1	9.59	0.412	13.5
	13.0	1885.3		3	4.61	0.182	14.7
	14.7	1696.2		4	1.07	0.047	13.2
	16.3	1518.9		5	1.64	0.081	11.74

* 莽山、资兴八面山、雪峰山、衡山按各山头实测资料每升高100m，气温分别下降0.41℃、0.49℃、0.53℃和0.52℃，降水量提高58.5mm、60.2mm、32.5mm和59.1mm推算而来。

** 有机质和全氮用A层至B层(含BC层)，以各层深度为权的加权平均数。

* SOIL TYPE
1 Alpine meadow soils
2 Dark yellowish brown soils
3 Yellow soils
4 Yellowish red soils
5 Red soils

由表1-24可见，串灌串排粘粒流失量大，比正常灌溉含粘粒少12%，物理性粘粒降低了28%；化学性状也变劣，有机质降低5.5%，全氮降低了0.11%，全磷降低0.05%，速效养分也相应减少。

红壤旱地的退化，一般是因在陡坡地上开垦而引起，特别是顺坡种植，地表径流增大，土壤受到冲刷而导致肥力衰退。据浏阳县宝盖洞观测站资料，降雨量及降雨强度相同，封山育林地、坡地与梯田土壤侵蚀量有较大差异(表1-25)。

Table 1-25 Precipitation, runoff and soil erosion under different utilization of red soils.

Date	Precip. (mm)	Intensity of precip. (mm/s)	Runoff (m^3/ha)			Soil erosion index (T/km^2)		
			Sloping land	Forest reserv.	Terrace land	Sloping land	Forest reserv.	Terrace land
29-30 May	29.3	1.2	5.046	2.395	2.901	7.10	0.092	0.417
10 August	29.4	48.0	44.61	18.675	17.385	13.83	121.0	84.5

表5-11 Soil profile properties of different subgroups of red soils

Soil subgroup	Location	Hor.	Depth (cm)	干湿度	Colour	Texture	Structure	Compaction	Porosity	Root	Concretions 种类	Concretions 形态	Concretions 数量	侵入体	pH
Red soils on Quaternary red earth	湘潭 白托乡	A	3～12	润	红棕	clay-loam	granular	松	多	多	无	—	—	—	5.0
		B	12～120	湿	棕红	clay	blocky	紧	少	少	无	—	—	—	5.0
		C	120以下	湿	淡棕红	"	blocky	紧实	少	无	铁锰	结核	多	—	4.5
Red soils on granite	资兴市 青市乡	AB	2～24	潮	淡红棕	sandy-loam	crumby	散	大孔中量	多	无	—	—	—	5.6
		B	24～100	润	红棕	loamy-sand	blocky	散	小孔中量	中	铁锰	胶膜	少	—	5.8
		BC	100～150	润	淡棕红	sandy-loam	-	散	小孔中量	极少	无	—	—	—	5.6
Red soils on slate and shale	会同县 肖家乡	A	0～13	湿	暗黄棕	clay	blocky	较紧	—	多	铁锰	胶膜	少	—	5.6
		B	13～105	湿	淡棕红	"	blocky	紧实	—	少	铁锰	胶膜	中	—	5.6
		C	105～150	湿	淡棕红	"	blocky	紧实	—	极少	无	—	—	—	5.6
Red soils on sandstone	双峰县 五里牌乡	AB	0～28	润	红棕	loam	lumpy	较松	大孔中量	多	铁锰	胶膜	中	—	5.6
		B	28～83	润	红棕	"	blocky	较紧	中孔中量	较多	铁锰	胶膜	少	20%碎石	5.4
		BC	83～150	润	淡红橙	"	blocky	紧	小孔中量	中量	无	—	—	—	5.2
Red soils on limestone	桂阳县 林场	A	0～16	—	暗红	clay-loam	granular	松		多	无	无	无	—	4.8
		B	16～60	—	暗棕红	"	blocky	紧		少	铁锰	结核	少	—	5.2
		BC	60～108	—	暗棕红	"	nutty	紧		极少	铁锰	结核	多	—	5.6

红壤，土质较粘重。据27个剖面样颗粒分析，小于0.01mm的物理性粘粒的均值达57.67～60.13％(表5-12)，而小于0.001mm的粘粒达30％左右，这些细微粘粒的矿物组成中，除氧化硅、铝含量较高外，还含有较多的铁。氧化铁、铝是粘结性较强的胶结物质。因此，质地较粘重，特别是淀积层，因接受上层淋溶下来的粘粒而更为紧实。据在华容县胜峰乡先峰林场的第四纪红土红壤上测定：A层紧实度为3.1kg/cm^3，B层为32.7kg/cm^3，C

表5-12 不同母质红壤的物理性状

Subgroup	Horizon	Physical sand (%)	Physical clay (%)	Bulk density (g/cm^3)	Specific gravity (g/cm^3)	Porosity (%)
on quaternary red earth	A	42.33±24.2	57.67±26.43	1.32	2.57	48.6
	B	39.96±24.99	60.04±25.19	1.32	2.44	45.9
	C	39.87±25.39	60.13±39.60	1.27	2.57	50.6
on granite	A	60.22±34.07	39.78±20.27	1.38	2.52	45.2
	B	60.53±35.04	39.42±24.32	1.48	2.94	49.7
	C	69.68±42.74	30.32±25.61	1.61	2.85	43.5
on slate and shale	A	50.58±31.51	49.42±22.22	1.47	2.65	44.5
	B	47.18±31.08	52.82±22.93	1.27	2.58	50.8
	C	46.94±29.00	53.06±26.62	1.49	2.71	45.0
on sandstone	A	53.04±31.23	46.96±20.79	1.42	2.52	43.7
	B	53.68±33.58	46.32±22.76	1.52	2.61	41.8
	C	51.91±37.33	48.09±27.32	1.65	2.80	41.1
on limestone	A	46.40±28.80	53.60±24.74	1.39	2.62	46.9
	B	45.84±32.79	54.16±25.16	1.52	2.62	42.0
	C	39.06±32.43	60.94±36.24	1.55	2.67	43.8

层达42.7kg/cm³。土体紧实，加上有机质含量低，土粒遇水吸湿膨胀分散成糊状，水分蒸发散失，土块变得坚硬板结。土壤结构性差，通气透水性不良，虽然孔隙度可达40～50%，但大孔隙少，在多雨季节土粒遇水糊化，阻滞水分下渗，地表常渍水或造成地表径流，冲刷表土。

(三)土壤化学性质

1. 土壤酸碱反应 红壤表面吸附的盐基往往易被H^+、Al^{3+}所代换而流失。同时铝的大量累积，易于产生水解性酸，致使土壤呈酸性反应。据全省382个土样分析统计，红壤A层pH值(水浸)在4.5～5.5之间的占59.8%；5.5～6.5之间的占37.5%；<4.5的占0.6%；>6.5的占2.1%。红壤的酸碱性因母质不同而有较大差异，以石灰岩风化物发育的红壤pH值最高，平均可达5.65，板、页岩最低，达4.98(表5-13)。

表5-13 Soil pH of red soils developped on different parent materials.

