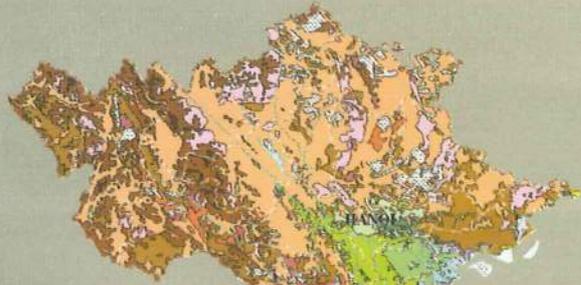
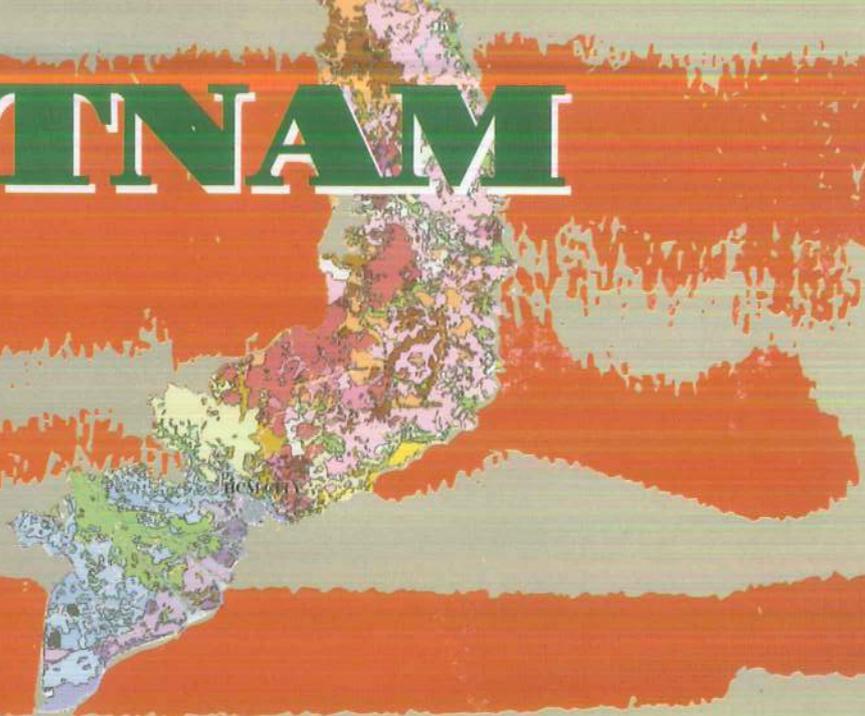


NATIONAL INSTITUTE FOR
SOILS AND FERTILIZERS

DEPARTMENT OF SCIENCE,
TECHNOLOGY AND PRODUCT QUALITY



THE BASIC INFORMATION OF
MAIN SOIL UNITS OF
VIETNAM



THEGIOI PUBLISHERS - HANOI, 2002

MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT

NATIONAL INSTITUTE FOR
SOILS AND FERTILIZERS

DEPARTMENT OF SCIENCE,
TECHNOLOGY AND PRODUCT QUALITY

VN 2002.02

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HA NOI, 2002

ISBN 26691 db

FORWARD

In the social development, people need more and more information. Recently, the requirement of information may be different, but in all aspects, including information on land resources.

In the World, especially in developed countries, establishment of soil and land database are concerned. The International Soil Reference and Information Center (ISRIC) was set up in Wageningen, The Netherlands. Of course, it is not established in each country, because of limitation of fund, equipments and high capacity staff and new technology.

In the international relation, the National Institute for Soils and Fertilizers (NISF) has opportunity to send his staff to be trained on establishment of soil database and information, especially the new technology on soil monolith processing. That so, with the investment of Vietnam Government, the first system of National Soil Reference and Information Center (NaSRIC) was established. The Department of Science, Technology and Product Quality (DSTPQ) and NISF publish the book "*The Basic Information of Main Soil Units of Vietnam*".

Thanks to the updating of research results of Vietnamese Scientists, this book provides information in quantity and distribution of soil resources as well as the basic pictures of soil quality. These data of soil analysis can be considered as the basic reference in research of soil fertility and soil environmental monitoring.

The authors tried to introduce to readers the pictures on landscape, soil profiles properties, farming systems to help readers in understanding the possibility of soil changing in land use processes.

For international and regional exchange, the authors tried to establish the reference of soil names by FAO-UNESCO soil classification and Soil Taxonomy of USDA. Of course, it needs further research for higher accuracy.

The book published right the time of government policy would like to change the economic development/production from low competitive quantity into high competitive quality. So, information in this book provide scientific basis for exploiting maximum advantages of land resources in the course of changing and limitation of soil/land for considering effective combination the context of soil-crop with agricultural market-crops. In the course of compiling the book, the authors have been accepted the recent relevant research results/publications, applying new soil analysis methods with sophisticated equipments for higher quality of research results.

The book is not only a scientific reference one, but also a contribution for application in land use planning, determination of relevant strategy, information exchange between national, international scientists, in education for students.

In spite of high endeavor of experiences scientists, there are maybe a lot of shortcomings, we would like to receive the valuable advises for higher quality.

Thanks.

Assoc. Prof. Dr. Nguyen Van Bo
Director, Department of Science, Technology and Product Quality
Ministry of Agriculture and Rural Development

INTRODUCTION

Soil/Land is the most important resource, is special material of production for human life. The resource is exploited in maximum level to serve the life of billion people in the world. Vietnam is high population country, but low in land area, especially cultivated land is extremely limited, the understanding of soil nature and changing in the course of exploitation for long time in appropriate land use, protection of soil and environment is necessary.

In many decades, the scientists of NISF have had more and more efforts in soil research and transfer technologies of farming for development in all units of soils in the whole country. One of his effective activities is establishment of Soil Reference and Information Center in Hanoi, that is a remarkably success of NISF scientists who have ideas since the years of 80s, but just implemented recently.

The database of the NaSRIC will be used as information exchange in soil quality in the whole country, as the basic for land use planning, change of farming systems, modernization in agricultural and rural development, contribution in education and scientific development regarding to soil/land resources.

In the years of 1983 and 1989, some staffs of NISF were sent to be trained in ISRIC, Netherlands, about new technology in collection, maintenance, display and protection of soil monoliths. The soil collection is applied the most advance international technology.

The book "*The Basic Information of Main Soil Units of Vietnam*" can be used as reference for scientists of soil and agricultural research, for teachers, students, extension workers, for policy makers regarding to agriculture and forest development.

Kindly introduce to readers.

Dr. Tran Khai
President, Vietnam Soil Science Society

Chapter 1

OVERVIEW ON NATURAL CONDITIONS, THE MAIN PROCESSES OF SOIL FORMATION AND SOIL CLASSIFICATION IN VIETNAM

1.1. Natural condition

Vietnam consists of main land, flood-plain bench and offshore bench in South-east Asia. Its main land area is 330,992 sq. km with the length about 2000 km, but narrow in wide. The widest part is in Northern part with about 600 km, and the narrowest one is about 50 km in the Central part. The area in East Sea is about 1 million sq. km. The length of seashore from Mong Cai to Ha Tien is about 3,650 km. Vietnam has many archipelagoes allocating in the gulf of North and the gulf of Thailand, among them there are a lot of big islands, e.g. Cai Bau, Cai Ban, Cat Ba, Bach Long Vi, Con Son, Phu Quoc, and two huge archipelagoes such as Hoang Sa and Truong Sa.

1.1.1. Topography and geology of Vietnam

Recent geography and geology of Vietnam were gone through many phases of complicated tectonics. It needs further research, but up to now, it can be divided into 3 stages, namely Pre-Cambri, Ancient Tectonics, Recent Tectonics. The stages of Ancient Tectonics and Recent Tectonics were happened in the edge platform of South China, the earthquake zone of China-India, and land block of Indoxini.

- *The stage of Pre-Cambri:* From the recent traces, we know that far away from 570 million years, the oldest tectonics in our territory was active block of metamorphic rocks - the nuclear of recent territory of Vietnam. It is the land block of Chay River, the range of Hoang Lien Son, the bow-shaped range of Ma River, land block Pu Hoat, the range of Pulaileng Rao Co and land block Kontum. Because the continuously shaking of the land block at the stage of Pre-Cambri in South-East Asia making land and rock to be disordered, to be penetrated by magma caused many times of metamorphoses, therefore at that time the territory of Vietnam consists of almost metamorphic rock, especially the genesis rock at the lower place also originated from sediment or magma, after that the metamorphic rock originated by sedimentary rock such as crystallized shale. The upper part is the weak metamorphic rock.

- *The stage of Ancient Tectonics:* This stage is far away from now about 65 million years with the different circles, such as the circle of Caledoni in Hecxini in the period of paleobiology, and the circles of Indonesi, Kimeni far away from now about 40 million years. The specific characteristic of this stage is many times of sea displacement, many times of subsidence, replacement.

- *The stage of New Tectonics:* This stage is very important one for the world as well as for Vietnam, because almost the characteristics of recent topography and geology in the world are formed in this stage. After 6 cycles of New Tectonics, the old Vietnam formed in the period of Old Tectonics - from the area of low plain, undulating, swampy valleys, become hilly mountainous country with the pick of 3,000 m above sea level (ASL) and distributed by climatic belt. Many strong faults formed different Rivers' valleys, deep abysses, caused the big changes in the net of hydrology and climate, soil cover and ecosystem.

Because of New Tectonics, the topography of our country is higher in the Northwest part directed toward the high plateau Tay Tang and the range of Himalayas, and depression toward Southeast, therefore the territory of Vietnam is descent the direction of North-West to South-East, and divided into 3 obvious part: the hilly mountainous zone, flat zone, and sea shore zone.

1.1.1.1. Topography and geology of hilly mountainous zones:

Topography of hilly mountainous zones of Vietnam is very complicated and its geography is diversified. It can be divided in 3 zones as follows:

a) Hilly and mountainous zone of North and Northeast:

This zone is included from the vault of Chay River to islands of Ha Long. Topography is rather low, about 1,000 m ASL, and lower to the east and south direction. The upper part of Chay River there is high mountain 2,000 m and the hills in the East and South is about 500 - 100 m ASL.

The direction of the hills and mountains is also complicated, the range of Voi mountain and hilly area along the depressed part of Cao Bang - Lang Son have Northwest - Southeast direction, meridian direction of the range along the Gam River, the Northeast direction of the range of Ngan Son, the direction of Northeast-Southwest of the range Bac Son. The direction of rocky mountains has big influence to the climatic condition in the region. There is Northeastern cold wind in winter, and in summer there is wind from the sea of Bac Bo gulf, therefore many parts in this region have dry and fresh wind.

The topography in the mountainous region of the North and Northeast is ugly and inaccessible terrain and deeply separated, with the highest about 2,000 m to the lower part of the valleys 200 m, making the lands with high slope. The terraces are developed in the mountainous areas in the North and Northeast of Vietnam.

The rocks in the mountains of the North and Northeast regions is formed from gneiss, mica schist, crystal shale, and in the center the block of magma granite is penetrated, recent limestone.

The hilly areas are allocated from West to East direction, including the picks are under 2,000 m; such as Phia Ya 1,977 m; Phia Oac 1,931 m; and the low hills are mostly in average of 500 m. The valleys are between the hills.

The hilly areas are formed from different rocks. In the Gam River area there are limestone, sandy rock, shale and granite, in the Hien River area there are shale in Ngan Son; shale, sandy rock and some thin layer of limestone in Yen Lac; in the Cau River area there are shale, sandy quartzite rock and the thin layer of limestone between the shale; in the Thuong River area - mainly marine alluvial including sandy rock, shale, mainland alluvial with coal, red sand.

Midland is situated between mountainous area and plain, including undulating hills with the flat valleys. It can be call as old peneplain. The relative high of the hills is about 50 - 60 m, and 80 - 100 m nearby the mountains, but at the edge with plain about 20 - 30 m only. There are different units of valleys.

Beside 3 above-mentioned regions, in the North and Northeast of the country there is a region of limestone with many curves.

b) Hilly mountains of Northwest region

In this region, range of mountains is lying in the Northwest - Southeast direction. It is the region with the higher mountains in Vietnam: Fansipan - 3,143 m; Ta Yang Pin - 3,096 m; Pu Luong - 2,983 m; Sa Phin - 2,897 m. The topography is very complicated, along the length of 180 km there is one mountainous pass less than 1,000 m. There are peneplains at the different altitudes from 1,300 to 2,200 m. There are also large valleys, such as Than Uyen, Quang Huy, Nghia Lo. From Van Yen, the range Hoang Lien Son is gradually lower to the direction of Da River. In contrast, to the direction of Red River there are many hills with the altitude lower than 500 m. The range Hoang Lien Son is formed mainly from old crystallized rock or magma, granite, hyalite, porphyrites.

Between the shale rock mountains there are limestone plateaus from the north of Phong Tho to south Moc Chau with the width about 25 - 40 km, at the altitude of 1,000 m and 300 km long. There are 3 plateaus in Lai Chau province: Ma Lu Thang in the north of Nam Na valley, Sin Ho plateau (1,600 - 1,700 m altitude) is situated between Nam Na and Da watershed, the plateau Tua Chua (1,585 m) in the south of Da watershed. There are 2 plateaus in Son La province: Na San (600 m), Moc Chau (1,000 m) with the Yen Chau valley in between.

After the limestone range there are regions of large, low, and complicated mountains with many faults with the most important one is the fault of Lai Chau - Dien Bien along the direction of minidian affected by geological structure of the west of peninsulas of China-India, Laos and Thailand. In the West of the fault, sandy sediments cover it therefore the topography is rather flat. The watersheds of Ma and Ca Rivers are situated in the east of the fault.

c) The region of mountainous range Truong Son

This range is along the seashore from the west of the north to the south of Central part. Based on the process of its formation and structure, the range Truong Son can be divided into 3 parts: the west of northern central part - Hai Van, Hai Van-east of southern part, and the most of southern central part.

- The west of Northern central - Hai Van part (the Northern Truong Son)

It is the narrowest width of Vietnam with many northwestern to southeastern parallel mountains formed by granite combining with sediment and hyalite, limestone. At the same time there are western-eastern mountains and limestone Ke Bang-Khe Ngang with the famous curve Phong Nha. The mountainous part of Deo Ngang-Hai Van with the altitude of 1,800 m with many passes relevant to the fault of volcanic basalt (in Quang Tri Province).

- Hai Van - Southeastern part (the Southern Truong Son)

It is large mountains - plateau with different shapes. The hilly part in the North of Bung River in Quang Nam, Da Nang Provinces is lying in the parallel of altitude. In the central there are high mountains (the pick Ngoc Linh - 2,598 m ASL) with mainly granite rock. In the south, the topography is lower gradually, mostly hills and plateaus, typically the high plateaus Kon Tum-Pleyku and Dak Lak with basalt rock in the altitude of 700 - 800 m, and the famous Krong Ana River and the Lak lake.

- *The mountainous part of Southern Central part*

There are many high mountains, such as Chu Mu - 2,020 m ASL, Chu Yang Sin - 2,405 m, mostly sandy rocks, and high basaltic plateaus Di Linh, Bao Loc, Mo Nong.

1.1.1.2. *Topography and geography of plain regions*

There are a lot of river's deltas from the North to the South. Its characteristics depend on its formative conditions. The followings are the flat lands in Vietnam:

- *The Red River Delta:* It is the one of two biggest deltas in Vietnam. Based on the data from the map at scale 1/250,000 of National Institute for Soils and Fertilizers, data from the General Department of Cadastral, the General Department of Statistic in 1997 in the wider concept, the area of Red River Delta is about 1,900 sq. km, and 1,500 sq. km by administrative border. Its topography is higher in the northwest and north, and gradually lower in the south and southeast. The plain is mostly flat, less slope, and the altitude is not more than 100 m. It can be divided as follows:

+ *The hilly-mountainous of the edge of plain:* There are two terraces of old alluvial soil in the northwest edge. The first terrace is flat and continuously land 10 - 12 m ASL, the second terrace is lying in 30 - 35 m ASL and separated by small hills. In the southwest edge, there are terraces of old alluvial soil 25 - 40 m ASL. There are also many mountains at the edge of plain in Quang Ninh, Hai Phong, Hai Duong, Hoa Binh, Ha Tay, Ninh Binh.

+ *The central part:* It is the alluvial soils from the Red River and the Thai Binh River, 2 - 4 m ASL with the different topography: the dry farming of cropping systems in the higher place, 2 - 3 rice crops in the lower place.

+ *The eastern part nearby the sea:* It is the youngest place in terms of geology and topography, including the recent delta, 0 - 2 m ASL, affected by the tide. It is cumulated by clay and sandy sediment of flooding water, half decomposition of mangrove vegetation in the swampy areas with the flat topography.

- *The plain at the seashore of northern central region:* It is formed by the sediment of Ma, Ca, Ngan Sau Rivers. At the area nearby the foothills, the alluvial soil with thin layers scattered with the hills and sand dunes with the high 4 - 10 m. There are also deepwater areas.

- *The plain at the seashore of central region:* It is formed by sedimentation of the Gianh, Thach Han, Phu Bon, Tra Bong, Tra Khuc, Ha Giao, Ba Rivers, separated by many ranges of mountains along the west-east direction. The topography is divided as follows: sand and sandune at the edge of sea water, planted with Casuarinas; after that the sedimentation with fertile soils, and at the estuary is the swampy areas of mangrove, and nearby the foothills there are many hillock with old alluvial soils.

- *The plain of East-southern region:* It is included the plain of old alluvial more than 100 m ASL in the provinces Dong Nai, Binh Duong, Tay Ninh. It is a large plain that is not flooded in the rainy season. There are some mountains in the plains.

- *The Mekong River Delta*: It is the young plain with the development in the estuaries of the Rivers Dong Nai, Vam Co, Tien, Hau, and the headland Ca Mau (60 - 80 m/year). It is about 2 m ASL. The area is about 4,000 sq. km. It can be divided into the following regions: The most deep water region in Long Xuyen, Cao Lanh to border with Cambodia; The deep water region includes Sa Dec, Vinh Long, Can Tho, Northern Soc Trang and western My Tho; The higher region includes Tan An, My Tho, Go Cong, Ben Tre, Tra Vinh, Soc Trang. Apart that, in the Northeast part there is deepwater area of acid sulphate soils in Dong Thap Muoi. In the past, Dong Thap Muoi was an area plenty of rushes, weeds, but now become important rice growing one.

1.1.1.3. Topography and geology of the coastal areas

The topography and geology of our country is affected by the courses of sedimentation of the Rivers, the tidal waves, sea currents and the participation of biological bodies, as well as the influence of coastal mountains.

The coastal areas in Quang Ninh and Rach Gia-Ha Tien are similar with many limestone islands. The coastal areas of Red and Thai Binh Rivers are rather flat, muddy, plain, and sand dunes. In the coastal area of northern central part of the country, the sedimentation of the sea is very important from Deo Ngang to Vung Tau. The range of Truong Son mountain is formed by granite and hyalite rocks, the sedimentation of the valleys is very slow. The area from Vung Tau to Rach Gia is a large deepwater delta with mangroves.

1.1.2. Climate and vegetation

Together with the other natural conditions, the climate plays an important role in the formation of vegetation, hydrological systems and weathered cover, among them there is close relation between climate and vegetation.

Through the length from 8° 30' to 23° 22' North, Vietnam has different amplitude of temperature between the North and the South (Hochiminh city: 136,4 Kcal/sq.cm/year; Hanoi: 111 Kcal/sq.cm/year) and the different time of sunshine.

Vietnam has 2 monsoon regimes: the northeast monsoon (from November to April) and the southwest monsoon (from May to October). The high pressure mainland air from Sibir bring to Vietnam the northeast cold and dry monsoon in the North and the north of Central part, and the Southeast hot dry wind in the central, southern central part and the South. The Southeast monsoon is from Bengal gulf or from the South of hemisphere after stopping the northeast monsoon. Therefore, in summer, there is the gust of wind from the sea, big rains and typhoons - the causes of serious erosion and landslide.

Based on the temperature regimes and relation between temperature and humidity, it is divided the different climate regimes with correlative primitive forests. For example, the dry equatorial unit of grasses and shrubs savanna (Ninh Thuan, Binh Thuan, Khanh Hoa, etc.), the thin forest (in Binh Dinh, Phu Yen, east of southern part), the ever green forest in the tropical humid areas (in plain of the North, Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Quang Tri, Thua Thien-Hue), and evergreen forest in sub-tropical in the mountainous areas, high humidity, there are mosses in the pick of mountains.

The climate of Vietnam is tropical, monsoon and humidity, with abnormal temperature and humidity regimes, and diversity in climatic zones. Therefore, the natural vegetation and crops are changed by climate. Vegetation cover is diversified and it is divided into 14 groups. On the high mountains under the forest the soils contains high organic matter content. On the 700 - 1,000 m ASL there are no bamboos, jack fruit trees; and more than 2,000 m – the sub-tropical pines.

Based on the natural characteristics and the habit of farming, mainly topography, climate, and vegetation, it is divided into 9 ecological zones in the whole country (National Institute of Agricultural Planning and Projection, 1995):

- The Northwest zone
- The Northern zone
- The Northeast zone
- The Red River Delta
- The North of Central
- The Coastal area of Southern Central zone
- The High Plateau Tay Nguyen
- The East of the South
- The West of the South (Mekong Delta)

1.1.3. Hydrology

Vietnam has a dense River net, about 2,360 Rivers, but mostly small Rivers (92.5%). Many rivers are originated from the high mountains. There are rivers that originated in the country, and the Rivers originated from other countries. It is divided in 9 big River systems forming plains with different alluvial soils that are very important in the agricultural production of our country.

1.1.3.1. The system of Bang Giang - Ky Cung Rivers

The system is originated from Na Vai mountain along the direction Northwest-Southeast, via Cao Bang town, Thang Khau to China. The River has 108 km long with the watershed of 4,560 sq.km, high sedimentation; the average of suspended content is 244 g/cub.m. The system of Ky Cung River is originated from the mountain Ba Xa, along the direction of Southeast-Northwest, via Lang Son town to That Khe and to China. The River has 243 km long, with the watershed area of 6,660 sq. km; suspended content in the water averages 686 g/cub.m.

1.1.3.2. The system of Thai Binh River

The system of this River is originated from 3 Rivers: Cau River is originated from Cho Don-Bac Kan; Thuong River is originated from the Lang Son town; Luc Nam River is started from Dinh Lap and integrate in Pha Lai become Thai Binh River. After that the Thai Binh River receives the water from Duong and Luoc Rivers. Therefore, the lower part of Thai Binh River becomes one part of Red River delta. If taking in account of area in Pha Lai, the area of River of Thai Binh delta is about 12,680 sq.km, and suspended content averages 118 g/cub.m.

1.1.3.3. The system of Red River:

The Red River is started from the mountain Yiang Giang (China) along the Northwest-Southeast direction via the border to Lao Cai, Yen Bai, Phu Tho, Vinh Phuc and Hanoi to Bac Bo gulf at the estuary Ba Lat (Nam Dinh). It has total of 1,126 km long, with 556 km in the territory of Vietnam and the basin area of 70,700 sq.km (occupy 45.6% total area of the River's basin). There are 2 important rivers flowing to Red River, namely Da and Lo Rivers. The Da River has 1,010 km long, and 570 km in Vietnam with basin area of 26,800 sq.km (30.7% total of delta area). The Lo River has 470 km long, and 275 km in Vietnam with basin area of 22,600 sq.km (57.9% of the total).

The water of Red River has suspended content of 1,010 g/cub.m calculating the sediment of 120 million tons per year. Especially the suspended content in the stream part is higher than that in the downstream one, for example in Lao Cai has the suspended content of 2,730 g/cub.m, in Son Tay is 1,010 g/cub.m, and it is higher in rainy season than in the dry season. The alluvial soil in Red River Delta is very fertile.

1.1.3.4. The system of Ma River

The Ma River is originated from 2 sites: from mountainous part of Lai Chau, and from Bac Pu Tam Sao, flow along the northwest-southeast direction via Hua Phan (Laos), Thanh Hoa and finally flow to 3 estuaries: Cua Len, Lach Truong, Lach Trao. The length of the main River is 512 km, (the middle part is 102 km in the Lao area). The total area of the basin is 28,400 sq.km. The alluvial soil of Ma River is rather fertile. The suspended content in Cam Thuy is 402 g/cub.m calculating the sediment of 4.35 million tons per year. The Chu River (one branch of Ma River) has lower discharge and suspended content.

1.1.3.5. The system of Ca River (Lam River)

The Ca River is originated from two parts: one from the mountainous range of Pu Loi of Nam Non, one from plateau Tran Ninh of Nam Mo. The length of River from Nam Non is 531 km, and calculating from Nam Mo is 432 km, and the area of basin is 27,200 sq.km, among them in Vietnam - 17,750 sq.km, occupy 65% of total basin area. The River flows the Northwest - Southeast direction via Cua Rao, Do Luong and Vinh city to Cua Hoi estuary. The sediment content is not high, about 206 g/cub.m in Yen Thuong, calculating 3.5 million tons per year.

1.1.3.6. The system of Thu Bon River

The Thu Bon River is originated from north of Ngoc Linh on the altitude 1,600 m, flowing along south-north direction, and after that the West - East to An Hoa gulf (Quang Nam). The length of the River is about 205 km, and basin area is 10,350 sq.km. The sediment of Thu Bon River is not high and the average of suspended content is 120 g/cub.m.

1.1.3.7. The system of Ba River (Da Rang River)

The Da Rang River is started from Cong Ca Rin mountain (1,761 m). At the head, it flows by Southern-Northern direction, after that to Northwest-Southeast direction, and to Cung Son the flowing changes Western-Eastern direction, and flows to estuary Da Diet in Tuy Hoa (Phu Yen province). The River has 388 m long; its basin area is 13,900 sq. km. The suspended content of the River in Cung Son is 227 g/cub.m.

1.1.3.8. The system of Dong Nai - Vam Co Rivers

This is the third big River system in Vietnam in comparison to Mekong and Red Rivers. The main flow of the Dong Nai River is 635 km with the total area of the basin of 44,100 sq.km. It is originated from south of High Plateau Tay Nguyen flowing via East of the Southern and West of Southern regions, through Cambodian part of 15% of the total area of the basin. The suspended content in the water is about 200 g/cub.m, calculating as 3.36 million tons sediment per year.

1.1.3.9. The system of Mekong River

Mekong River has 4,350 km long, starting from the plateau Tay Tang at the altitude 5,000 m, mostly flow by North - South direction, via 6 countries (China, Myanmar, Laos, Thailand, Cambodia and Vietnam), and flows to Eastern Sea by 9 estuaries. It is the biggest River system in Indochina. Its total basin area is 795,000 sq.km, but there is only 5% of the area in Vietnam territory (40,000 sq.km). In spite of the suspended content in water is not so high, but there is big amount of sediment, because of big discharge.

Based on the conditions of geography, topography affected by climate, hydrology, biology and human, the soils in Vietnam is formed as different soils units with different natural and effective fertility.

1.2. The main soil forming processes in Vietnam

Because of integrated affect of conditions as parent rocks, topography, vegetation, temperature, humidity systems and human that formed different soil units. The followings are some main processes of soil formation:

1.2.1. The process of weathering

The weathering process is the change of physical and chemical states of parental rocks and its mineralogy under the affect of the conditions (temperature, water, microbiology etc) on the surface of the globe.

Based on the characteristics of the affecting elements, it can be divided as physical (mechanical) weathering, chemical weathering and biological weathering.

1.2.1.1. Physical weathering

It is the process that the parental rocks mechanically break down and no change in its chemical composition. The reason is the change of temperature, the change of pressure, the freeze of water in the slits of the rock, the crystallization of chemical salt, etc. In the physical weathering, no change in chemical composition, but the rock has new characteristic of water and air infiltration creating the favorable condition for chemical weathering more strictly.

1.2.1.2. Chemical weathering

It is the process to destroy rock and minerals affected by chemically impact of water and water solution, making up new minerals and new compound. The important elements of this process are water, CO₂ and O₂. The result of this process is the change of the physical status of the parent rock and mineralogical nets, creating the new minerals which has characteristics of stick, water holding, exchange capacity, and others.

1.2.1.3. Biological weathering

It is the physical and chemical changing of the minerals and rocks under the activities of microorganisms and their by-products. By this way, the fauna and vegetation contribute to destroy the rocks to be broken the rocks to pieces.

In general, in the tropical condition, the process of chemical weathering occurs very strong, but different parent rocks have different mineralogical and chemical compositions, so the intensity of weathering is not the same.

- The rocks have solid minerals, the weathering is very week, such as the granite has many quartz and other stable minerals making up the soils with thin horizon. Farming on this soil is not favorable.
- The rocks have easy weathering minerals and chemical compositions, forming thick soil layers, such as the soil derived on basaltic rock, shale etc. It is good soil for agricultural development.

In the tropical rainy condition, the alkaline elements in the soils are eroded, so the content of iron and aluminum relatively increased. Soil minerals are mainly kaolinite, so soil cation exchanged capacity (CEC) is very low.

1.2.2. The process of humus formation

This is the process of changing the biomass becoming humus in the soils thanks to the activities of microorganisms, fauna, oxygen and water. The role of humus in formation of soil and nutrient as soil fertility for crops is as follows: promoting the biological weathering, formation of soil profile, regulation of soil water temperature and air regimes, development of soil fertility (water and nutrient holding, increasing CEC, formation of soil structure etc), providing the nutrient for microorganism and crops.

Soil organic matter plays an important role in the soil forming process. Inappropriate farming leads to decrease the organic matter content in the soil. Soil degradation is firstly decreased organic matter content. It needs regularly add fertilizers into the soils (organic and inorganic fertilizers), growing green manure crops, and returning the by-product biomass to the soil, especially leguminous crops. One crop of peanut can return one amount of biomass of 2 - 3 tons, while cassava no more than 1 ton only.

At present, the cultivated sloping land has organic matter content about 1.5% to 2%, the basaltic soil can reach 3%, but it is not active, so the soil is poor in organic matter content. Shifting cultivation leads to decrease the organic matter in soils, so after several crops, the soil has to be fallow to restore the soil fertility by natural vegetative cover. The main purpose of the fallow is to restore the organic matter in soils, so we can use the improve fallow by fast growing leguminous crops/trees in the fallow time to have big amount of biomass in the short time of fallow.

1.2.3. Alluvial process forming the plain in the low land and valleys in the mountainous region

This process formed different soils having different mineralogical composition, physical, chemical and biological characteristics, because of sediment from River's water flowing through the different soils derived on different rocks. Depending on geology and topography, the alluvial soils nearby the sea is affected by the activities of rivers and seawater.