Soil subgroup	A A horizon层		B horizon层		C C horizon	
	nb. of samples	pH (extracted by water)	nb. of samples	pH (extracted by water)	no. of samples	pH (extracted by water)
Quaternary red earth	97	5.05	142	5.23	56	5.26
Slate and shale	159	4.98	180	5.01	88	5.00
Sandstone	132	5.02	159	5.06	75	5.02
Limestone	83	5.34	94	5.38	30	5.65
Granite	92	5.00	99	5.03	50	5.05

2. 红壤的交换性能 红壤总的特点是阳离子交换量，交换性盐基总量都低，交换性铝的含量高(表5-14)。

表5-14 CEC and exchangeable acidity of red soils on different parent materials

Subgroup	Hor. 次	pH water extr. (水浸)	阳离子交换量 (me/100g土)	Exchangeable bases me/100g土)					Exchangeable acidity (me/100g土)			BS
				Total	Ca^{2+}	Mg^{2+}	K^+	Na^+	Total	H^+	Al^{3+}	(%)
Granite red soils	Surf. layer	5.3	10.51	1.19	0.25	0.39	0.36	0.19	3.68	0.38	3.30	11.35
"		4.8	11.80	1.44	0.60	0.32	0.42	0.10	6.30	0.15	6.15	12.20
Slate and shale		6.2	6.23	1.25	0.53	0.18	0.23	0.31	1.30	0.45	0.85	20.10
"		4.7	9.10	1.46	0.90	0.33	0.18	0.05	5.69	0.58	5.11	16.04
Cultivated slate and shale		4.8	8.50	3.09	2.10	0.66	0.29	0.04	3.61	0.30	3.31	36.35
Limestone		5.6	12.19	1.30	0.707	0.212	0.141	0.239	3.41	0.33	3.08	12.19
"		4.4	15.20	5.28	3.79	1.12	0.24	0.13	4.41	0.17	4.24	34.74
Sandstone Quat. red earth		4.5	8.50	1.08	0.51	0.15	0.22	0.20	4.52	0.22	4.30	12.71
Cultivated quat. red earth		5.1	14.25	0.83	0.32	0.14	0.21	0.16	4.83	0.81	4.02	5.76
"		4.7	9.5	1.50	1.20	0.16	0.10	0.04	4.68	0.25	4.43	15.79

3. 矿物组成 红壤的矿物组成，一般以硅、铁、铝或硅、铝、钾为主。土壤发生层(B层)与母岩或母质比较，明显的表现为脱硅、富铁、铝现象(表5-8)。

Table 5-15. Nutrient status of red soils from different parent materials

Subgroup	Hor.	Org.Mat. (%)	Total (%)			Available (ppm)			pH (H_2O)
			N	P_2O_5	K_2O	N	P	K	
Quat. red earth	A	0.77	0.052	0.094	1.055	26	9.3	23	5.0
	B	0.61	0.040	0.091	0.947	—	—	—	5.0
	C	0.51	0.034	0.098	1.405	—	—	—	5.0
Cultivated Quat. red earth	A	1.74	0.085	0.130	0.410	51	4.0	80	6.6
	B	0.60	0.037	0.117	0.544	—	—	—	5.0
	C	0.45	0.026	0.111	0.612	—	—	—	4.7
Granite	A	1.98	0.079	0.041	3.11	51.1	0.7	100	5.1
	B	0.73	0.038	0.054	2.02	—	—	—	5.0
	C	0.72	0.023	0.043	3.36	—	—	—	5.1
Slate/shale	A	1.16	0.09	0.08	2.81	76	0.5	50	4.5
	B	0.92	0.03	0.08	2.70	—	—	—	—
	C	1.11	0.07	0.09	2.78	—	—	—	—
Sandstone	A	1.45	0.09	0.07	1.66	97	0.5	39	4.5
	B	0.76	0.05	0.08	1.50	—	—	—	4.7
	C	1.09	0.05	0.08	1.65	—	—	—	4.8
Timestone	A	1.72	0.072	0.068	1.57	62.5	1.8	84	4.8
	AB	1.48	0.076	0.059	1.48	—	—	—	4.9
	B	0.79	0.065	0.081	0.28	—	—	—	5.1
Cultivated limestone	A	1.29	0.12	0.19	2.6	85	4.1	55	6.1
	B	0.65	0.10	0.14	3.0	—	—	—	6.0
	C	0.44	0.06	0.13	2.4	—	—	—	6.0

红壤中的有效微量元素含量，根据540个样品的化验结果，按土属平均，有如下特点：一是铜、铁、锰、钼的平均含量都超过临界值，第四纪红土红壤、花岗岩红壤锌、硼的平均含量都在缺乏范围之内；二是耕作土壤的有效微量元素含量普遍高于自然土壤（表5-16）。

Table 5-16. Available micronutrient of red soils

Family 属	No. of sample	Ca (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	B (ppm)	Mo (ppm)
Quat. red earth	24	0.48	0.29	20.9	32.0	0.164	0.173
Cultivated quat. red earth	120	0.88	1.12	25.6	31.83	0.290	0.20
Granite	13	0.24	0.29	12.2	9.0	0.196	0.163
Cultivated granite	68	0.81	0.85	25.7	19.31	0.240	0.133
Slate and shale	33	0.46	0.61	27.7	25.7	0.268	0.140
Sandstone	31	0.45	0.64	30.7	20.0	0.28	0.128
Cultivated sandstone	106	0.71	0.86	23.2	27.5	0.268	0.197
Limestone	13	0.59	0.50	15.7	49.83	0.280	0.310
Cultivated limestone	132	0.94	0.85	16.4	42.1	0.271	0.325

二、棕红壤的主要特征特性

(一)剖面形态特征

棕红壤一般土层深厚，红色风化层可达一米至数米，土体构型多为A—B—C型。表土层厚20～30cm，暗棕至红棕色，粒状结构，较松，硬度<1kg/cm³，根系中到少；心土层厚30～60cm，红棕色，块状结构，较紧实，硬度1～2kg/cm³，根系少，有少量铁锰斑纹及斑块；底土层厚50～100cm以上，核块状及块状结构，硬度>2kg/cm³，网纹层或其他母质层有铁锰胶膜或半风化岩片。土壤质地因发育的母质不同差异较大，为粘土至砂壤，全剖面呈酸性反应，pH值4.8～5.8。

现以汨罗县桃林乡新和四队第四纪红土发育的土壤剖面为例(表5-31)。

Table 5-31. Profile property of brownish red soils

Hor.	Depth	Colour	Texture	Structure	Compactness (kg/cm³)	Porosity	Roots	New growth
A	0～30	7.5YR5/6	Light clay	gran.blocky	0.64	many	few	not clear
AB	30～55	7.5YR5/6		blocky	1.56	moderate	few	few Fe-Mn stain
C	55～100	7.5YR5/8		nutty blocky	2.00	few	no	Fe-Mn film in mottles