The biggest areas of alluvial soils are Red River delta and Mekong River delta. Alluvial soil of Red River has appropriate silt and clay contents making loamy soil. Many crops can be grown on this soil. In the higher place, the soil has light texture, in the lower place- heavy texture. Alluvial soil has high natural fertility, neutral reaction and high base saturation. The typical alluvial soil has high content of alkaline elements.

The alluvial soil in Mekong Delta is concentrated in the Tien and Hau Rivers. The soil has heavy texture, medium content of organic matter, total phosphorus, and high natural fertility, because of annual flooding with sediment. Because of activity of geology, regular flooding with sedimentation, influence of seawater; alluvial soil of the Mekong Delta has acid sulphate soil, saline soil, potential acid sulfate soil, called River-sea alluvial.

The characteristics of alluvial soils of other Rivers depend on the sediments of each River. The flat lands in the coastal areas in the central of Vietnam formed by sedimentation of the short Rivers.

Sedimentation process makes flat land in the valleys by the products of alluvium of streams. There are many flat lands in high plateau Tay Nguyen, such as Da Te, Easoup, Krong Ana, Ajunpa, DakBla. There are 4 big flat lands in the midland and mountainous areas of the North region, such as Dien Bien, Van Chan, Phu Yen, Than Uyen. These are important agricultural lands in the mountainous areas.

1.2.4. Gleyic process

This process occurs in the deep water or high soil water content (paddy rice, swampy soil, peat soil, etc...), where the water table is high.

The gley layer is in the depth of 0-50 cm, blue or blue-grey color. It is the color of Fe^{++} in combination with Silica and Aluminum, etc and many traces of iron rust along the root. These soils normally do not have structure. The crops can be affected by soil toxicities. This soil is situated in the depressed areas of Red River delta, north of central region, some in Tay Nguyen, coastal area of southern central area, and south region.

1.2.5. The process of salinization

The saline soils formed by soil emerging in the marine water, or from underground water, or saline content in the parental rock (the saline-alkaline soil in Ninh Thuan province, but a small area only, locally name is "Ca giang muoi", "Ca giang dau"). This soil can divide in following soil units: alkaline-saline soil, mangrove saline soil, strong saline soil, medium saline soil and weak saline soil.

The coastal saline soils in Vietnam are affected by NaCl. The total saline content is from 0.25% to 1%. It contains Cl^- , SO_4^{2-} , HCO_3^- , CO_3^{2-} , but the low content of HCO_3^- and CO_3^{2-} only in mangrove saline soil about 0.1 - 0.2%. The mangrove soil has neutral to alkaline react, high content of potassium and phosphorus. The medium and low saline soils contain medium organic matter, nitrogen, medium to poor phosphorus. Based on the research results of many authors, the indicators for evaluating saline levels are total soluble salt content, Cl^- , EC, no influence of SO_4^{2-} , and CO_3^{2-} . The strong saline soil has total soluble salt > 1%, Cl^- > 0.25% and EC > 10 dS/m (mmhos/cm).

In the condition of humid tropic, soils are formed with obvious dry and wet seasons. In the rainy season the salt in the surface is washed, in dry season the salt from underground water is taken up along the soil capillary to soil surface. In the coastal area, if no appropriate construction of preventing saline water, seawater intrudes along the rivers, especially in the tidal flow. In the rainy season, the overflow of sea water causes the soil becoming saline,

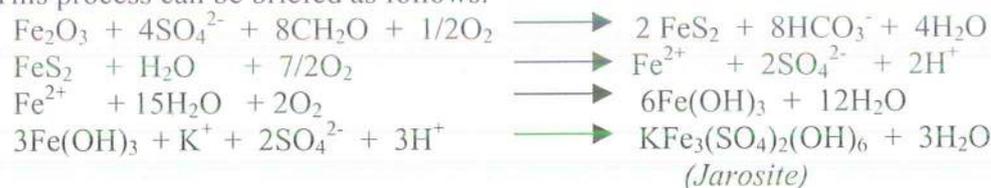
Management of water and hydrologic constructions to prevent the saline water intrusion and management of water at the fields play an important role in the control of saline content in the soils. The saline soil group is distributed along the seashore from the North to the South except the potential saline-acid sulphate soils in Provinces: Quang Ninh, Hai Phong, Thai Binh, Ba Ria-Vung Tau, Bac Lieu, Ca Mau.

1.2.6. The process of alumification

Acid sulphate soil is formed and developed in the swampy mangrove area, in the estuary of the rivers, because of alluvium and aluminum products (vegetative biomass contains sulfur: pyrites). The concentration of pyrites is limited by the effectiveness of organic matter, Sulfate, Fe and oxygen.

Swampy alluvium has high content of S and dead body of vegetation and fauna, especially vegetation of mangrove forest with *Rhizophora* and *Avicenia* botanical family in which high content of S. In the condition of oxygen lacking, S is changed from SO_4^{2-} to S^{2-} (pyrite - FeS_2). FeS_2 in the condition of oxidation will become sulfate Fe and acid sulfuric form the soil very acid. Sulfate Fe in the condition of oxydate become hydroxide Fe, after that forming *jarosite*.

This process can be briefed as follows:



This process has participation of deoxidation of bacteria of deoxidized sulphate, and *Thiobacillus Ferroxydans*. Because of alluvium over time the swampy potential saline acid soil under mangrove forest becomes higher and gradually less affect of tidal. The process of deoxidization in the soil becomes weaker, and process of oxydization will be stronger, the potential saline acid sulphate soil becomes actual acid sulphate soil.

Jarosite layer is the clayey layer which contains sulfur product or swampy organic matter, normally in the anaerobic condition the SO_3^{2-} is more than 1.7% (equivalent 0.75% sulfur), when oxidization lead to $\text{pH} = 3.5$. The difference of pH in jarosite layer in oxydization condition is about 2.5 units. Jarosite layer is B layer that occurs in the process of formation and development from the potential acid sulphate soils, mainly jarosite minerals in the units of spots or traces of yellow color (Munsell colour 2.5 Y), pH is below 3.5. The jarosite layer is indicator of the actual acid sulphate soil.

The actual acid sulphate soil has strong acid reaction (pH water is about 3 - 4), low saline content, mangrove forest is developed. The typical characteristic depends on total S content in the soil. When the SO_3^{2-} is 1.75%, strongly acid ($\text{pH}_{\text{H}_2\text{O}} = 2.91$), high content of Fe^{2+} and Fe^{3+} (236 - 379 mg/100g soil), and toxicity for crops. With the same content of total S, the active acid sulfate soil contains higher content of Al^{3+} in comparison with that in potential acid sulfate soil. Available Al^{3+} is element to form exchangeable acidity. When $\text{pH} > 5.5$, the Al content decrease suddenly (< 1 mg/100g soil).

The acid sulphate soil has high content of organic matter, and high content of total N, but low content of P. The actual acid sulphate soil contains about 0.02 - 0.04% of total P. The

total phosphorus contents in salt-affected acid sulphate soil and in potential acid sulphate soil are 0.04 - 0.05% and 0.08 - 0.12% respectively.

The acid sulphate soil concentrates in the Mekong Delta, and is remarkable acid sulphate soil in the World. There are here special acid sulphate soils with different characteristics in Dong Thap Muoi, Long Xuyen, Ca Mau.

1.2.7. Ferralitic process

In the tropical pedology there are two processes of accumulating Fe, Al:

- Relative accumulation of Fe, Al, or ferralitic process.
- Absolute accumulation of Fe, Al, or lateritic process.

1.2.7.1. The process of relative accumulation of Fe, Al:

This process is very complicated. First of all, the rock and minerals, especially strong weathering of silicate minerals become the secondary clay minerals as clay. One part of clay continues to be destroyed to become oxide Fe, Al, Si. At the same time, some base elements and SiO_2 are leached and lead to accumulation of $\text{Fe}(\text{OH})_3$, $\text{Al}(\text{OH})_3$. That is why, the proportion $\text{SiO}_2/\text{Al}_2\text{O}_3$, $\text{SiO}_2/\text{Fe}_2\text{O}_3$, $\text{SiO}_2/\text{R}_2\text{O}_3$ to evaluate the ferralitic process. This value the lower the stronger ferralitic process. This process formed the ferralitic soil.

According to V.M. Fritland (1964) there are following important characteristics:

- Very low content of primary minerals, except quartz and other stable minerals.
- High content of hydroxide Fe, Al, Mn, Ti. The rate $\text{SiO}_2/\text{R}_2\text{O}_3$ and $\text{SiO}_2/\text{Al}_2\text{O}_3$ in soil clay is, normally lower, or the rate of $\text{SiO}_2/\text{Al}_2\text{O}_3$ is equivalent to 2. In many cases, where available Al content is high, Kaolinite is predominant in soil clay and big amount of hydroxide Fe, Al, and Ti.
- The clay mineral has low CEC.
- Stable soil aggregate.
- In the content of humus, the acid fulvic is higher than acid humic, the index $\text{H/F} < 1$.

The influence of several surrounding condition to intensity of ferralitic process:

- The influence of absolute altitude above sea level to ferralitic process: Because the weather is changed by altitude, therefore the more higher elevation the typical ferralitic process the more weaker, and the process of soil formation is likely in the sub-tropical and temperate zones.
- The influence of parental rock and topography to ferralitic process: The ferralitic process is the leaching process of base elements and silica leading to accumulate Fe, Al. The favourable condition such as slope topography, easy drainage, will promote the process. In mountainous region where lower topography is, the base elements accumulate there to prevent the relative accumulation of Fe, Al.

In other hand, for consideration of this process, it is needed to consider the relative relation in quantity of base elements, silica with Fe, Al. So, there is big influence of its primary quantity in maternal rocks. It should be deal with the followings:

+ The rock with high Ca content (limestone):

- Slope topography, easy drainage, hard rock, strong ferralitic process
- Slope topography, easy drainage, good vegetative cover, the rock is easy to broke, high content of Ca, the soil is less acidic, the ferralitic process is week.

- Hollow topography, poor drainage, the soil is black color, Ca cumulate, the weak or no ferralitic process.
- + The rock with high content of silica, low Ca, Mg (sandy rock, magma rock, acidic rock):
 - Slope topography, easy drainage and strong ferralitic process.
 - Hollow topography, poor drainage and weak ferralitic process.
- + The rock rather low content of silica, rather high Ca, Mg, Fe, Al (base, split):
 - Slope topography, easy drainage, pumice stone, crushed, the poor ferralitic process.
 - Hollow topography, poor drainage, the poor or no ferralitic process.
- + The rock poor silica, poor Al, high Mg, Fe (Serpentine rock):
 - Slope topography, easy drainage, Fe accumulated in the soil.
 - Hollow topography, poor drainage, the black soil accumulate Mg, alkaline cation, poor or no ferralitic process.

1.2.7.2. *The process of absolute accumulation of Fe, Al or lateritic process:*

The Fe, Al are containing in the soils or moving from other place, cumulating in the soil and finally causing laterite formation.

a- Units of concretions:

Based on the shapes and the causes of formation, it can be divided to different forms: round, cylinder, pseudo ... and other forms.

b- Units of laterite:

Based on the shapes, it can be divided to bee-hive laterite, bean seed shape laterite, block laterite.

The composition of the laterite is different kind of oxide and hydroxide Fe. In the rainy season, because of high temperature, in the acidic condition, the Fe-contained elements are soluble in water in the form of bivalent oxide Fe and move with underground water and cumulate in hollow places. In the dry season, the underground water moves along the soil capillaries to near topsoil and become trivalent Fe and precipitated. The traces of oxide Fe have typical spotted yellow-red color in the degraded soil. The accumulation of oxide Fe becomes the thick layer of laterite.

In the soils, the laterite is soft, after moving to air condition the traces oxide Fe to oxidization, drying, becoming hard laterite. The kaolinite is eroded to form the holes, so it is called bee-hive laterite.

The bee-hive laterite: It can be observed at the low terrace between flat land and hilly land in the Provinces: Ha Tay, Bac Giang, Vinh Phuc... In the barren land there are many laterites because of strong evaporation of soil water. On mountainous region there is few laterite. In the high plateaus at the flat places the laterite can be found.

The bean seed shape laterite: It consists of many pieces adhering Fe, Mn, Al round shape like bean seed. This unit of laterite is formed at the limestone mountains or other rock containing lime. Fe is flows with water from the hills to the lower places in the neutral or alkaline conditions, it will be precipitated in round shape and formed laterite over time.

The unit of block laterite: It contains many Fe overlapping layers. This unit is not be researched in details.

In brief, in low hilly areas, and high plateaus the laterite can be found in the condition of obvious wet and dry seasons, and mainly formed at the foothills. Its composition is oxide Fe, silica, Al.

This soil unit has thin top soil layer because of strong erosion and leaching, poor nutrient content, P fixation, dry, poor activities of microorganism, poor crop growing. The influence of laterite to plant growth depends on the depth and thickness of laterite layer.

The control measure to limit the laterite formation is controlling the evaporation of soil water by vegetative cover in dry season. In fact, where the soil covered by forest, the few laterite to be found in comparison with that on barren land.

1.2.8. The process of cumulating oxide aluminum

This process can be found at the altitude from 1,700 - 1,800 m in Northern mountainous region, where high humidity and low soil erosion and leaching. The characteristic of this process is deep weathering and keeping the primary arrangement and structure of the rock, especially in the acidic rock.

This process mostly depends on weather and vegetative conditions. In the North of Vietnam, this process is controlled by altitude. Research results showed that kaolinite and gibbsite are two main clay minerals. It is typical process of cloudy forest. In the weathering cover of this process there are few amount of Fe because of big amount of rainfall (2,500-3,000 mm/year), low evaporation (300 - 500 mm/year), and high content of soil organic matter, so Fe is in the available status. According to V.M.Fritland, the weathering cover contains high content of free oxide Al occurred in the condition of frequent humidity, but the weathering cover contains high free oxide Fe in the condition of seasonal humidity.

1.2.9. The sialit process

This process occurs in the young soil region in the North at the delta, alluvial ground at the seashore. It consists mainly the sandy alluvium, after that parent rock, flooding sedimentation, in the shallow underground water (about 1 m).

Sialit weathering cover can be divided into 2 groups: saline group, and non-saline group.

1.2.9.1. The non saline sialit process

This process occurs in the alluvium of sediment from the Rivers. There are different characteristics of parent rocks forming many units of alluvial soils with different mineral, physical and chemical properties.

In the North, the big sedimentation area is Red River alluvial soil, having different texture depends on forming condition. In the higher places as the old seashore, the soil texture is light, and heavy texture in the lower places, high clay content. The typical alluvial soils have high contents of alkaline elements. In the old alluvial soil, the content of alkaline is lower because of erosion and leaching.

The changing of chemical mineralogy occurs in the sedimentation of the Northern plain with different forms and physical properties. This sediment layers have no red color because of becoming gley with grey color. In the swampy areas, this process changes very fast.

1.2.9.2. The saline sialit process

This process occurs at the coastal areas suffering directly seawater. Salt affected water contains 1 - 5 to 30 g salt per one litter of water. In the humid tropical condition in Northern Vietnam, the possibility of salt affected soil is in the condition of soil emerging in water.

1.2.10. The process of improving soil fertility and soil degradation

1.2.10.1. The process of soil improvement

Soil is alive substance and formed through many millenniums. In this long process the parent rock was weathered, the activities of composition and decomposition of microorganisms for accumulating humus and nutrient to change the rock to soil. In the process of its evolution gradually formed soil horizons with the physical, chemical and biological properties. The soil profiles reflect its historical formation. Thanks to harmonious components (solid, liquid, air substances), the soil fertility is formed for alive vegetation.

In the farming activities, the soil is happened by two processes: soil improving or soil degradation in terms of soil fertility, increasing or decreasing soil productivity in terms of land use. The soil improving process makes the inherent soil that is not suitable for crop growing to become fertile soil. The soil improvement is based on human activities making the inherent low soil fertility to become for high effective soil fertility. For example, the degraded soil in Vinh Phuc province, in spite of low natural soil fertility, low nutrient contents, but thanks to the reasonable investment in terms of labour and materials, so the harvest of crop yields and crop production is almost the same as that on fertile alluvial soil of Red River delta. The basaltic soil has high inherent soil fertility, but there are shortages of low effective content of phosphorus and potassium.

1.2.10.2. The process of soil degradation

Contrary to the soil improvement process is the soil degradation one. The elements of soil fertility are gradually exhausted for certain crops. It must be restored by natural fallow, and very difficult for soil reclamation, because of high investment and in the most cases, it is failed and soil becomes abandoned. On the red soil derived on limestone in Yen Bai after soil cleaning, the corn yield was 3 tons/ha, next year (1990) - 2,3 tons/ha, in 1991 - 1,4 ton only, and in 1993 no corn yield. In general, the over exploitation of soil is leading to quickly decreasing of crop yields. Right on the undulating fertile basaltic soil is also not excepting, the continuous cultivation of upland rice in the third year the crop yield decreased to one thirds only, and no yield in the fourth year. The farm's head play the key role in the controlling the effective soil fertility.

The upland and sloping land in Vietnam is about 24 million ha, including 6 groups, 13 soil units to distribute on 4 belts of altitude:

- From 25 - 50 m to 900 - 1,000 m: 16 million ha; occupies 51.14%;
- From 900 - 1,000 m to 1,800 - 2,000 m: 3.7 million ha; 11.8%;
- From 1,800 - 2,000 m to 2,800 m: 0.16 million ha; 0.47%;
- From 2,800 m to 3,143 m: 1,200 ha; 0.02%.

If the intensive flat land, the soil improving process is general decisive trend, then on sloping land the soil degradation is the main process, because of inappropriate farming for a long time. This degradation process is caused by human in deforestation for livelihood, lack of strategy of exploiting the natural soil resource with the point of view of soil conservation, protection of ecological environment for recent and next generations. The soil degradation is expressed by soil erosion, leaching, physical, chemical and biological degradation.

a- Erosion and leaching

Recent sloping land is distributed on the different slopes, of which serious degraded area is about 5.5 million ha, medium degraded soil is about 4.6 million ha. The research results showed that the soil erosion depends on many reasons: rainfall, rain intensity, slope, soil unit, vegetative cover, farming system, socio-economic condition, policy, national law, education, etc. Soil under forest has lowest amount of soil erosion (about 2 - 5 ton/ha/year), tea contour plantation: 3 - 4 ton/ha/year, soil under cassava and annual crops has amount of soil erosion about 40 - 100 ton/ha/year, depending on slope, soil unit and vegetative cover. The big amount of soil erosion suffers on barren soils (about 80 - 100 ton/ha/year).

The research results of measures for erosion control and soil conservation showed that:

- Biological measure play effective role for soil erosion, because vegetative soil cover, especially in the rainy season. A group of cropping systems by agroforestry creates good soil cover, soil erosion decreases remarkably.
- Hedgerow farming (alley cropping) can decrease the runoff and amount of soil erosion decreases 50 - 60% compared to control. Crop yield increases by 15 - 25%, in spite of the hedgerow occupies about 5 - 10% cultivated area.
- More effective soil erosion control when biological measures in combination with simple mechanical measures as contour hillside ditches, ridges, water ponds, etc.
- Apply organic in combination with mineral fertilizers and biomass returning to the soil for improving soil fertility to promote crop growing for good soil cover to decrease soil erosion.

Land slide, sedimentation, flash flooding are common phenomena in mountainous region.

With lizimeter measure can determine the nutrient contents in leaching water to the subsoil as N, P, K, Ca, Mg.

b- Physical degradation

In general, at the country and regional levels the physical degradation is not serious as water and wind erosion and chemical degradation, but in the agricultural production at the field it is obstructed in many cases, because of soil compaction, the seeds are not to be germinated. Overgrazing also caused by soil degradation that could not give the plants to develop. Physical degradation is resulted by erosion washing topsoil.

After soil cleaning, the monoculture of cassava and upland rice makes soil compact, low water infiltration. Right on the coffee plantation, the soil between the plant rows is more compact if the soil is not harrowed. If intercropping of leguminous cover crops, the soil has more organic matter content with light texture. The mountainous soils have thin layer or no layer of A₀ and A₁. The biomass is taken out.

In degraded soil the soil aggregate less than 0.25 mm is increased and aggregate valuable for crop growing decreased in comparison with forest soil. The small aggregate is washed out by water erosion, so when soil aggregate is destroyed, the content of soil organic matter and N are decreased.

After a cycle of shifting cultivation on basaltic soil, the soil aggregate valuable for agricultural production is decreased by 50% compared to the soil under forest. In the big aggregate of degraded basaltic soil is almost no content of Ca, Mg, and a big decrease of organic matter content. The aggregate is glued mostly by sesquioxide R₂O₃. The soil surface is crusted when drying. The small aggregate is eroded easier, so when the soil has no structure meaning low soil water and nutrient regimes. Laterization is common phenomena in degraded soils. It is occurred at middle and foothills. It is very serious when the vegetation and topsoil are taken out, the laterite is exposed on the soil surface, the soil will not be used for agricultural and forest production.

c- Soil water regime

In degraded soil the field capacity and effective water are decreased. Only 7 - 10 days after rain with rainfall of 100 mm, the soil water content in soil derived on shale in the layer of 0 - 15 cm decreased to wilting point. The research results showed that after land clearing for upland rice growing the soil become compact, low water infiltration, when the rain comes a big runoff, big erosion leading to fallow.

d- The depletion of soil organic matter

After land clearing for agricultural activities the soil organic matter is decreased quickly. Hass (1957) used CI (cultivation index) to express the speed of organic matter depletion from soil under forest to agricultural soil. CI is showed by % of soil organic matter content in cultivated soil compared to that of soil under forest. According to Nguyen Tu Siem (1990), in the upland soils of Vietnam, CI % is very low, about 16 - 18% only, when in India 30% and in America 40 - 75% (Jenny And Raychaudhuri, 1960). Investigation of 68 soil samples after 27 - 30 years, the soil organic matter content is decreased by 45 - 60%, even by 80%. From soil under forest to soil under coffee growing a big decrease of organic matter is occurred. If the organic matter content decreased 1%, the capacity of P fixation can be increased about 50 ppm P (Nguyen Tu Siem *et al.*, 1981).

e- Chemical degradation and acidification

Acid upland soil in Vietnam occupies about 70% total area, with pH_{KCl} in topsoil 4.0 - 4.5. Except the soil covered by secondary forest, soil under annual crops has low capacity in soil conservation. Almost all uplands are acidic, but in this case we would like to deal with the strong acid soils (pH : 3.5 - 4.0) and trend to be higher, in spite of high soil buffer.

The upland in Vietnam has limited factors. There are 86% areas of strong acid soils that are distributed on strong slope more than 25° . It is resulted by erosion and acidification making the strong soil degradation.

All barren lands on sloping land are acidic. If the desertification is expressed as the final stage of soil degradation making the soil can not be used for either agriculture and forestry, then the 0.5 million ha of skeletal soils are included.

In general, there are 20 - 30%, even 50% of rainfall becomes runoff and infiltration together with SiO_2 and other soluble elements (NH_4^+ , K^+ , Na^+ , Ca^{2+} , Mg^{2+}), resulting low base saturation, and high Al saturation in the content of exchange capacity. Almost acidic soils have Al saturation of 65-85% and concentration of available Al^{3+} is inverse proportion with pH_{KCl} ($r = -0.81^{**}$ with the pair Al^{3+}/pH , and $r = -0.63^{**}$ with the pair H^+/pH). Comparison of series of soil samples taken at the beginning of land clearing (1964-1970) with recent ones we can see that after about 35 - 40 years the soil organic matter is 40 - 60% compared to primary soil under forest, the index of pH_{KCl} decreased about 0.5 to 1 unit. It is resulted of strong decomposition of organic matter in the condition of low soil vegetative cover. The coefficient of humudification was decreased, only 3% per year, because the composition of humus is mainly acid fulvic, apocrenic, organic acid combined with Fe_2O_3 and Al_2O_3 having strong capacity of dissolving and breaking up minerals.

The results of investigation showed that acidification process occurred stronger in the soil growing annual crops than that of perennial crops, in the barren lands than in household garden, in monoculture than diversified farming.

Liming can partially decrease pH, decrease the toxicity of available Fe and Al, improve the status of nutrient of Ca and Mg and increase exchange capacity. But because of buffering capacity of soils, neutralization of acid soils at the field cannot be realized. On red basaltic soil, application of 3 tons lime/ha leads the pH increased a little and returned to the primary index after 2 - 3 months. Sometimes, high amount of liming can be harmful for the growing of crops.

It is emphasized that in our cropping systems, there are many acid tolerant crop varieties which can be grown on the acid soil as tea, coffee, litchi, longan, apricot, plumb, citrus, upland rice, cassava, etc. Some crops have requirement Ca as black pepper, sugarcane, leguminous crops, liming with low amount (300-500 kg/ha) is necessary to decrease the partial acid, Al and Fe toxicity, provide Ca, Mg, increase the activity of microorganisms.

In fact, liming on sloping lands is not realized, but thanks to intensive cultivation the crop yield is high and keep the fertility of soil. It is because of acid tolerant crops; in other hand, the base elements can be supplied by organic fertilizers, green manures, mineral fertilizers (fused calcium magnesium phosphate) and biomass. One of active measures for regulating soil acidity, increasing the component of base elements in the exchange capacity, is providing to farmers the low physiological alkaline or neutralize fertilizers, and decrease providing physiological acid fertilizers.

In brief, soil forming and improving is a long period, while the degradation is occurred very quickly, if mismanagement in land use process in the short time, the cultivated topsoil will be lost. The two processes (improvement and degradation) can affect to the change of soil fertility. It is emphasized that reclamation of soil fertility is not easy for the human activities.

1.3. Soil Genesis and Classification Research in Vietnam:

Soil Genesis and Classification Research in Vietnam have been carried out long time ago. Since 15th Century, some knowledge of agriculture science could be found in "Geography book" of Nguyen Trai. After that, a lot of Le Tac, Le Quy Don, Nguyen Nghiem, Van An... books concerned to climate, soils, water and crops have also been introduced. Knowledge of soils or agriculture activities related have had sum up as recommendations of soil reclamations. Based on soil genesis and land use characteristics, soil classification have been brought up such as *hill soils, alluvial soils, acid sulphate soils, saline soils, degraded soils, etc*; or based on soil colours such as *red soils, grey soils, etc*; or based on soil texture such as *clay soils, silt soils, young sandy soils, old sandy soils, etc*; or based on soil fertilities such as *first class field, second class field, etc*. That knowledge has been largely implemented in practices of agriculture activities.

The soil classification research in Vietnam should be divided into some stages as follows:

1.3.1. Period before 1954:

Before independent of the country, Vietnam was a backward agriculture production country. The scientific soil research was very rare. The French had carried out a few soil researches in exploitation for farm development in Indochina. There were some research results of Indochina Agriculture and Trade Department (1898), Saigon Agriculture Chemical Analysis and Technology Bureau (1898), Namky Agriculture Department (1899)... In 1886, Pavie and collaborators had carried out soil survey in Central part of Laos, Central and Southeast parts of Vietnam and his results were considered as an initial soil research of Vietnam and Indochina. After that, a lot of soil research results were published, such as *Compte rendu des travaux du laboratoire d'analyse de la Cochichine (1898-1901)* and *Remarques sur la composition physico-chimique des terres de rizieres de la Cochichine* - P. Morange, BEI. 1902; *Les sols en Agriculture* - J. Lan, IDEO. 1925; *Terres et culture de la Region de Thanhhoa* - F. Roule and Than Trong Khoi, BEI. 1923; *Etudes sur les terres et les eaux alunees* - R.F. Auriol and Lam Van Vang, BEI. 1934; *Terres rouges et terres noires basaltiques d'Indochine. Leur mise en valeur* - Y. Henry, IDEO. 1931 etc. Since 1930, E.M. Castagnol and collaborators had some more detail and regular researchs such as: *Relation du pouvoir de dispersion et de la capacité d'absorption des sols vis-a-vis de la composition du complexe colloidal* - IRAI. 1935 - 1936; *Etude des principaux units de laterites de l'Indochine*, 1940; *Influence des processus biologiques sur les proprietes physico-chimiques des sols tropicaux*, BEI. 1937; *Etude comperative des principaux units de sol en place du Nord de l'Indochine*, IRAI 1932 - 1933; *Etude des terres de schistes de Phuho*, BEI. 1932.

In the South Vietnam, some soil researches of B. Tkatchenko should be remarked such as: *Remarques sur le processus de laterisation en terre gris de Cochichine*, BEI. 1936; *Contribution a l'etude pedologique de quelque sols dacitiques du Haut-Donnai*, BEI. 1935; *Contribution a l'etude des taches steriles s'observant sur les plantations de cafeier dans la province du Haut-Donnai*, IDEO. 1940.

1.3.2. Period from 1955 to 1975:

Because of Vietnam was divided into 2 regions in this period (North and South) soil and soil classification research have been carried out in separate regions.

1.3.2.1. In the North of Vietnam:

After French war with Dienbienphu victory, Vietnam had gained independent in 1954. For reconstruction and development of the country, land use and exploitation problems have been raised urgently. At the time, Bureau of Soil Research of Agriculture Research Institute have been established and reached a lot of successes. In 1959, a group of soil survey,

classification and mapping of soil map at scale 1/1,000,000 under guidance of V.M. Fridland have completed a soil map of the North Vietnam at that scale with an explanatory note. The theory basics of soil classification is soil genesis doctrine, which considered soils as a product of integrated soil forming factors such as climate, parent materials, topography, fauna and human activities. Soil properties of soil genetic horizons of the profiles are characterized for each soil unit.

The first Vietnamese soil classification system is as follow:

- I. Lateritic red soils derived from basic and medium magmatic rocks.
- II. Lateritic red and yellow soils mainly derived from sediment and acid magmatic rocks.
- III. Lateritic brown soils mainly derived from old layers of Quaternary.
- IV. Lateritic soils are changed by rice cultivation.
- V. Lateritic soils derived from limestones weathered products.
- VI. Lateritic soils in mountains.
- VII. Lateritic soils with humus in mountains.
- VIII. Humic Lateritic soils in mountains.
- IX. Margalit soils.
- X. Endohumic soils formed by leaching with different lateritic levels.
- XI. Annual deposit riverside alluvial soils.
- XII. Mountain valleys and alluvial soils without annual deposit.
- XIII. Alluvial soils with strong gleyic stagnic phase in summer.
- XIV. Gleyic soils.
- XV. Saline soils.
- XVI. Mangrove saline soils.
- XVII. Acid sulphate soils.
- XVIII. Coastal marine sandy soils.

These classified units were grouped in 5 major soil groupings: Lateritic soils, Margalitic soils, Alluvial soils, Gleyic soils and Saline soils. It is initial basic and important soil and soil classification research in Vietnam.