(二)理化性质

1. 机械组成 由于棕红壤发育的母质不同，土体中的粘粒含量差异较大，根据分析资料，<0.002 mm的粘粒含量以第四纪红土母质发育的为最高，一般都在45%以上；砂岩、板、页岩风化物发育的次之，一般为30～35%；花岗岩风化物发育的粘粒含量最少，一般小于30%。棕红壤的B层一般都有粘粒的淋淀现象，特别是砂性母质发育的土壤，更为明显。如花岗岩风化物发育的棕红壤，其Bt/A值可达1.36；砂岩，板、页岩风化物次之，一般在1.05～1.25之间；第四纪红土母质发育的土壤则无一定规律，一般Bt/A值都大于1(表5-32)。

Table 5-32. Mechanical composition of Brownish red soils and the clay ratio of Bt/A and Bt/C

Parent material	Hor.	Depth (cm)	2～0.2mm (%)	0.2～0.02mm (%)	0.02～0.002mm (%)	<0.002 mm (%)	Bt/A和 Bt/C值
Quaternary red earth	A	0～28	1.25	10.71	42.29	45.75	
	B	28～68	0.73	9.49	43.55	46.23	1.01
	C	68～110	0.73	9.01	40.34	49.92	0.93
Quaternary red earth	A	0～12	1.45	17.43	40.75	40.37	
	B	12～41	1.64	12.89	40.75	44.90	1.11
	C	41～110	2.50	15.27	40.38	41.85	1.07
Sandstone	A	0～20	10.28	27.15	34.37	28.20	
	B	20～45	5.68	18.92	40.13	35.27	1.25
	BC	45～75	6.28	20.15	40.91	32.26	1.09
	C	75～90	5.88	24.46	31.95	37.71	0.93
Granite	A	0～40	26.14	22.72	24.34	26.80	
	B	40～83	25.16	15.79	22.64	36.41	1.36
	C	83～150	46.05	21.75	14.45	17.75	2.05
Slate and shale	A	0～23	3.81	17.83	39.10	39.26	
	B	23～44	3.83	15.51	39.71	40.95	1.04
	BC	44～130	4.05	14.28	42.87	38.80	1.06
	C	130～160	16.00	16.36	44.51	23.13	1.77

Table 9-1. Mechanical composition of soils derived from different parent materials

Parent materials	Soil type No. of sample	样本数 (n)	各粒径(mm)含量.%($\bar{X}$) 1~0.25	0.25~0.05	0.05~0.01	0.01~0.005	0.005~0.001	<0.001	物理性粘粒含量% ($\bar{X}$)
Granite	红壤、黄壤、暗黄棕壤	574	31.51	20.54	14.90	6.91	10.12	16.10	33.13
Sand/gravel	红壤、黄壤、暗黄棕壤	609	13.32	22.96	20.79	10.31	14.43	18.16	42.90
Plate/shale	红壤、黄壤、暗黄棕壤	1092	11.54	19.59	19.83	12.38	17.89	18.77	49.04
Purple sand/shale	紫色土	425	9.79	28.79	21.68	9.38	13.09	17.18	39.66
Limestones	红壤、黄壤、石灰土	750	6.67	19.73	21.96	12.26	16.85	22.33	51.44
Quat. red soil	红壤	293	5.77	15.38	22.34	13.71	17.32	25.37	56.41
Fluvial	潮土	169	8.33	27.08	26.46	10.77	12.28	15.08	38.13
加权平均		371.2	12.06	21.33	20.63	10.36	15.48	12.29	

类之间也有明显差异，如红壤各亚类的物理性粘粒含量顺序是：红壤(22.10%)>黄红壤(19.00%)>红壤性土(15.50%)。半淋溶土纲的红色石灰土和初育土纲的黑色石灰土粘粒的含量，红色石灰土(22.85%)>黑色石灰土(18.50%)。同样初育土纲的紫色土类中酸性、中性、石灰性紫色土亚类，其差异亦粗略可见。综上所述，就我省土壤的机械组成总的状况而言，土壤发育程度愈强，土壤中的<0.001mm和<0.01mm颗粒的含量有愈高的趋势(表9-2)。

Table 9-2. Particle sizes of natural and cultivated soils

土类	亚类	非耕地(A) No. of sample	sand	silt	clay	耕地(B) 样本数	沙粒	粉粒	粘粒	A-B 沙粒	粉粒	粒粒
Red soil	红壤	262	31.44	45.34	23.22	386	29.97	51.11	19.19	1.74	-5.77	4.03
	黄红壤	159	36.08	46.06	17.87	141	31.16	52.23	16.64	4.92	-6.17	1.23
	红壤性土	53	38.92	45.38	15.70	21	38.57	46.39	15.04	0.35	-1.01	0.66
Yellow earth	黄壤	171	37.68	45.75	16.57	85	31.86	52.98	15.17	5.82	-7.23	1.40
Red limestone soil	红色石灰土	44	29.97	47.18	22.85	37	26.66	52.24	21.10	3.31	-5.06	1.75
	淋溶红色石灰土	18	35.57	43.52	20.91	16	28.66	50.49	20.85	6.91	-6.97	0.06
Black limestone	黑色石灰土	44	29.41	52.09	18.50	33	25.58	56.47	17.94	3.83	-4.38	0.56
Purple soil	酸性紫色土	57	39.12	41.17	19.71	64	40.85	44.43	14.73	-1.73	-3.26	4.98
	中性紫色土	17	35.88	44.56	19.64	24	40.07	46.16	13.77	-4.19	-1.60	5.87
	石灰性紫色土	23	33.29	48.19	18.53	29	36.56	46.21	17.23	-3.27	1.98	1.30
Humid alluvial	潮土	12	17.73	66.18	16.09	91	39.98	46.92	13.10	-22.25	19.26	2.99

我省山地土壤机械组成在不同海拔高度的变化，受到坡积和土壤发育的双重影响。土壤A层>0.25mm的沙粒，有随海拔的降低而增加的趋势。如湘西北花岗岩风化物发育的土壤，从海拔1590m到海拔1300m、870m和460m，>0.25mm的颗粒分别为17.1%、18.1%、