This soil classification system has been improved and revised in 1964, increased 18 soil units to 28, changed term "Lateritic" to "Feralit", rejected parent materials in the soil names, changed "Humic Lateritic soils in mountains" to "Humic Alitic soils in mountains". These additions and revisions were not only pure in terms of soil nomenclature but also in improvements of soil research quality based on data of accurate soil analyzing in laboratories.

In classification system, lower soil unit levels were classified as soil sub-units and lower based on such factors as parent rocks, soil horizon thickness, concretions, mixed rock fragments, gleyic property, salinity, acidity, humus, particle size, etc... depended on soil map scales.

After that, a lot of soil survey for compiling soil maps at medium and large scales for provinces and districts, beginning in Hadong province. From 1961 to 1971, Bureau of Soil Survey (Department of Land Management) has established soil classification system serving compilation of soil maps at large scales in the North Vietnam. Integrating the results of soil map compilation of Northern Vietnam provinces, the authors of *Soil map of Midlands and Flat plains of the North Vietnam at scale 1/200,000* had proposed a soil classification system that is considered as basics for soil map legends (1965-1968). The authors tried to put in order systematically *major soil groups, soil units* with clear principles and hierarchy. In spite of some shortcomings, the soil classification research of this period has achieved important and basic results: to establish a soil classification system with *unit* and *subunit* hierarchy.

In 1972, the Editorial Board for Vietnamese Soil Map (Ministry of Agriculture) established that assembled lots of famous staff of soil science and soil classification researchers in Vietnam. In this period (1972-1975), a national soil classification system had been improved and completed that served as basics for small scale soil map and issued *Soil Map of the North of Vietnam at scale 1/500,000*.

1.3.2.2. In the South of Vietnam:

At that time, in the South of Vietnam, soil and soil classification researches have also been carried out. Some soil classification related results could be listed as follows: *Tropical acid sulphate soils* (F.R. Moorman, 1960); *Soils of Republic of Vietnam ...* (1961). According to this publication, proposed soil classification adopting USDA Soil Taxonomy had been introduced. In 1967, Truong Dinh Phu carried out researches on soil characteristics of Mekong Delta, after that Truong Dinh Phu and Chau Van Hanh compiled *Soil Map of Mekong Delta at scale 1/250,000*. In 1972, soil maps at scales 1/100,000 and 1/200,000 of Provinces have been printed by Saigon Geographic Department and attached explanatory notes by soil scientists of the South Vietnam have been issued (*Soil of the Mekong Delta, Soil of Highland and Southeast parts*). The applied soil classification system for soil map legends have usually been adopted USDA Soil Taxonomy.

In general, in this period, there were important and basic soil researches in both North and South parts of the country. However, different soil classification tendencies of the North and South regions caused a lot of difficulties to integrate soil maps of two regions of the country. This has only been completed after reunification of Vietnam (1975).

1.3.3. Period from 1976 to 1990:

Soil classification researches in the whole country have been concentrated and promoted under supervision of the Editorial Board for Vietnamese Soil Map and famous soil classification researchers from National Institute for Soils and Fertilizers, National Institute of Agricultural Planning and Projection, Universities and Colleges.

Remarkable research results related to soil classification were: Soil classification system and Legend of Soil Map of Vietnam at scale 1/1,000,000 (1976); Soil classification system and legend system applying for compilation soil maps of the whole country at scale 1/500,000 (1976); Soil classification system and legend system applying for compilation soil maps of the provinces at scale 1/100,000 (1976); Soil maps of Regions at scale 1/250,000 (Highland Plateau, Mekong River Delta...); Soil maps of provinces at scale 1/100,000 (Mountainous and hilly areas) or 1/50,000 (Flat plain areas); some districts, communes, State Farms, Stations... at large scales compiled by different Institutions and Universities; *Major Soil Units of Vietnam* (Nguyen Vy, Do Dinh Thuan. 1977); *Soil Chemistry Research of the North Vietnam* (Nguyen Vy, Tran Khai. 1978); *Sandy Marine Soil Research* (Phan Lieu. 1986); *Textbooks of Pedology* have also been edited and issued (Cao Liem *et al.* 1976; Tran Kong Tau, Ngo Van Phu, Hoang Van Huay *et al.* 1986).

Thanks to the soil survey experiences and plentiful soil research data, the published soil classification and soil map legends in this period have achieved remarkable results as follows:

- Completed soil nomenclature system (soil names were changed in Vietnamese).
- Identified changes of soils by elevation zones.
- Found out and added into the soil classification system some new major soil groups and soil units, for example, *tropical black soils, tropical podzolic soils, alkaline soils, grey degraded soils*, etc.
- Classified in details (Under *soil subunits* levels) some important soil units for agriculture production.
- Compiled soil symbol systems and addition symbols for soil map compiling.

At the same time, Vietnamese soil scientists have been applying USDA Soil Taxonomy and FAO-UNESCO-WRB soil classification systems in soil classification researches and achieved remarkable results which are basic data for further researches.

1.3.4. Period from 1991 up to now:

A lot of soil maps of Regions, Provinces, Districts and Communes... have been supplemented, edited and completed based on new soil classification research results by Research Institutes and Universities of the whole country.

At the same time, Vietnamese soil researchers have been updating and selectively adopting the USDA Soil Taxonomy and FAO-UNESCO-WRB soil classification systems for compilation of soil maps of many localities in order to exactly evaluate soil resource in terms of both quantity and quality. In some localities, soil maps were compiled with soil classification systems of FAO-UNESCO-WRB or USDA Soil Taxonomy as required.

Many related publications and researches on adopted soil classification systems of FAO-UNESCO-WRB and USDA Soil Taxonomy in this period have step by step improved knowledge on soil classification of Vietnamese pedologists.

During nearly a half of century, in spite of very short time in research compared with other developed countries, soil researches in generally and soil classification researches in particularly in Vietnam have attained remarkable achievements. At the first time up to now, the staffs of soil classification researches are grown up. Many research results on soil and soil classification have reached high levels that are recognized worldwide.

However, many problems and issues in soil classification researches should be solved in the next time:

- Lacks of synchronous equipments for soil analysis as well as limited Government funds for both soil and soil classification researches can seriously affect to completely application of FAO-UNESCO-WRB and USDA Soil Taxonomy soil classification systems, especially in quantitative soil parameter assessment.

- Soil classification researches in detail (applying selected international soil classification systems) for Vietnamese soil classification system compilation of lower categories *Units - Subunits - Families - Series* should be carried out in order to serve compilation of soil map legends at medium and large scales for the whole country at international level.

Chapter 2

THE BASIC INFORMATION OF THE MAIN SOIL UNITS OF VIETNAM

This Chapter is exposed the Main Soil Groups of Vietnam in orders based on Soil Classification of Vietnam edited by the Editorial Board for Vietnamese Soil Map (Ministry of Agriculture) in 1976.

The information is described in orders as follows: General introduction of soil group; soil forming conditions; occupied area (Data estimated by computer); main distribution; soil units in the group; capability of use; landscape and soil profile morphology and soil chemical, physical characteristics of the typical soil profiles. Vietnamese soil names are by the times; names in *Italic* are present names. Soil names in FAO-UNESCO-WRB and USDA Soil Taxonomy are proposed.

The symbol (-) in soil property data in tables is meant that these parameters are either erroneous or unable sampling samples.

2.1. The Sandy soils:

Sandy soils have an area of 530,000 hectares; occupying 1.61% of the total natural area. This soil unit distributes in Nghe An, Ha Tinh, Quang Binh, Quang Tri, Thua Thien- Hue, Ninh Thuan, Binh Thuan Provinces. In addition, some areas are distributed along big riversides or in some regions that are derived *in situ* from sandstone or granite rocks.

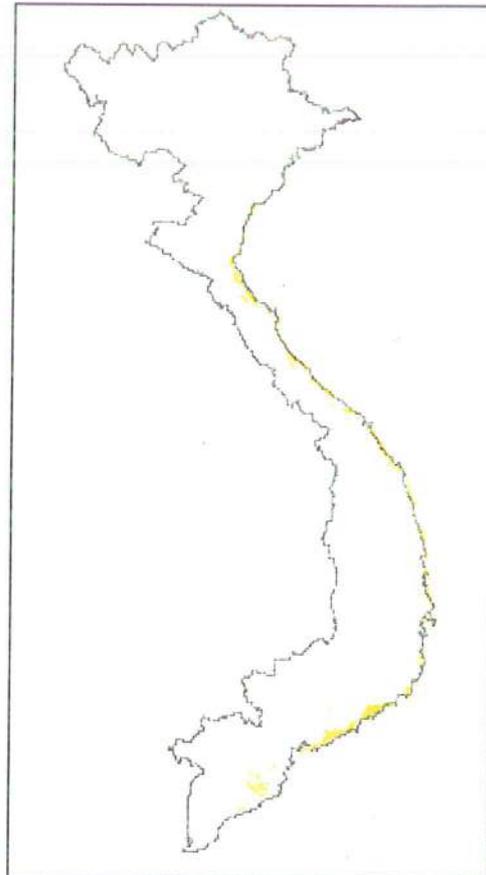
General characteristics: These soils are poor in nutrition, low in moisture and water retention capacity.

Having 3 sandy soil units in Vietnam:

- White and yellow sand dunes soils;
- Red sand dunes soils; and
- Sandy marine soils.

- *White and yellow sand dunes soils:*

This soil unit occupies an area around 220,000 hectares, distributes mainly in the seashore central region, from Quang Binh to Binh Thuan Provinces. These sand dunes are very high with white or yellow colour.



The sand dunes usually make rather high hills with 2 slope directions: steep slope on the mainland side, gradual slope on the seashore side. It is needed to plant suitable trees (Casuarinas, Acacias...) for preventing sand dune moving in these areas.

Soil profile **VN 41** is characterized for this soil unit.

- Red sand dunes soils:

This soil unit has an area of 80,000 hectares; distributes mainly in the seashore Ninh Thuan and Binh Thuan Provinces. Unlike white and yellow sand dunes soil, red sand dunes are usually stable. On this soil, cash crops as well as Casuarinas, Acacias can be planted.

Soil profile **VN 46** is characterized for this soil unit.

- Sandy marine soils:

Having approximately 230,000 hectares; distributes along seashore, from Thanh Hoa to Binh Thuan Provinces. Besides, there are some sand dunes (so-call *cat giong*) in the Mekong River Delta. Profile development: A(B)C or AC-profiles.

Soil fertility is higher than above-mentioned soil units so many crop varieties can be cultivated. Completing irrigation system, using organic fertilizers, applying balanced fertilizer system, controlling leaching are effective measures for this soil.

Soil profiles **VN 25** and **VN 53** are characterized for sandy marine soil.

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 41



Location:

- Commune: Hai Ninh
- District: Quang Ninh
- Province: Quang Binh

Soil name:

- VIETNAMESE: *Yellow and white sand dune soils*
- FAO-UNESCO: *Haplic Arenosols*
- USDA (Soil Taxonomy): *Ustipsamments*



THE INFORMATION OF SOIL PROFILE VN 41

Location: Hai Ninh Commune, Quang Ninh District, Quang Binh Province

Latitude: 17° 22' 00" N; **Longitude:** 106° 42' 00" E; **Elevation:** 5 m (ASL)

Parent materials: Sand; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Casuarina

Soil name: Vietnamese: Yellow and white sand dune soils (1976; 1996)

Yellow and white sand dune soils

FAO-UNESCO-WRB: Haplic Arenosols

USDA (Soil Taxonomy): Ustipsamments

Soil profile description:

Ap (0 - 30 cm): Light yellow (2.5Y 7/3 moist; 10YR 3/3 dry); sand; moist; many roots; gradual smooth boundary.

C (30 - 150 cm): Dull yellow orange (10YR 7/3.5 moist; 10YR 7/4 dry); sand; moist; some black root mottles; some light sand.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 30	1.31	2.62	50.0	3.1	3.8	96.2	0.0	0.0
30 - 150	1.35	2.61	48.3	3.2	2.2	97.8	0.0	0.0

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 30	0.08	Trace	Trace	0.02	0.27	3.01	0.04	0.48	6.3	5.4
30 - 150	0.02	Trace	Trace	0.01	0.32	3.01	0.02	0.16	6.3	5.3

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 30	0.16	Trace	0.06	0.03	0.25	0.80	-	31.2
30 - 150	0.08	Trace	0.06	0.02	0.16	0.48	-	33.3

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 46



Location:

- Commune: Hong Phong
- District: Bac Binh
- Province: Binh Thuan

Soil name:

- VIETNAMESE: *Red sand dune soils*
- FAO-UNESCO: *Rhodic Arenosols*
- USDA (Soil Taxonomy): *Ustipsamments*



THE INFORMATION OF SOIL PROFILE VN 46

Location: Hong Phong Commune, Bac Binh District, Binh Thuan Province

Latitude: 11° 04' 00" N; **Longitude:** 108° 19' 00" E; **Elevation:** 120 m (ASL)

Parent materials: Sand; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Grass

Soil name: Vietnamese: Red sand dune soils (1976; 1996)

Red sand dune soils

FAO-UNESCO-WRB: Rhodic Arenosols

USDA (Soil Taxonomy): Ustipsamments

Soil profile description:

- Ap (0 - 20 cm): Bright reddish brown (5YR 5/7 moist; 7.5YR 4/6 dry); sand; moist; porous; friable; many small roots; many yellow sand mottles; some black coal mottles; clear smooth boundary.
- AC (20 - 35 cm): Reddish brown (5YR 4/8 moist; 7.5YR 4/6 dry); sand; slightly moist; slightly firm; many small roots; some sand mottles; some black coal mottles; clear smooth boundary.
- C1 (35 - 90 cm): Brown (10YR 4/8 moist; 10R 4/8 dry); sand; moist; stick; slightly firm; some small roots; some small coal mottles; some animal channels; gradual smooth boundary.
- C2 (90 - 120 cm): Brown (10 YR 4/8 moist; 10R 4/8 dry); sand; moist; some black coal mottles; some sand mottles; some animal channels; some small roots.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 20	1.48	2.63	44.0	3.65	29.4	67.2	1.7	1.7
20 - 35	1.51	2.65	43.0	3.90	24.8	69.1	1.6	4.5
35 - 90	1.52	2.64	42.0	5.05	22.6	67.7	0.2	9.5
90 - 120	1.43	2.64	46.0	6.08	21.4	67.1	1.0	10.5

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 20	1.43	0.08	0.03	0.15	2.78	3.76	0.04	0.87	5.1	4.2
20 - 35	1.12	0.07	0.03	0.15	3.55	3.76	0.06	0.91	5.2	4.1
35 - 90	0.09	0.05	0.03	0.17	3.23	3.76	0.08	0.87	5.0	4.0
90 - 120	0.29	0.03	0.03	0.15	1.40	2.35	0.36	1.39	5.0	4.0

Soil horizon thickness, cm	Exchangeable Cation, cmol(+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 20	0.53	0.14	0.08	0.01	0.76	1.04	3.35	73.0
20 - 35	0.80	0.16	0.08	0.00	1.04	1.20	3.87	86.6
35 - 90	0.62	0.16	0.08	0.00	0.86	1.12	3.12	76.7
90 - 120	0.23	0.07	0.05	0.02	0.37	1.12	3.12	33.0

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 25



Location:

- Commune: Dien Ky
- District: Dien Chau
- Province: Nghe An

Soil name:

- VIETNAMESE: *Sandy soils*
- FAO-UNESCO: *Haplic Arenosols*
- USDA (Soil Taxonomy): *Udipsamments*



THE INFORMATION OF SOIL PROFILE VN 25

Location: Dien Ky Commune, Dien Chau District, Nghe An Province.

Latitude: 19° 02' 00" N; **Longitude:** 105° 34' 00" E; **Elevation:** 1 m (ASL)

Parent materials: Sand; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Maize at flowering stage

Soil name: Vietnamese: Sandy soils (1976; 1996)

Sandy soils

FAO-UNESCO-WRB: Haplic Arenosols

USDA (Soil Taxonomy): Udipsamments

Soil profile description:

- Ap (0 - 20 cm): Brown (10YR 4/4 moist; 10YR 6/4 dry); loamy sand; moist; very fine; some small roots; clear smooth boundary.
- AB (20 - 40 cm): Yellowish brown (10YR 5/8 moist; 10YR 6/6 dry); sandy loam; very fine; moist; few termite channels; clear smooth boundary.
- Bc1 (40 - 90 cm): Yellowish brown (10YR 5/6 moist; 10YR 5/8 dry); sandy loam; moist; many slightly hard violet concretions (30%); gradual smooth boundary.
- Bc2 (90 - 150 cm): Brown (10YR 4/6 moist; 10YR 5/6 dry); sand; moist; many violet concretions (>30%) tender than above lying horizon; occurrence of ground water.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 20	1.51	2.65	43.0	24.3	0.4	76.4	11.6	11.6
20 - 40	1.40	2.64	47.0	22.3	0.2	71.1	8.7	20.0
40 - 90	1.43	2.73	47.6	28.6	1.5	80.3	5.7	12.5
90 - 150	1.44	2.68	46.3	31.2	0.1	96.2	1.5	2.2

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 20	0.52	0.06	0.10	0.22	5.50	3.76	0.03	2.00	7.5	6.3
20 - 40	0.17	0.02	0.04	0.40	4.25	2.35	0.03	3.00	7.0	6.2
40 - 90	0.09	0.01	0.05	0.51	2.00	2.35	0.04	2.00	7.9	6.4
90 - 150	0.04	0.01	0.06	0.50	3.70	2.35	0.03	2.00	8.2	5.9

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 20	2.24	0.31	0.08	0.08	2.71	9.00	25.11	30.1
20 - 40	2.33	0.23	0.05	0.08	2.69	7.76	19.94	34.6
40 - 90	2.44	0.26	0.05	0.08	2.83	5.68	15.85	49.8
90 - 150	2.52	0.62	0.05	0.26	3.45	7.04	22.74	49.0

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 53



Location:

- Commune: Binh An
- District: Thang Binh
- Province: Quang Nam

Soil name:

- VIETNAMESE: *Sandy soils*
- FAO-UNESCO: *Haplic Arenosols*
- USDA (Soil Taxonomy): *Ustipsamments*



THE INFORMATION OF SOIL PROFILE VN 53

Location: Binh An Commune, Thang Binh District, Quang Nam Province

Latitude: 15° 38' 30" N; **Longitude:** 10° 26' 20" E; **Elevation:** 15 m (ASL);

Parent materials: Sand; **Topography:** Flat; **Slope:** 0 - 3°;

Present land use: Rice just harvested

Soil name: Vietnamese: Sandy soils (1976; 1996)

Sandy soils

FAO-UNESCO-WRB: Haplic Arenosols

USDA (Soil Taxonomy): Ustipsamments

Soil profile description:

- Ap (0 - 20 cm): Dull reddish brown (10YR 5/4 moist; 10YR 7/2 dry); sand; moist; porous; many rice roots; some black organic remains mixed yellowish iron mottles; clear smooth boundary.
- AB (20 - 30 cm): Dull reddish brown (10YR 5/4 moist; 10YR 7/4 dry); sand; moist; slightly firm; porous; friable; many rice roots; many black concretion; fragment rocks; clear smooth boundary.
- B (30 - 55 cm): Yellowish brown (10YR 5/8 moist; 10YR 6/6 dry); sand; moist; some gray mottles; some fragment rocks; gradual smooth boundary.
- C1 (55 - 50 cm): Yellowish brown (10 YR 5/6 moist; 10YR 7/4 dry); loamy sand; moist; porous; friable; some rock fragments; gradual smooth boundary.
- C2 (90 - 125 cm): Gray (5YR 6/1 moist; 2.5YR 8/1 dry); sandy clay; moist; firm; some brown concretion mottles (7.5R 3/4 moist; 10R 3/6 dry).

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2,0 - 0,2 mm	0,2 - 0,02 mm	0,02 - 0,002 mm	< 0,002 mm
0 - 20	1.55	2.62	41.0	8.6	21.0	75.7	1.0	2.2
20 - 30	1.75	2.66	34.0	7.1	18.8	68.5	9.5	3.2
30 - 55	1.67	2.65	37.0	9.4	18.6	68.2	7.5	5.7
55 - 90	1.72	2.59	34.0	10.6	18.1	62.6	10.0	9.3
90 - 125	1.80	2.57	30.0	12.1	18.0	62.1	9.8	10.1

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 20	0.48	0.03	0.03	0.10	2.91	2.35	0.08	1.27	5.0	4.1
20 - 30	0.13	0.01	0.02	0.10	0.66	2.35	0.04	0.32	5.9	4.7
30 - 55	0.10	0.01	0.02	0.07	0.71	1.41	0.04	0.55	6.1	4.4
55 - 90	0.17	0.01	0.02	0.10	0.43	1.41	0.04	0.59	6.0	4.5
90 - 125	0.13	0.01	0.02	0.18	0.21	2.35	0.04	0.40	6.4	5.9

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 20	0.63	0.06	0.05	0.27	1.01	3.12	5.68	32.3
20 - 30	0.97	0.08	0.05	0.19	1.29	3.04	6.22	42.4
30 - 55	0.36	0.05	0.03	0.20	0.64	2.72	7.11	23.5
55 - 90	0.72	0.17	0.03	0.65	1.57	2.92	6.20	53.7
90 - 125	0.30	0.08	0.05	2.28	2.71	3.28	6.10	82.6

2.2. The Saline soils:

These soils are coastal alluvial soils derived from sea salt affected sediments or saline water in estuaries.

There are more than 1 million hectares of saline soils of the whole country. Saline soils are mainly distributed in the plain of Southern region as Bac Lieu, Ca Mau, Kien Giang, Tra Vinh, Ben Tre Province and in the plain of Northern region as Quang Ninh, Hai Phong, Thai Binh, Nam Dinh, Ninh Binh, and Thanh Hoa Provinces.

Saline soils are divided into 4 soil units:

- Mangrove saline soils;
- Strongly saline soils;
- Medium and weak saline soils; and
- Alkaline saline soils.

- *Mangrove saline soils:*

There are approximately 180,000 hectares of mangrove saline soils concentrated at the seashore but biggest areas are in the plain at the seashore of the South (Ca Mau, Ben Tre). The component of soil association in mangrove forests depended on soil horizon thickness, tightness, salinity and period of salt water flooding.

Mangrove saline soils are usually in slime form, very saline with neutral pH and contain a lot of organic matters. Soil profile **VN 37** is characterized for this soil unit.

- *Strongly saline soils:*

There are approximately 300,000 hectares of strongly saline soils concentrated in the plain at the seashore of the North such as Thai Binh, Nam Dinh, Ninh Binh.... and the plain at the seashore of the South such as Tien Giang, Tra Vinh, Bac Lieu, Ca Mau... The sea salt water (mainly NaCl) with total soluble salt contains of more than 0.5% and ion Cl⁻ contain of 0.2 - 0.3% made soils become very saline. Electric conductivity usually is more than 4 dS/m at 25°C. Base saturation usually is high and pH is neutral. Strong saline soils are unstructured, very plastic and sticky when moist; swell and shrink when dry. In these soils paddy, coco palm, sedge can be planted. Irrigation is the main countermeasure for these soils.

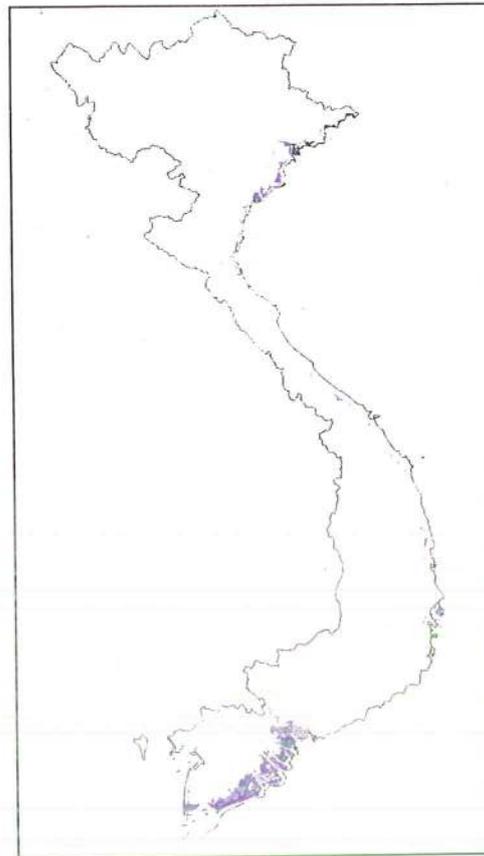
Soil profile **VN 31** is characterized for this soil unit.

- *Medium and weak saline soils:*

There are approximately 700,000 hectares of medium and weak saline soils that concentrated in the seashore where strong saline soils distributed but farer from seashore. Main characteristics of these soils are less salinity, productivity and crop yields are usually higher than strong saline soils. Soil profile **VN 01** is characterized for this soil unit.

- *Alkaline saline soils:*

The alkaline saline soils have only a small area in Ninh Thuan and Binh Thuan Province, (Local name is "Ca giang soil"). This soil can be divided in 2 soil units: "Ca giang muoi" and "Ca giang dau". Soil profile **VN 48** is characterized for this soil unit.



LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 37



Location:

- Commune: Thanh Phuoc
- District: Binh Dai
- Province: Ben Tre

Soil name:

- VIETNAMESE: Mangrove saline soils
- FAO-UNESCO: Salic Fluvisols
- USDA (Soil Taxonomy): Epiaquents

THE INFORMATION OF SOIL PROFILE VN 37

Location: Thanh Phuoc Commune, Binh Dai District, Ben Tre Province

Latitude: 10° 08' 45" N; **Longitude:** 106° 43' 30" E; **Elevation:** 5 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Mangroves (Latin: *Rhizophora*)

Soil name: Vietnamese: Mangrove saline soils (1976; 1985; 1996)

Mangrove saline soils

FAO-UNESCO-WRB: Salic Fluvisols

USDA (Soil Taxonomy): Epiaquents

Soil profile description:

- Ap (0 - 15 cm): Dark reddish brown (5YR 3/3 moist; 5YR 6/2 dry); clay; wet, pasty at the top; sticky and plastic at the bottom; many rotten leaves mixed with alluvium in 1 - 2 cm of the surface; many fresh and rotten roots; many yellow brown iron mottles along the root; gradual smooth boundary.
- AB (15 - 60 cm): Dark brown (7.5YR 3/3 moist; 5YR 5/3 dry); clay; wet; plastic; sticky; many decomposing leaves and roots; many black and grey mottles; many soft yellow brown iron concretions; gradual smooth boundary.
- Bghn1 (60 - 110 cm): Very dark reddish brown (5YR 2/3 moist; 5YR 5/2 dry); clay loam; wet; plastic; sticky; some small roots; some big roots diameter of 5 - 8 cm; gley; gradual smooth boundary.
- Bghn2 (110 - 150 cm): Very dark (7.5YR 2/3 moist; 7.5YR 6/3 dry); clay; wet; pasty; plastic; sticky; some dark mottles; some plant remains; gley.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	0.97	2.43	60.1	37.0	0.7	15.5	37.1	46.7
15 - 60	1.02	2.51	59.0	35.0	0.2	17.5	34.7	47.6
60 - 110	0.97	2.51	61.0	39.0	0.2	22.2	37.8	39.8
110 - 150	1.06	2.53	58.1	36.0	3.1	20.6	36.2	40.1

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH		EC, dS/m
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange	Potential	H ₂ O	KCl	
0-15	2.45	0.15	0.22	2.22	14.48	86.6	0.16	1.58	7.2	6.8	4.5
15 - 60	1.40	0.07	0.15	2.47	12.17	97.1	6.16	19.78	7.6	7.0	5.6
60 - 110	1.86	0.07	0.11	2.32	10.67	93.3	2.72	12.46	7.5	6.9	6.0
110 - 150	1.48	0.05	0.11	2.13	7.00	74.9	0.08	0.63	7.6	7.1	5.5

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %	Cl, %	SO ₄ ⁻² , %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay			
0-15	1.36	3.88	1.84	11.45	18.53	21.12	19.60	87.7	1.15	0.14
15 - 60	1.02	2.21	2.06	11.21	16.90	17.06	22.20	99.0	0.98	0.51
60 - 110	1.48	2.14	2.19	10.66	16.47	17.72	22.40	92.9	1.15	0.61
110 - 150	2.02	4.85	1.54	10.05	18.46	22.52	21.86	81.9	1.17	0.40

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 31



Location:

- Commune: Hiep Thanh
- District: Bac Lieu
- Province: Bac Lieu

Soil name:

- VIETNAMESE: *Saline soils*
- FAO-UNESCO: *Salic Fluvisols*
- USDA (Soil Taxonomy): *Hydraquents*

THE INFORMATION OF SOIL PROFILE VN 31

Location: Hiep Thanh Commune, Bac Lieu District, Bac Lieu Province

Latitude: 09° 15' 30" N; **Longitude:** 105° 44' 15" E; **Elevation:** 2 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Rice just harvested

Soil name: Vietnamese: Saline soils (1976; 1985; 1996)

Saline soils

FAO-UNESCO-WRB: Salic Fluvisols

USDA (Soil Taxonomy): Hydraquents

Soil profile description:

- Ap (0 - 20 cm): Dull reddish brown (5YR 4/2.5 moist; 5YR 6/3 dry); clay; moist; many black grass residues and rice roots; some small brown concretion mottles; brown clay (5YR 4/3.5 moist; 5YR 4/4 dry) in bottom; brown cracks (2.5YR 4/6 moist; 5YR 5/8 dry); gradual smooth boundary.
- AB (20 - 50 cm): Dull reddish brown (5Y 4/3 moist; 5YR 5/2 dry); clay; moist; friable; many small black concretions and some yellow brown iron mottles; gradual smooth boundary.
- Bn (50 - 100 cm): Dull reddish brown (5YR 4/3 moist; 5YR 5/2 dry); clay; moist; many cracks; many yellow brown iron mottles (7.5YR 4/6 moist; 7.5YR 5/6 dry); some brownish black concretions; gradual smooth boundary.
- Bnc (100 - 120 cm): Greyish brown (5YR 4/2 moist; 5YR 5/2.5 dry); clay loam; moist; many cracks; many concretion mottles; gradual smooth boundary.
- Cl (120 - 140 cm): Greyish brown (7.5YR 4/1.5 moist; 7.5YR 5/3 dry); clay loam; wet; sticky; some big concretion mottles vertically the profile.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 20	1.22	2.65	54.0	25.8	0.8	7.8	35.8	55.6
20 - 50	1.32	2.66	50.4	23.5	1.3	9.9	36.4	52.4
50 - 100	1.19	2.66	55.3	29.8	0.8	14.3	32.2	52.7
100 - 120	1.01	2.63	61.6	36.2	1.6	29.1	34.1	35.2
120 - 140	1.02	2.58	60.5	37.5	2.0	30.0	31.8	36.2