Table 10-19. Composition of humus of soils in mountainous areas

Location	土 壤	层次	parent rocks	Total C (%)	Total N (%)	C/N	占全C(%)		胡敏酸/富里酸 (HA/FA)	无密度 (E_4)
							胡敏酸 (HA)	富里酸 (FA)		
Mufu Mt	mountain meadow	A_1	花岗岩	5.65	0.381	14.83	15.22	34.87	0.44	2.21
	dark yellowish brown	A		7.55	0.419	18.02	20.13	20.53	0.98	1.95
	yellow earth	A		3.81	0.223	17.08	11.81	34.65	0.51	0.80
	red earth	A		1.53	0.119	12.86	7.19	26.80	0.27	0.53
Hengshan Mt	mountain meadow	As	花岗岩	7.80	0.554	14.08	26.79	24.10	1.11	1.72
	dark yellowish brown	A_1		7.91	0.500	15.80	16.06	27.43	0.58	1.18
	yellow earth	A_1		3.49	0.251	13.90	10.89	34.67	0.31	0.64
	red earth	A		1.47	0.167	8.80	6.80	43.53	0.16	0.59
Bamian Mt	mountain meadow	A_1	花岗岩	6.16	0.370	16.65	15.10	28.90	0.52	1.68
	dark yellowish brown	A_1		5.67	0.350	16.20	10.76	32.80	0.33	1.26
	yellow earth	A_1		4.71	0.266	17.71	11.46	22.08	0.52	0.78
	red earth	A_1		2.76	0.166	16.63	10.14	32.97	0.31	1.81
莽山(宜章)	暗黄棕壤	A_1	花岗岩	10.70	0.618	17.31	15.42	34.58	0.45	0.67
	黄壤	A_1		7.19	0.352	20.43	13.07	24.76	0.53	0.98
	红壤	A_1		4.29	0.294	14.59	11.42	34.27	0.33	0.89
都庞岭(道县)	暗黄棕壤	A_1	板页岩	10.23	0.511	18.57	11.44	21.90	0.52	1.21
	黄壤	A_1		5.37	0.282	19.04	11.73	35.00	0.34	1.24
	红壤	A_1		3.34	0.285	11.72	8.08	35.03	0.23	0.93
羊峰山(永顺)	暗黄棕壤	A_1	白云岩	3.66	0.296	12.36	8.74	23.22	0.38	0.72
	黄壤	A_1		2.57	0.229	11.22	7.78	19.46	0.40	0.73
	黄红壤	A_1		1.37	0.135	10.15	8.76	24.08	0.36	0.65
顶平山(石门)	meadow dark yellow brown 生草暗黄棕壤	A_1	灰岩	5.44	0.492	11.06	13.60	30.88	0.44	1.15
	暗黄棕壤	A		1.89	0.187	10.11	8.47	36.51	0.23	1.40
	黄壤	A		1.30	0.134	9.70	10.00	35.38	0.28	1.32
	黄红壤	A		0.80	0.105	7.62	2.50	27.50	0.09	0.67

土壤有机质含量既受自然环境因素的影响，又受人为因素特别是不同利用方式的影响。根据全省第二次土壤普查农化样有机质测定结果，按不同利用方式进行分级统计结果表明(表10-20)：水田土壤平均有机质含量最高，有机质含量>3%的水田占水稻土总面积57.32%，小于2%的仅占10.22%。而旱土有机质平均含量明显低于水田，有机质平均含量>3%的只有15.68%，而<2%的却有51.44%。山地土壤在有良好植被下有机质含量

带土壤的测定结果表明，有机质含量与海拔高度有明显的正相关，相关系数多在0.927～0.978之间。以衡山为例，海拔在600m以下，在温暖、湿润的亚热带季风的影响下，土壤以红壤化过程为主，多发育成红壤，有机质积累较少。在海拔600～1200m之间的黄壤与暗黄棕壤，在温凉湿润的生物气候条件下，有机质积累明显。在海拔1200m以上的山顶，气候冷湿，风大，树木难以生长，为茂密的灌丛草甸覆盖，腐殖化过程比较明显，土壤以山地草甸土为主，有机质有大量积累。从胡敏酸的光密度曲线(图10-2)看出，冷湿气候条件不但有利胡敏酸的形成和积累，也有利于胡敏酸分子进一步缩合。

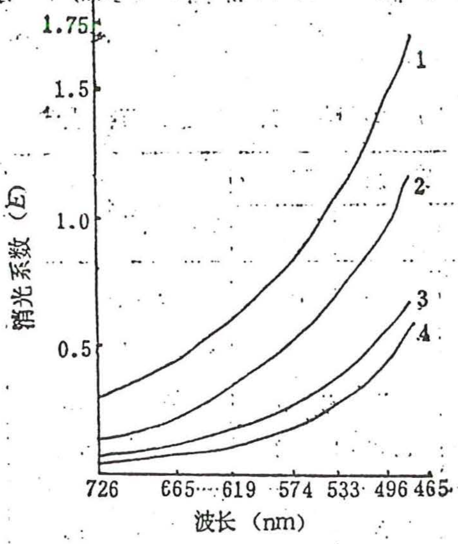

图10-2 不同土壤的光密度曲线

取样地点：衡山

1. 山地草甸土 2. 黄棕壤 3. 黄壤 4. 红壤

永顺县羊峰山土壤有机质含量随土壤垂直分布高度而变化，棕色石灰土、黑色石灰土、黄色石灰土、红色石灰土的有机质含量，随海拔高度的下降逐渐减少。腐殖中胡敏酸含量、胡敏酸和富里酸的比值均明显降低(表10-21)。

表10-21 土壤腐殖质组成与不同海拔高度的关系

地点	Soil	Hor.	a.s.l. (m)	parent material	C (%)	N (%)	C/N	% of Total C		HA/FA	E_4
								胡敏酸 (HA)	富里酸 (FA)		
羊峰山	brown limest.	A	1429	weathering products of dolomite	4.59	0.360	12.75	10.12	19.17	0.84	1.32
	black limest.	A_1	789		4.64	0.392	11.84	15.95	15.09	1.06	1.56
	yellow limest.	A_1	718		2.43	0.204	11.91	6.58	13.58	0.49	1.32
	red limestone	A_1	315		1.34	0.115	11.65	7.46	13.43	0.56	2.22

(三)不同母质对土壤有机质的影响

同一土类，因母岩母质不同，土壤有机质含量也有明显的差异(表10-22)。

从表10-22可以看出，在红壤亚类中，以板、页岩、砂岩风化物发育的红壤有机质平均含量最高，石灰岩风化物发育的红壤次之，第四纪红土红壤含量最低。在黄红壤亚类中，同样以板、页岩、砂岩风化物发育的黄红壤含量最高。这与在板、页岩、砂岩地区植被覆盖率

积占10%，碱性土壤占8%左右。

不同利用方式的旱土和山地土壤，其酸碱度级别及比例与上述趋势大致相同。但微酸性至中性的水稻土占水稻土总面积的65%，碱性水稻土占22.4%左右。

二、各类土壤的酸碱性状况

(一)主要自然土壤的酸度状况

1. 红壤、黄壤的酸度：我省红壤、黄壤全剖面一般呈微酸性至强酸性反应。

(1)红壤、黄壤的酸度由表10-27可知，我省红壤的pH值一般在4.5～6.0之间，由于母质、地形及植被等因素的影响有一定的差异。

Table 10-27. pH values of Red soils

土壤 \ 母质	Quaternary red earth	Weathering products of granite	Weathering products of sandstone	Weathering products of slate & shale	Weathering products of limestone
Typic red soils	4.5～5.5	4.5～5.5	4.5～5.5	4.5～6.0	4.8～6.0
Yellowish red soils	4.5～5.5	4.5～6.0	4.5～6.0	4.5～6.0	5.0～6.0
Young red soils	4.2～5.0	4.5～5.5	4.5～5.5	4.5～4.8	—

在红壤亚类中，板、页岩红壤和石灰岩红壤的酸性稍弱，这可能是由于板、页岩红壤的植被覆盖较好，有机残落物较多，土壤的淋溶作用较弱而减缓土壤酸性发展的缘故。石灰岩红壤的pH较高，主要与母岩母质中含有较多的碳酸盐类有关。

黄壤的富铝化作用虽较红壤弱，但自然植被比红壤好。在终年湿润的气候条件下，土壤水分不断下渗，土壤淋溶作用较强，导致盐基大量流失，使土壤呈微酸至强酸性反应。pH值为4.5～6.0，大多在5.0左右，与同一地带母质的红壤相近。黄壤性土则由于所处地形陡峻，植被稀疏，水土流失严重，目前多为疏林荒山，故其酸性较黄壤略强。我省各类黄壤的pH值见表10-28：