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH		EC, dS/m
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange	Potential	H ₂ O	KCl	
0 - 20	0.95	0.07	0.12	2.58	5.29	44.28	0.06	0.30	5.1	5.0	6.5
20 - 50	0.36	0.02	0.15	2.17	6.24	65.01	0.04	0.31	7.4	6.4	6.0
50 - 100	1.28	0.04	0.13	2.01	4.25	65.01	0.04	0.27	7.3	7.1	2.5
100 - 120	0.95	0.03	0.12	1.91	8.02	42.87	0.04	0.38	7.5	6.9	1.7
120 - 140	1.50	0.05	0.12	1.91	5.22	51.34	0.04	0.31	7.1	6.9	2.7

Soil horizon thickness, cm	Exchangeable Cation, cmol(+)/kg					CEC, cmol(+)/kg		BS, %	Cl ⁻ , %	SO ₄ ²⁻ , %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay			
0 - 20	5.34	6.69	0.94	3.60	16.57	16.32	20.80	87.7	1.13	0.09
20 - 50	4.39	9.30	1.38	6.15	21.22	18.08	23.00	99.0	0.14	0.07
50 - 100	4.98	6.85	1.38	8.67	21.88	15.52	22.80	92.9	0.56	0.29
100 - 120	2.51	5.30	0.91	8.65	17.37	14.00	26.88	81.9	0.43	0.11
120 - 140	2.02	3.05	1.09	6.97	12.95	14.08	23.79	59.1	0.69	0.33

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 01



Location:

- Rang Dong Farm.
- District: Nghia Hung
- Province: Nam Dinh

Soil name:

- VIETNAMESE: *Alluvial coastal salt affected soils*
- FAO-UNESCO: *Salic Fluvisols*
- USDA (Soil Taxonomy): *Udifluvents*

THE INFORMATION OF SOIL PROFILE VN 01

Location: Rang Dong Farm, Nghĩa Hung District, Nam Dinh Province

Latitude: 20° 00' 00" N; **Longitude:** 106° 06' 00" E; **Elevation:** 1 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Summer rice (CR 203) just harvested

Soil name: Vietnamese: Alluvial coastal salt affected soils (1976; 1985; 1996)

Alluvial coastal salt affected soils

FAO-UNESCO-WRB: Salic Fluvisols

USDA (Soil Taxonomy): Udifluvents

Soil profile description:

- Ap (0 - 20 cm): Dark reddish brown (5YR 3/4 moist; 5YR 6/4 dry); clay; moist; porous; slightly firm; many rice roots; many black root mottles; gradual smooth boundary.
- AB (20 - 60 cm): Dark reddish brown (5YR 3/4 moist; 5YR 6/4 dry); many yellow concretions (7.5YR 4/6 moist; 7.5YR 6/6 dry); clay loam; moist; some small black roots; gradual smooth boundary.
- B (60- 85 cm): Dark reddish brown (5YR 3/3 moist; 5YR 6/3 dry); few yellow concretions (7.5YR 4/6; moist; 7.5YR 6/6 dry); sandy clay loam; moist; few small fine sand grain; gradual smooth boundary.
- Cr1 (85 - 105 cm): Dark reddish brown (5YR 3/2 moist; 7.5YR 5/3 dry); sandy loam; moist; fine at the upper part; coarser at the lower part; gradual smooth boundary.
- Cr2 (105 -125 cm): Brownish black (7.5YR 3/2 moist; 7.5YR 5/3 dry); sand; mixed of few dark brown clay; wet; some shells.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 20	1.05	2.65	60.4	32.9	2.2	22.5	45.0	30.3
20 - 60	1.34	2.69	50.2	25.6	0.7	39.3	32.6	27.4
60 - 85	1.39	2.62	47.0	24.4	0.4	55.8	21.1	22.7
85 - 105	1.33	2.66	50.0	25.4	0.3	60.7	25.8	13.2
105 - 125	1.38	2.65	48.0	26.1	0.8	89.8	5.8	3.6

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 20	0.40	0.11	0.04	2.05	8.15	8.47	0.04	1.02	7.3	5.9
20 - 60	0.34	0.11	0.04	2.05	8.00	4.23	0.04	0.85	7.5	5.9
60 - 85	0.43	0.07	0.03	2.00	7.63	2.82	0.04	0.50	7.7	6.3
85 - 105	0.24	0.07	0.03	1.65	6.15	2.82	Trace	0.38	7.9	6.5
105 - 125	0.21	0.04	0.03	1.09	6.10	2.82	Trace	0.27	8.2	6.9

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 20	4.19	3.17	0.18	0.32	7.86	12.58	24.15	62.5
20 - 60	4.49	1.83	0.09	0.29	6.70	11.21	21.52	59.8
60 - 85	3.40	3.36	0.06	0.27	7.09	13.98	31.87	50.7
85 - 105	4.55	3.96	0.06	0.15	8.72	14.66	33.42	59.5
105 - 125	7.25	5.77	0.06	0.25	13.33	17.77	40.51	75.0

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 48



Location

- Commune: Phuoc Hai
- District: Ninh Phuoc
- Province: Ninh Thuan

Soil name:

- VIETNAMESE: *Alkaline saline soils*
- FAO-UNESCO: *Sodic Solonchaks*
- USDA (Soil Taxonomy): *Aquicambids*

THE INFORMATION OF SOIL PROFILE VN 48

Location: Phuoc Hai Commune, Ninh Phuoc District, Ninh Thuan Province
Latitude: 11° 33' 00" N; **Longitude:** 108° 57' 30" E; **Elevation:** 35 m (ASL)
Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°
Present land use: Grasses.

Soil name: Vietnamese: Alkaline saline soils (1976; 1996)

Alkaline saline soils

FAO-UNESCO-WRB: Sodic Solonchaks

USDA (Soil Taxonomy): Aquicambids

Soil profile description:

Ap (0 - 7 cm):	Brownish gray (7.5YR 4/1 moist; 7.5YR 6/2 dry); clay loam; moist; stick; plastic; slightly firm; mud black layer on surface (7.5YR 2/1 moist; dry); many roots; many decomposed black mottles; gradual smooth boundary.
AB (7 - 20 cm):	Grayish olive (5Y 5/2 moist; 7.5Y 7/2 dry); sandy clay loam; plastic; stick; firm; many brown sand mottles; clear smooth boundary.
Bs1 (20 - 50 cm):	Yellowish brown (10YR 5/6 moist; 2.5Y 7/4 dry); sand; moist; porous; some brown mottles; many slight sand mottles; gradual smooth boundary.
Bs2 (50 - 80 cm):	Yellowish brown (10YR 5/6 moist; 2.5Y 7/4 dry); sand; moist; slightly firm; many black mottles; some gray sand mottles; clear smooth boundary.
Bw1 (80 - 120 cm):	Yellowish brown (10YR 5/8 moist; 10YR 7/4 dry); sandy loam; moist; slightly firm; porous; friable; many dark mottles.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 7	1.11	2.56	56.0	34.0	3.3	29.3	29.3	38.1
7 - 20	1.51	2.70	44.0	20.8	3.3	42.9	22.5	31.3
20 - 50	1.36	2.69	49.0	21.6	0.7	83.9	11.0	4.4
50 - 80	1.21	2.68	55.0	28.8	1.1	90.4	5.4	3.1
80 - 120	1.22	2.76	56.0	26.8	0.7	52.3	28.4	18.6

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH		EC, dS/m
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange	Potential	H ₂ O	KCl	
0 - 7	1.00	0.05	0.13	2.82	25.41	20.73	0.06	0.32	6.7	5.8	2.5
7 - 20	0.87	0.05	0.13	2.82	42.11	16.96	Trace	Trace	7.7	6.7	2.5
20 - 50	0.87	0.01	0.08	2.83	13.87	2.35	Trace	Trace	7.5	6.6	2.5
50 - 80	0.58	0.02	0.10	1.90	13.90	1.41	Trace	Trace	7.6	6.6	2.0
80 - 120	0.29	0.03	0.10	1.90	13.90	1.41	Trace	Trace	7.9	6.5	2.0

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %	Total soluble Salts, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay		
0 - 7	5.39	1.95	0.44	8.49	18.84	19.72	24.42	95.5	0.06
7 - 20	5.57	1.66	0.36	8.37	15.61	16.32	27.17	95.6	0.28
20 - 50	1.03	0.54	0.05	7.63	9.20	10.20	27.14	90.1	0.38
50 - 80	1.15	0.45	0.03	8.75	10.35	15.76	18.60	65.6	0.03
80 - 120	1.07	0.55	0.03	7.40	9.02	13.76	35.36	65.5	0.04

2.3. The Acid Sulphate soils:

Acid sulphate soils are formed from alluvial sediment products with sulfidic materials (vegetative biomass contains sulfur: pyrites) and developed in the swampy areas with bacteria activity.

Acid sulphate soils have an area around 2 millions hectares. The biggest area is in Long An, An Giang, Kien Giang, Can Tho, Soc Trang, Bac Lieu, Ca Mau Provinces... In the Northern region, a small area in Hai Phong, Thai Binh Provinces can be found.

Acid sulphate soils can be divided into 2 soil units:

- Potential acid sulphate soils.
- Actual acid sulphate soils.

- *Potential acid sulphate soils:*

This soil unit occupies an approximately estimated 600,000 hectares; concentrated in the Mekong Delta. It forming process based on presence of sulfidic horizon that contains sulfidic materials characterized by clay and flooded organic layers normally in the anaerobic condition with SO_3^{2-} contain is more than 1.7% (equivalent 0.75% of sulfur), when oxidate pH reduced to 3.5. The Δ pH (Difference pH between oxidization with reoxidization conditions) is about 2.0 units. Potential acid sulphate soils can exploit and cultivate rice, shrimp culture etc. Potential acid sulphate soils under mangroves and acid sulphate soils with special characteristics need to preserve for coastal sea area protection.

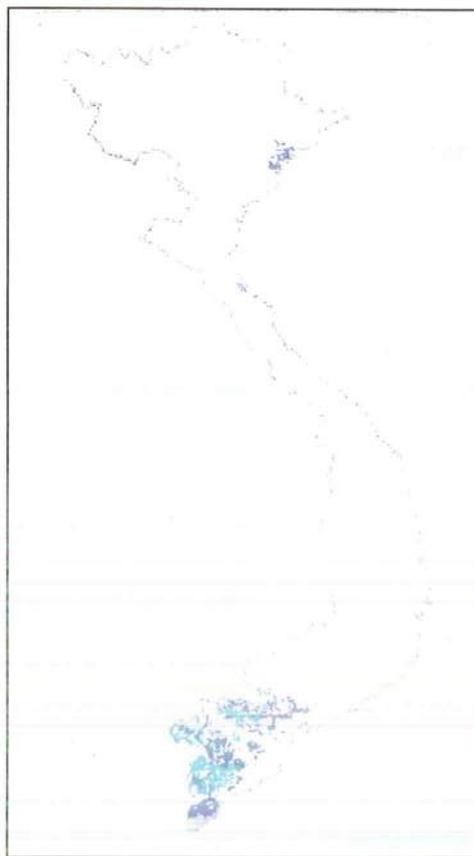
Soil profile **VN 28** is characterized for this soil unit.

- *Actual acid sulphate soil:*

This soil unit occupied an approximately estimated 1.4 million hectares distributed in the Mekong Delta of Southern region and some Provinces of Northern region. It is formed because of having jarosite layer (Sulfuric horizon). Jarosite layer is B layer which occurs in the process of forming and developing from the potential acid sulphate soils, mainly jarosite minerals in the forms of spots or traces with yellow colour (Munsell color 2.5 Y), pH is below 3.5. The jarosite layer is indicator for actual acid sulphate soils.

Paddy rice can be planted on actual acid sulphate soils with shallow plough, keeping fresh water and regular drainage. Nowadays, more than 1 million hectares of actual acid sulphate soils in Vietnam can produce rice and that increase 6 - 7 millions tons of rice annually. Besides pineapple, cashew, yam etc can be found on these soils.

Soil profile **VN 33** is characterized for this soil unit in the Mekong Delta and soil profile **VN 04** is characterized for actual acid sulphate soils in Northern region.



LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 28



Location:

- Commune: Tam Giang
- District: Ngoc Hien
- Province: Ca Mau

Soil name:

- VIETNAMESE: *Potetial acid sulphate soils*
- FAO-UNESCO: *Protohionic Gleysols*
- USDA (Soil Taxonomy): *Sulfaquents*



THE INFORMATION OF SOIL PROFILE VN 28

Location: Tam Giang Commune, Ngoc Hien District, Ca Mau Province

Latitude: 08° 49' 45" N; **Longitude:** 105° 14' 00" E; **Elevation:** 1 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: 30-40 years natural mangroves

Soil name: *Vietnamese:* Mangrove saline soils (1976); Potetial acid sulphate soils (1985)

Potetial acid sulphate soils (1996)

Potetial acid sulphate soils

FAO-UNESCO-WRB: Protothionic Gleysols

USDA (Soil Taxonomy): Sulfaquents

Soil profile description:

- Ap (0 - 15 cm): Greyish brown (7.5YR 4/2 moist; 10R 6/2 dry); clay; wet; some black organic and plant residue's mottles; thin black organic layer in surface; some small iron mottles; many channels; gradual smooth boundary.
- AB (15 - 35 cm): Brownish black (7.5YR 3/2 moist; 2.5YR 6/2 dry); clay; wet; plastic; sticky; some black organic mottles; some root and plant residues; some dark grey clay in lower part; gradual smooth boundary.
- Bw1 (35 - 55 cm): Yellowish grey (2.5Y 4/1 moist; 2.5YR 6/1 dry); clay; wet; plastic; sticky; some remains decomposed; clear smooth boundary.
- Bw2 (55 - 95 cm): Brownish black (10YR 2/2 moist; 10Y 6/2 dry); clay; moist; porous; some remains decomposed; mixed clay mottles of upper horizon; clear smooth boundary.
- Br (95 - 125 cm): Dull yellowish brown (5Y 5/1 moist; 5Y 6/1 dry); bright yellowish brown (10YR 6/6 moist; 2.5YR 6/4 dry); clay; moist; sticky; plastic; less concretions.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	0.64	2.40	73.3	52.2	0.4	35.6	12.4	51.6
15 - 35	0.59	2.44	75.0	53.6	2.4	13.5	30.7	53.4
35 - 55	0.71	2.49	71.5	50.0	2.3	11.2	34.3	52.2
55 - 95	0.20	1.81	89.0	82.3	10.8	23.7	20.1	45.4
95 - 125	1.00	2.57	60.7	38.6	0.2	8.8	28.3	62.7

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH		EC, dS/m
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange	Potential	H ₂ O	KCl	
0 - 15	4.89	0.26	0.13	2.24	5.22	79.14	0.32	2.01	4.8	4.5	2.6
15 - 35	4.89	0.24	0.11	2.20	6.21	88.09	8.42	35.12	4.0	3.6	2.2
35 - 55	5.25	0.18	0.08	2.20	7.60	5.60	22.65	67.96	3.1	2.8	4.4
55 - 95	16.87	1.01	0.07	1.00	1.80	89.50	14.34	93.24	3.4	3.1	6.9
95 - 125	1.24	0.06	0.07	2.58	8.08	115.89	6.18	18.38	4.2	3.7	3.4

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %	Cl, %	SO ₄ ²⁻ , %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay			
0 - 15	1.08	3.01	1.86	11.23	17.18	23.12	37.67	74.3	1.23	0.18
15 - 35	1.22	3.55	1.87	11.80	18.44	22.80	37.60	80.8	1.11	1.01
35 - 55	1.01	4.85	0.12	13.56	19.54	25.36	21.00	77.0	0.98	1.30
55 - 95	1.68	4.66	1.90	16.07	24.31	25.72	20.40	94.5	2.87	2.83
95 - 125	1.26	2.96	2.46	11.18	17.86	19.36	31.55	92.2	0.91	0.58