Table 10-28. pH values of Yellow soils

土壤 \ 母质	Weathering products of granite	Weathering products of slate & shale	Weathering products of sandstone	Weathering products of limestone
Typic yellow soil	5.0～5.5	5.0～5.8	4.5～5.5	5.0～6.0
Young yellow soil	4.5～5.5	4.5～6.0	4.5～5.5	5.5

(2)红壤、黄壤的交换性酸度。据第二次土壤普查测定，红壤的交换性酸低的只有0.08me/100g土，高的可达7.81me/100g土，大多集中在2.5～6.5me/100g土之间。由表10-29可知，在红壤各亚类中以红壤性土的交换性酸量最高，红壤次之，黄红壤较低。其中又以第四纪红土及砂岩风化物发育的红壤交换性酸量最高，以石灰岩风化物发育的红壤最低，与相应土壤的pH值大体一致。

黄壤交换性酸的情况大致与红壤相似，低的只有0.87me/100g土，高的可达10.9me/100g土，一般多在3～6me/100g土之间。在黄壤亚类中，一般也是黄壤性土的交换性酸度略高于黄壤，不同母质之间也以砂岩黄壤的交换性酸量最高，石灰岩黄壤最低（表10-29）。

表10-29 红、黄壤的交换性酸量(me/100g土)

母质 \ 土壤	红壤		黄红壤		红壤性土		黄壤		黄壤性土	
	$\bar{X}$	变幅	$\bar{X}$	变幅	$\bar{X}$	变幅	$\bar{X}$	变幅	$\bar{X}$	变幅
第四纪红土	5.78	4.83～6.73	—	—	6.11	4.56～8.15	—	—	—	—
花岗岩风化物	5.06	3.68～6.31	4.31	2.60～5.75	—	—	2.43	1.27～4.09	4.50	3.13～5.85
板、页岩风化物	4.47	1.3～7.3	4.39	2.7～5.19	5.31	5.26～5.66	3.74	2.11～4.94	6.21	4.39～8.03
砂岩风化物	5.37	4.53～6.21	7.32	6.97～7.67	5.7	—	7.25	5.0～10.9	—	—
石灰岩风化物	3.35	2.73～4.41	1.16	0.08～2.23	—	—	0.87	—	—	—
样品数	1119		516		157		386		32	

(3)红、黄壤酸度的剖面分布。各类红、黄壤典型剖面酸度的分布情况列表10-30、10-31。由表可见，红、黄壤全剖面均呈酸性反应，且在剖面的不同层次之间pH值的差异很小。交换性氢的相对含量大多以表土较高，随剖面深度的增加而逐渐降低，交换性铝的相对含量则相反。

(4)红、黄壤酸度的主要来源。由表10-30和表10-31可知，红壤、黄壤的酸度主要是由交换性铝引起的。红壤典型剖面表土交换性Al^{3+}的含量变化于0.26～7.57me/100g土之间，大多在4～6.7me/100g土的范围内，而交换性H^+的含量，除少数有机质含量较高的土壤和第四纪红土红壤交换性H^+的含量较高外，一般均在0.35me/100g土以下，低的可小到0.04me/100g土。可见，交换性Al^{3+}是红壤酸度变化的主要来源，一般占土壤交换性酸的90%以上，高的可达98%。同时，随着土层的加深，交换性Al^{3+}在交换性酸中所占的比例也随之增加，一般C层比A层平均增加5.03%(n=10)，高的可达18.5%。在红壤各亚类中，以红壤性土表层交换性Al^{3+}占交换性酸的比例最高，黄红壤中除石灰岩黄红壤外，其余均略高于红壤。

黄壤表土的交换性Al^{3+}含量变化于0.69～7.6me/100g土之间，大多集中于2.5～5.0me/100g土的范围内，交换性H^+的含量多在0.3me/100g土以下，交换性Al^{3+}在交换性酸中所占的比例一般也在90%以上，高的可达97%，在底层占的比例更高。平均C层比A层

Table 10-30. Acidity of Red soils

Soil Type (family)	采样地点	采样深度 (cm)	pH (H_2O)	pH (KCl)	交换性酸 (me/100g土)	交换性H^+ (me/100g土)	交换性Al^{3+} (me/100g土)	交换性Al^{3+}/交换性酸 (%)
on quaternary red earth	邵阳市	0～8	4.5	3.8	6.729	0.859	5.870	87.23
		8～50	4.4	3.5	9.749	0.877	8.872	91.00
		50～100	4.7	3.8	9.816	0.870	8.940	91.13
on granite	资兴	2～24	4.82	3.72	6.31	0.15	6.16	97.62
		24～100	5.00	3.84	4.69	0.07	4.62	98.51
		100～150	5.12	3.93	6.14	0.04	6.10	99.35

（续）

土 壤 类 型	采样地点	采样深度 (cm)	pH (H_2O)	pH (KCl)	交换性酸 (me/100g土)	交换性H^+ (me/100g土)	交换性Al^{3+} (me/100g土)	交换性Al^{3+}/交换性酸 (%)
on sandstone	双峰	0～28	4.50	3.70	4.53	0.22	4.31	94.92
		28～83	4.72	3.69	4.03	0.15	3.88	96.28
		83～150	4.84	3.69	4.68	0.18	4.50	96.15
on plate/shale	会同	0～13	4.70	3.45	5.69	0.58	5.11	89.81
		13～105	4.95	3.43	5.49	0.35	5.14	98.62
		105～150	5.12	3.84	3.38	0.12	3.26	96.45
on limestone	新化	0～9	4.92	3.92	4.41	0.17	4.24	96.15
		9～26	4.80	3.78	5.06	0.16	4.90	96.84
		26～66	4.85	3.80	5.89	0.16	5.73	97.28
		66～150	5.10	3.82	6.00	0.17	5.83	97.17
Yellowish red soils on granite	资兴	0～46	4.89	3.96	4.57	0.08	4.49	98.25
		46～104	4.91	4.06	3.67	0.13	3.54	96.46
		104～160	5.01	3.98	3.20	0.07	3.13	97.81
Yellow red earth on sandstone	双牌	0～6	6.62	5.88	0.04	0.04	0	0
		6～52	4.66	4.00	6.97	0.24	6.73	97.56
		52～106	4.65	4.12	5.66	0.11	5.55	98.00
		106～150	4.75	4.18	4.90	0.15	4.75	96.94
Yellow red earth on plate/shale	会同	2～2.5	4.64	3.64	4.25	1.05	3.20	75.29
		2.5～57	4.50	3.47	5.19	0.31	4.88	94.03
		57～117	4.59	3.35	3.76	0.31	3.45	91.76
		117～150	4.87	3.55	3.10	0.19	2.91	93.87
Yellow red earth on limestone	新化	0～15	5.18	4.78	0.08	0.05	0.03	37.50
		15～29	5.60	4.25	0.53	0.07	0.46	86.79
		29～100	5.10	4.20	0.79	0.08	0.71	89.87
Young red soils on quaternary red earth	长沙	0～38	4.48	3.59	7.81	0.24	7.57	96.93
		38以下	4.87	3.62	7.68	0.09	7.57	98.83
Young red soils on plate/shale	会同	2～3	4.70	4.07	2.12	0.32	1.80	84.91
		3～16	4.60	3.69	5.31	0.31	5.20	97.93
		16～35	4.72	3.63	3.15	0.20	2.90	93.66

中性紫色土除母岩母质为中性外，碳酸盐母质发育的土壤受到水的淋洗作用，碳酸钙不断淋失，但淋失的程度不及酸性紫色土强，全土层也无石灰反应，pH在6.5～7.5之间，据典型剖面土壤测定，中性紫沙土表土层的交换性酸很低，仅0.237me/100g土。

石灰性紫色土母岩母质本身含碳酸盐多，所受的淋溶程度也轻，在土体中有不同数量的游离碳酸钙残留，故全土层有弱至强的石灰反应，土壤pH在7.5～8.0之间，呈微碱性至碱性反应，土壤的交换性酸很低，据典型剖面土壤分析，表层土壤仅0.14me/100g土（表10-35和表10-36）。

Table 10-35. pH values of purple soils

Soil subgroup	Acidic purple soil		Neutral purple soil		Calcium purple soil	
Family	Typic	Sandy	Typic	Sandy	Typic	Sandy
	4.6～6.0	4.4～6.0	6.5～7.5	6.5～7.0	7.5～8.0	7.5～8.0

Table 10-36. Vertical distribution of soil acidity for purple soils

Soils	Loc.	Depth (cm)	pH (H_2O)	pH (KCl)	Exch. Acidity (me/100g土)	Exch. H^+ (me/100g土)	Exch. Al^{3+} (me/100g土)	Exch. Al^{3+}/exch. acidity (%)
Typic acidic purple soil	Hengyang	0～12	4.6	3.90	6.04	0.06	5.98	99.00
		12～60	4.8	3.95	6.88	0.07	6.81	99.00
Sandy acidic purple soil	Hengyang	0～14	4.9	3.7	7.54	0.20	7.34	97.35
		14～51	4.4	3.7	7.13	0.15	6.98	97.90
		51～80	4.5	3.7	8.12	0.17	7.95	97.91
Sandy neutral purple soil	Shaoyang	0～16	6.5	5.4	0.24			
		16～60	6.6	5.5	0.84			
		60～100	6.7	5.8	3.46			

（二）主要旱土的酸度状况

旱土由于耕作、灌溉及施肥等农业技术措施的作用，使土壤在酸度方面发生了较显著的变化。凡精耕细作熟化度高的土壤，其酸碱度趋于微酸性至中性反应。如若开垦利用不当，灌溉施肥不合理，也可使土壤向更酸的方向发展，但一般自然土壤垦殖为耕作土壤后，酸性大多得到一定程度的改善。

由表10-37、10-38、10-39可见，由各种母质发育的旱土，其pH值普遍较同母质自然土壤略高，一般约提高0.5左右。

其次，各类耕作旱土的交换性酸量较同母质自然土壤也有较显著的降低，例如耕型第四纪红土红壤的交换性酸平均为4.02me/100g土，耕垦前为8.77me/100g土，相差一倍以上。又如耕型酸性紫色土的交换性酸变化于0.06～4.75me/100g土之间，比酸性紫色土也低得多。

从耕型旱土剖面的酸度状况还可看出，除发育于石灰性母质旱土的pH值有随土层深度

离子交换容量最低，变化于7.0～17.3me/100g土之间，平均为11.31me/100g土。

黄壤阳离子交换量较相同母质红壤稍高，据测定，黄壤的阳离子交换量变化于7.3～32.8me/100g土之间，平均为15.48me/100g土。其中以板、页岩黄壤最高，其次为砂岩和石灰岩黄壤、花岗岩黄壤较低。暗黄棕壤土壤的阳离子交换量又高于相同母质的黄壤，在暗黄棕壤中以砂岩暗黄棕壤阳离子交换量最高，生草暗黄棕壤较低。

山地草甸土由于受冷湿气候条件的影响，土壤累积了大量的有机质，阳离子交换量较高，一般在20me/100g土以上，高的可达50me/100g土左右(表10-45)。

Table 10-45. CEC of toplayers of red soils, yellow soils and yellowish brown soils

Parent material	项 目	Quat. red earth	Products of granite	Slate and shale	Sandstone	Limestone
Red soils	1= Range of CEC	8.9～21.4 (18)	8.9～10.7 (34)	6.9～15.5	7.6～11.65 (6)	12.9～27.1 (26) ← Number of samples
	2= Average	13.86	11.56	11.62 (18)	8.74	15.69
	3= Org.Mat. (%)	1.63	2.41	2.55	2.57	2.04
Yellowish red soils	1	—	9.5～10.2 (46)	8.6～12.1 (15)	10～16.8 (15)	11.0～18.5 (20)
	2	—	12.8	11.3	13.64	13.63
	3	—	2.02	3.44	3.28	2.86
Young red soils	1	8.9～13.8	9.45～12.6	7.0～15.6	10.19～17.3	—
	2	10.84	10.88 (3)	10.92	12.92	—
	3	—	2.80	2.95	2.99	1.47
Yellow soils	1	—	7.3～19.6 (19)	11.2～32.8 (24)	9.2～19.3 (5)	9.4～22.8 (12)
	2	—	12.99	17.96	15.56	14.42
	3	—	3.77	3.59	3.64	2.75
Young yellow soils	1	—	6.65～15.55 (7)	15.25～19.48 (4)	-	7.3～12.7 (4)
	2	—	12.2	18.4	—	10.40
	3	—	—	—	—	—
Dark yellowish brown soils	1	—	9.8～17.43 (14)	15.9～26.03 (14)	13.49～29.99 (5)	12.96～19.14
	2	—	13.88	21.86	19.51	15.90
	3	—	6.34	5.65	5.28	—

注：括号中的数据为样品数。

2. 影响红壤、黄壤等土壤阳离子交换量的因素

（1）土壤的发育程度及土壤有机质含量，土壤的脱硅富铝化作用从红壤→黄壤→黄棕壤→山地草甸土逐渐减弱，土壤的发育程度逐渐降低，而有机质的含量逐渐增加。因此土壤的阳离子交换量逐渐增高。

（2）土壤游离氧化铁及铁的活化度。游离氧化铁含量及铁的活化度对红壤阳离子交换

平均为18.34me/100g土。石灰性紫沙土在11.50～21.0me/100g土之间，平均为15.29me/100g土。

(三)旱土的阳离子交换量

我省各类旱土阳离子交换量大小的变化趋势与其相应的自然土壤大体相同。自然土壤阳离子交换量高的，其旱土阳离子交换量也高，反之亦然。但由于旱土受到农业耕作施肥等措施的深刻影响，其阳离子交换量有时稍高或稍低于同母质相应的自然土壤(表10-47)。

Table 10-47. The CEC of cultivated limestone soil and purple soils (me/100g)

Soil type	Cultivated black limestone soil	Cultivated reddish limestone soil	Cultivated leached limestone soil	Cultiv. yellowish limestone soil	Cultivated acidic purple soils
Ranges average	18.6～39.2 26.85	16.8～19.9 17.97	15.1～19.0 18.55	13.6～17.3 15.45	15～24.17 19.59
	Cultivated acidic sandy purple soils	Cultiv. neutral purple soils	Cultiv. neutral sandy purple soils	Cultiv. calcium purple soils	Cultiv. calcium Sandy purple soils
	6.1～13.7 9.8	7.5～13.2 10.22	12.4～16.2 14.40	14.29～29.35 17.54	12.47～22.92 17.16

(四)水稻土的阳离子交换量

水稻土多数是由旱土淹水种稻以后发育而成。由于水耕、施肥的影响，水稻土的有机质含量一般常高于母土，质地也略为粘重，故其阳离子交换量亦常高于母土。据第二次土壤普查测定，酸性水稻土耕层的阳离子交换量变化于5.0～23.9me/100g土之间，平均约为14.12me/100g土。其中以石灰岩风化物发育的灰黄泥最高，砂岩风化物发育的浅黄沙泥和黄沙泥最低。中性和石灰性水稻土的阳离子交换量较高，变化于6.6～23.42me/100g土之间，其中尤以碱紫泥及浅碱紫泥最高，平均分别为18.68me/100g土和18.25me/100g土，其余平均在14.5me/100g土左右，就水稻土的亚类来说，潴育性水稻土阳离子交换量大多略高于同母质的淹育性水稻土(表10-48)。

从典型剖面的分析数据还可看出，由于施肥的影响，耕层有机质的含量较高，并随剖面深度的增加而逐渐降低，故各类水稻土的阳离子交换量均以耕层最高。

二、土壤的交换性盐基及其组成和盐基饱和度

(一)主要自然土壤的交换性盐基

不同类型的自然土壤在盐基离子的总量、组成和盐基饱和度上都存在有一定的差异，总的来看，红壤、黄壤的交换性盐基总量和盐基饱和度较低，石灰土和紫色土较高。

1. 红壤、黄壤及暗黄棕壤等的交换性盐基

(1)红壤、黄壤的交换性盐基状况。红壤因酸性淋溶作用强、盐基离子大量淋失，故盐基总量不高，盐基饱和度低。据第二次土壤普查测定，红壤亚类表土的盐基总量稍低于同母质的黄红壤，稍高于同母质的红壤性土，变化于0.7～6.4me/100g土之间，其中80％以上集中在3me/100g土以下，在红壤亚类中，以第四纪红土、石灰岩风化物等母质发育的红壤较高，盐基饱和度一般在30％以下，低的仅6％左右，只有石灰岩红壤和少数自然

Table 10-50. Exchangeable bases of Red soils, Yellow soils and Dark yellowish brown soils

项目 / Subgroup	Family	CEC (me/100g土)	BEC (me/100g土)	Exchangeable Ca^{2+} 含量 (me/100g土)	Exchangeable Ca^{2+} of BEC (%)	Exchangeable Mg^{2+} 含量 (me/100g土)	Exchangeable Mg^{2+} of BEC (%)	Exchangeable K^{+} 含量 (me/100g土)	Exchangeable K^{+} of BEC (%)	Exchangeable Na^{+} 含量 (me/100g土)	Exchangeable Na^{+} of BEC (%)	Base satur. (%)
Red soils on	Q. red earth	14.71	3.29	1.96	59.57	1.00	30.40	0.24	7.9	0.09	2.74	22.37
	Granite	10.25	2.00	0.78	39.00	0.62	31.60	0.36	18.00	0.24	12.00	19.51
	Slate and shale	9.11	1.44	0.73	50.69	0.29	20.14	0.20	13.89	0.22	15.28	15.81
	Sandstone	11.21	1.08	0.43	39.81	0.34	31.48	0.17	15.74	0.14	12.96	9.63
	Limestone	11.35	2.83	1.68	59.36	0.76	26.97	0.24	8.48	0.14	4.95	25.15
Yellowish red soils on	Granite	12.85	1.99	1.18	59.30	0.37	18.59	0.23	11.56	0.21	10.55	15.49
	Slate and shale	10.85	0.89	0.41	46.07	0.185	20.79	0.16	18.54	0.13	14.61	8.49
	Sandstone	12.56	1.755	0.77	43.87	0.51	29.06	0.17	9.69	0.29	16.52	13.97
	Limestone	11.50	15.67	12.57	80.22	2.86	18.25	0.19	1.21	0.05	0.32	99.18
Young red soils on	Q. red earth	10.77	1.015	0.56	55.17	0.08	7.88	0.19	18.72	0.195	19.21	9.42
	Sandstone	11.23	0.813	0	0	0.46	56.58	0.35	43.05	0.003	0.37	7.18
Yellow soils on	Granite	11.02	3.29	2.04	62.01	0.67	20.36	0.30	9.12	0.28	8.51	29.85
	Slate and shale	12.68	2.94	1.87	63.61	0.55	18.71	0.32	10.88	0.20	6.80	23.19
	Sandstone	17.70	2.61	1.18	45.34	0.79	30.27	0.42	16.09	0.22	8.43	14.74
	Limestone	10.40	6.91	4.49	64.99	1.73	25.04	0.34	4.92	0.35	5.07	66.44
Young yellow soils on	Slate and shale	17.05	1.16	0.48	41.38	0.38	32.76	0.20	17.24	0.10	8.62	6.8
	Granite	15.54	1.74	0.65	37.36	0.69	39.66	0.32	18.39	0.08	4.60	11.20
Dark yellowish brown soils on	Granite	17.53	1.50	0.49	32.05	0.49	32.31	0.37	24.07	0.15	9.61	8.55
	Slate and shale	19.66	5.15	3.96	76.89	0.71	13.79	0.32	6.21	0.16	3.11	26.20
	Sandstone	23.46	7.41	4.28	57.76	1.74	24.09	0.78	10,57	0.56	7.53	31.59
Mountain meadow soils on	Sandstone	52.08	1.69	1.20	71.42	0	0	0.40	23.56	0.09	5.18	3.25
	Granite	52.08	2.96	1.45	48.99	0.32	10.81	0.49	16.55	0.70	23.65	5.68

沙土最低(表 10-51)。

Table 10-51. Exchangeable bases of limestone soils and purple soils

项目 / Subgroup	Family	CEC (me/100g土)	BEC (me/100g土)	Exch. Ca^{2+} 含量 (me/100g土)	Exch. Ca^{2+} (% of BEC)	Exch. Mg^{2+} 含量 (me/100g土)	Exch. Mg^{2+} (% of BEC)	Exch. K^+ 含量 (me/100g土)	Exch. K^+ (% of BEC)	Exch. Na^+ 含量 (me/100g土)	Exch. Na^+ (% of BEC)	Base satur. (%)
Reddish limestone soils	reddish limestone soils	14.26	8.57	4.81	56.13	2.43	28.35	1.13	13.19	0.20	2.33	60.10
	leached limestone soils	14.90	10.50	9.96	94.86	0	0	0.32	3.05	0.22	2.1	70.47
Yellowish limestone soils	yellowish limestone soils	12.60	10.80	8.43	78.06	1.73	16.02	0.26	2.41	0.38	3.52	85.71
Acidic purple soils	acidic purple	12.18	0.35	0	0	0	0	0.13	37.14	0.22	62.86	2.8
	acidic sandy purple	10.42	2.84	1.93	67.96	0.43	15.14	0.31	10.92	0.17	5.99	27.26
Neutral purple soils	sandy neutral purple	12.48	7.25	5.65	77.94	1.41	19.45	0.102	1.41	0.087	1.2	58.05
Calcium purple soils	sandy calcium purple soils	12.80	12.49	11.48	91.91	0.82	6.57	0.15	1.20	0.04	0.22	97.58

红色石灰土和黄色石灰土剖面的交换性盐基含量和盐基饱和度受母质影响较大，全剖面交换性盐基量和盐基饱和度都很高，一般表土因生物累积作用，交换性盐基含量和饱和度都比较高，至心土层稍为降低，达底土层后，因受母质碳酸盐的影响，土壤的交换性盐基含量和饱和度又升高，一般常高过表土层。紫色土中酸性紫色土和中性紫色土盐基含量的变化较小，但石灰性紫色土全剖面的交换性盐基含量和饱和度也很高，且随土层深度的增加而增加，至底土层盐基接近饱和状态(表 10-52)。

(二)主要旱土的交换性盐基

旱土的交换性盐基状况，除了受母土影响外，更主要是受耕作垦殖方式、施肥、灌溉排水以及耕作制度等农业技术措施的影响。在合理耕作栽培的基础上结合增施肥料，可以逐步提高土壤的交换性盐基含量和盐基饱和度，但如果垦殖不当或不施肥料，大水漫灌、串灌等，都可以使耕作土壤的交换性盐基总量和盐基饱和度低于自然土壤。从表 10-53 比较表 10-50、表 10-51 可以明显看出：

(1)各旱土盐基交换量和盐基饱和度大多较同母质发育的自然土壤显著提高，其中以红壤旱土增加的幅度最大。在耕型红壤中又以耕型砂岩红壤增加的幅度最大，交换性盐基量比砂岩红壤增加近 10 倍，盐基饱和度增加近 9 倍，耕型第四纪红土红壤增加的幅度最小，但交换性盐基增加 47.72%，盐基饱和度增加了 92.8%。这与红壤旱土的耕作熟化度高有关。黄壤旱土中，耕型板、页岩黄壤增加的幅度较大，交换性盐基和盐基饱和度增加近 3 倍，耕型砂岩黄壤的增加幅度较小，交换性盐基只增加 10%左右，盐基饱和度增加 38.74%。耕型紫色土中，耕型酸性紫沙土增加的幅度也很大，交换性盐基增加 4 倍多，盐基饱和度增加 3 倍左右。但耕型中性紫沙土增加的幅度较小，交换性盐基增加35.78%。在各类旱土中，耕型石灰土交换性盐基饱和度较同母质开垦前的土壤增加幅度最少，交换

类是降雨和径流时抵抗离散和侵蚀的土壤特性。二者兼顾，才能作出土壤抗蚀性的正确评价。

我省对土壤侵蚀的研究尚处在初期阶段，暂无法对影响土壤抗蚀性的若干物理力学特性作出定量评价。仅就影响抵抗离散作用的土壤机械组成作抗蚀性定性分析(表16-6)。

Table 16-6. Erosion resistance of soils with different mechanical composition

Soil type	Hor.	Mechanical composition (mm, %)						sand+silt/clay	Erosion resistance
		1~0.25	0.25~0.05	0.05~0.01	0.01~0.005	0.005~0.001	<0.001		
Red soils on									
q. red earth	A	5.00	16.56	20.17	12.45	15.79	29.43	1.21	high
granite	A	29.23	17.11	13.88	7.27	11.75	20.76	2.07	low
granite	A	36.77	15.80	17.11	7.15	8.64	14.53	3.31	very low
slate & shale	A	11.65	20.29	18.64	11.32	17.52	20.60	1.62	moderate high
sandstone	A	14.30	19.17	19.57	10.44	14.37	22.15	1.73	moderate high
limestone	A	5.84	21.81	18.75	11.19	15.89	26.52	1.35	high
Yellowish red soils on									
granite	A	31.39	21.03	16.02	5.77	9.60	16.19	2.87	low
slate & shale	A	12.26	21.63	19.23	11.61	17.67	17.60	1.83	moderate low
sandstone	A	14.33	23.32	20.47	10.21	15.22	16.45	2.15	low
limestone	A	6.48	19.14	23.00	11.29	17.04	23.05	1.49	high
Young red soils on									
granite	A	41.62	23.14	12.51	4.80	6.86	11.07	4.57	very low
slate & shale	A	15.42	21.33	18.97	10.75	18.12	15.41	1.98	moderate low
sandstone	A	17.95	21.02	22.51	10.51	13.32	14.69	2.57	low
q. red earth	A	6.42	6.17	24.86	13.08	22.36	27.12	1.02	high
Yellow soils on									
granite	A	31.52	22.57	15.99	6.38	9.09	13.55	3.24	very low
slate & shale	A	14.34	20.20	20.19	11.81	16.98	16.54	1.98	moderate low
sandstone	A	11.71	25.86	20.46	9.92	14.89	17.36	2.12	low
limestone	A	9.43	14.30	22.47	14.59	18.09	19.68	1.58	high
Young yellow soils on									
granite	A	44.86	20.28	11.42	6.38	7.90	9.16	4.86	very low
slate & shale	A	16.59	18.60	19.13	11.73	16.77	17.18	1.94	moderate low
sandstone	A	15.17	26.41	17.49	10.67	16.61	13.65	2.30	low
Dark yellowish brown soils on									
granite	A	33.99	22.93	15.66	6.31	10.35	12.76	3.32	very low
slate & shale	A	15.16	24.85	20.94	10.79	15.58	12.68	3.53	low
sandstone	A	17.20	25.28	18.99	9.95	13.28	15.30	2.49	low
limestone	A	7.63	16.11	27.80	12.23	18.03	18.2	1.76	moderate high
红色石灰土	A	6.65	23.32	18.64	12.02	16.52	22.85	1.54	强
淋溶石灰土	A	8.97	26.60	17.78	10.37	15.37	20.91	1.75	较弱
黑色石灰土	A	10.41	24.71	20.09	11.35	15.10	18.34	1.99	较弱
黄色石灰土	A	7.70	19.22	24.21	12.77	17.44	18.57	1.77	较强

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slate & shale	A	11.65	20.29	18.64	11.32	17.52	20.60	1.62	moderate high
sandstone	A	14.30	19.17	19.57	10.44	14.37	22.15	1.73	moderate high
limestone	A	5.84	21.81	18.75	11.19	15.89	26.52	1.35	high
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sandstone	A	15.17	26.41	17.49	10.67	16.61	13.65	2.30	low
Dark yellowish brown soils on									
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slate & shale	A	15.16	24.85	20.94	10.79	15.58	12.68	3.53	low
sandstone	A	17.20	25.28	18.99	9.95	13.28	15.30	2.49	low
limestone	A	7.63	16.11	27.80	12.23	18.03	18.2	1.76	moderate high
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黄色石灰土	A	7.70	19.22	24.21	12.77	17.44	18.57	1.77	较强