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 33

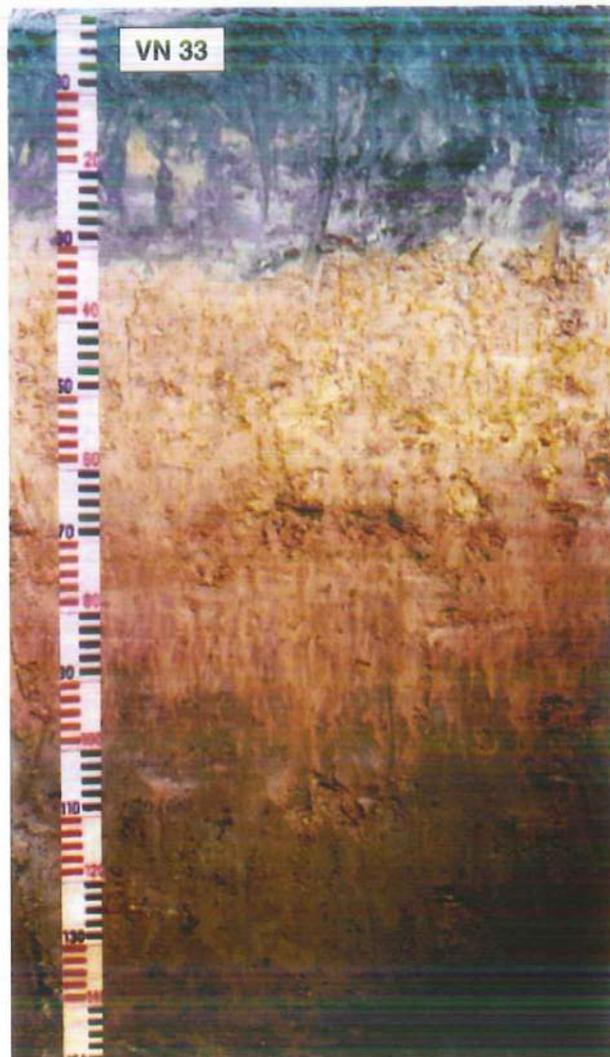


Location:

- Commune: Tan Lap
- District: Moc Hoa
- Province: Long An

Soil name:

- VIETNAMESE: *Actual acid sulphate soils*
- FAO-UNESCO: *Orthithionic Fluvisols*
- USDA (Soil Taxonomy): *Sulfaquepts*



THE INFORMATION OF SOIL PROFILE VN 33

Location: Tan Lap Commune, Moc Hoa District, Long An Province

Latitude: 10° 40' 15" N; **Longitude:** 106° 00' 30" E; **Elevation:** 1 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Rice just harvested

Soil name: Vietnamese: Acid sulphate soils (1976; 1985); Actual acid sulphate soils (1996)
Actual acid sulphate soils

FAO-UNESCO-WRB: Orthithionic Fluvisols

USDA (Soil Taxonomy): Sulfaquepts

Soil profile description:

- Ap (0 - 15 cm): Brownish black (10YR 2/1.5 moist; 10YR 5/1 dry); clay; wet; pasty; some hard piece; many decomposed straws and rice roots; gradual smooth boundary.
- Ap2 (15 - 30 cm): Brownish black (10YR 2/1.5 moist; 10YR 4/1 dry) mixed greyish yellow brown clay mottles (10YR 6/2 moist; 10YR 6/2 dry); clay; slightly wet; firm; some yellowish brown mottles along the rice roots; clear smooth boundary.
- Bj (30 - 70 cm): Greyish brown (7.5YR 5/2.5 moist; 10YR 6/2 dry); many yellow brown iron mottles (10YR 5/7 moist; 10YR 6/6 dry) at the top and slight yellow mottles (2.5Y 7/6 moist; 5Y 8/5 dry) at the bottom; clay; wet; sticky; slightly friable; gradual smooth boundary.
- Bh1 (70 - 95 cm): Dull brown (7YR 5/3 moist; 7.5YR 5/2 dry); clay; wet; plastic; sticky; many blackish brown decomposed residues; gradual smooth boundary.
- Bh2 (95 - 130 cm): Greyish brown (7.5YR 4/2 moist; 7.5YR 4/1 dry); clay; wet; plastic; sticky; many decomposed plant residues.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	0.64	2.33	72.5	53.0	2.1	14.1	35.2	48.6
15 - 30	1.14	2.55	55.3	30.5	1.1	14.2	28.8	55.9
30 - 70	1.06	2.59	59.1	34.1	4.8	19.6	17.8	57.8
70 - 95	0.73	2.46	70.3	48.3	0.6	16.9	24.4	58.1
95 - 130	0.73	2.45	70.2	49.2	4.5	18.6	32.0	44.9

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+) /kg		pH		EC, dS/m
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange	Potential	H ₂ O	KCl	
0 - 15	6.07	0.19	0.14	1.63	8.57	8.44	7.72	19.20	4.2	3.8	0.55
15 - 30	1.90	0.04	0.05	1.63	0.88	9.64	13.31	31.80	3.7	3.4	0.25
30 - 70	0.76	0.04	0.03	1.95	0.21	13.26	15.05	25.25	3.4	3.2	0.23
70 - 95	4.01	0.03	0.03	1.88	0.44	2.41	17.05	25.05	3.4	3.2	0.35
95 - 130	7.61	0.07	0.04	1.43	1.34	2.41	153.60	196.80	2.4	2.3	4.20

Soil horizon thickness, cm	Exchangeable Cation, cmol(+) /kg					CEC, cmol(+) /kg		BS, %	Cl, %	SO ₄ ²⁻ , %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay			
0 - 15	2.24	1.10	0.17	0.20	3.71	16.08	20.51	23.1	0.04	0.06
15 - 30	1.74	1.42	0.20	0.22	3.58	9.80	16.43	36.5	1.11	0.07
30 - 70	1.01	1.16	0.28	0.26	2.71	18.56	25.20	14.6	3.21	0.25
70 - 95	1.37	1.63	0.05	0.37	3.42	13.68	26.60	25.0	3.55	0.28
95 - 130	1.16	1.47	0.05	0.09	2.77	10.96	17.65	25.3	4.95	0.24

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 04



Location:

- Hai Phong City Plant seed Company
- District: Kien Thuy
- City: Hai Phong

Soil name:

- VIETNAMESE: *Actual acid sulphate soils*
- FAO-UNESCO: *Orthithionic Fluvisols*
- USDA (Soil Taxonomy): *Sulfaquepts*



THE INFORMATION OF SOIL PROFILE VN 04

Location: Hai Phong City Plant seed Company, Kien Thuy District, Hai Phong City

Latitude: 20° 46' 00" N; **Longitude:** 106° 42' 00" E; **Elevation:** 2 m (ASL)

Parent materials; Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Just harvested spring rice

Soil name: Vietnamese: Acid sulphate soils (1976; 1985); Actual acid sulphate soils (1996)

Actual acid sulphate soils

FAO-UNESCO-WRB: Orthithionic Fluvisols

USDA (Soil Taxonomy): Sulfaquepts

Soil profile description:

- Ap (0 - 15 cm): Brown (7.5YR 4/3 moist; 7.5YR 8/3 dry); clay; wet; many rice roots and organic remains; many iron mottles; clear smooth boundary.
- Ap2 (15 - 26 cm): Brown (7.5YR 4/4 moist; 10YR 7/3 dry); clay; firm; fine; wet; many rice roots; an yellow brown layer (5-10 %) around rice roots; clear smooth boundary.
- Bjg (26 - 67 cm): Brownish grey (7.5YR 4/1 moist; 10YR 7/3 dry); bright yellowish brown Jarosite mottles 30-40% (10 YR 7/6 moist; 2.5Y 8/6 dry); orange (7.5YR 6/8 moist; 10YR 7/4 dry); clay; fine; slightly firm; wet; gley; bright brown clay mottles; clear smooth boundary.
- Crg1 (67 - 95 cm): Brownish black (7.5YR 3/1 moist; 2.5YR 6/2 dry); clay; fine; wet; gleyic; decomposed remains (5-10%); gradual smooth boundary.
- Crg2 (95 - 120 cm): Brownish black (7.5YR 3/2 moist; 10YR 6/2 dry); loamy; fine; slightly firm; wet; gleyic; decomposed remains (5%).

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	1.07	2.40	55.4	36.8	0.8	26.5	26.8	45.9
15 - 26	1.36	2.37	42.6	26.1	2.3	23.4	33.8	40.5
26 - 67	1.20	2.45	51.0	31.0	3.4	17.7	22.6	56.3
67 - 95	1.08	2.45	56.0	35.0	0.6	30.1	27.6	41.7
95 - 120	1.19	2.43	51.0	31.0	0.7	34.0	38.8	26.5

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 15	1.16	0.15	0.04	1.45	13.7	14.60	3.10	15.55	4.5	3.5
15 - 26	0.59	0.10	0.02	1.54	5.1	19.78	6.60	16.13	3.8	3.2
26 - 67	1.10	0.10	0.02	1.38	1.0	7.53	10.11	24.80	3.1	2.8
67 - 95	4.03	0.10	0.02	1.38	15.9	3.76	93.10	115.20	2.5	2.3
95 - 120	2.58	0.09	0.02	1.20	15.7	3.76	45.60	93.60	2.7	2.5

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS %	SO ₃ %	SO ₄ ²⁻ %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay			
0 - 15	2.91	1.09	0.31	0.66	4.97	11.36	21.81	43.8	0.02	0.02
15 - 26	2.18	1.48	0.42	1.51	5.59	11.14	18.82	50.2	0.64	0.03
26 - 67	1.60	1.15	0.16	1.78	4.69	14.22	27.30	33.0	2.15	0.35
67 - 95	1.68	0.78	0.08	0.59	3.14	13.42	21.87	23.4	2.01	0.41
95 - 120	1.87	0.96	0.08	0.54	3.45	10.62	20.17	32.5	2.65	0.18

2.4. The Swampy soils and Peat soils:

According to the data of Editorial Board for Vietnamese Soil Map in 1976, Swamp soil and Peat soils are grouped into one soil grouping. Applying FAO-UNESCO-WRB, they are separated and Swampy soil names are changed to Gleyic soils (Gleysols).

- *Gleysols:*

Gleysols are soils that have a gleyic horizon formed from unconsolidated materials unless that materials with coarse texture and alluvial sediments. Gleyic properties exposed at the depth of 50 cm from the surface.

Gleysols occupy an estimated 450,000 hectares national-wide (1.3% of total natural area).

The formation of Gleysols is conditioned by excessive wetness at shallow depth, poor-drained. They are concentrated in Red River Delta, Central part of country, High plateaus, etc.

Gleysols have high potential fertility. They can be good soils for agricultural production if reclaimed.

Irrigation is the first countermeasure for using and improving Gleysols. The rice yield can be reached 10 tons/hectares/year if there is well irrigated, high yield rice variety and balanced fertilization applied on Gleysols.

Land use types should be changed to more effective crops systems if there is no irrigation supplied on Gleysols, such as change to paddy-fish, paddy-duck, paddy-fish-fruit tree, etc... system.

Soil profile **VN 60** is characterized for this soil unit.

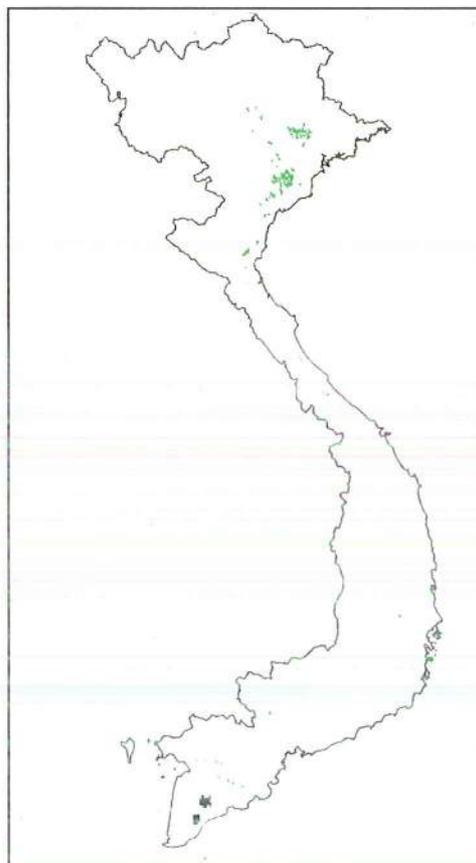
- *Peat soils:*

Peat soils are formed from organic soil material accumulations in conditions where plant matter is produced by an adapted vegetation and flooding. In the mountains and/or hills lands, peat soils usually formed from vegetation residues either in situ where groundwater table is shallow or drifted from mountains/hills surfaces. This occasion is usually met in the North area (Phu Tho, Hoa Binh, Ha Tay... Provinces). In the U Minh (Mekong Delta) peat soils are formed from vegetation residues in wetness and redox condition with depth of 1 - 2 meters from the surface.

Peat soils are occupied 35,000 hectares; concentratively distributed in U Minh (Ca Mau and Kien Giang Provinces) and scattered in the North Midland areas.

Peat soils are usually used for biofertilizer production. Rice can be planted in these peat soils, where organic layer is in 25 - 30 cm from the surface.

Soil profile **VN 29** is characterized for this soil unit.



LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 60



Location:

- Commune: Lien Chau
- District: Thanh Oai
- Province: Ha Tay

Soil name:

- VIETNAMESE: *Alluvial affected Gleysoils*
- FAO-UNESCO: *Fluvic Gleysols*
- USDA (Soil Taxonomy): *Udifluvaquents*

THE INFORMATION OF SOIL PROFILE VN 60

Location: Lien Chau Commune, Thanh Oai District, Ha Tay Province

Latitude: 20° 48' 40" N; **Longitude:** 105° 49' 11" E; **Elevation:** 1.6 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Rice just harvested

Soil name: Vietnamese: Gleyic soils (1976); Gleyic soils (1996)

Alluvial affected Gleysols

FAO-UNESCO: Fluvic Gleysols

USDA (Soil Taxonomy): Udifluvaquents

Soil profile description:

- Ap (0 - 20 cm): Bright brown (7.5YR 4/3 moist; 7.5YR 6/3 dry); silt; slightly moist; many rice roots; porous; many small cracks and brown ferrous mottles; slightly firm at the bottom of horizon; some black mottle of straw residues; sticky; soft; gradual smooth boundary.
- AB (20 - 40 cm): Light brown (7.5YR 4/4 moist; 7.5YR 6/2 dry); loamy silt; moist; some black mottles mixed with some light yellowish brown concretions at the upper; some moist yellowish brown mottles at the bottom; soft; firm; clear boundary.
- Bg1 (40 - 80 cm): Dark grey (2.5Y 5/2 moist; 2.5Y 6/2 dry); clay; moist; many small black mottles and soft yellowish grey concretions diameter of 2-5 mm; strongly gleyic; clear boundary.
- Bg2 (80 - 110 cm): Dull dark grey (2.5Y 3/1 moist; 2.5Y 6/2 dry); sandy clay; wet; some dark brownish grey fine sand in upper; some blackish brown decomposing plant residues; strongly gleyic; gradual smooth boundary.
- BC (110 - 150 cm): Dark brown (10YR 3/3 moist; 10YR 6/2 dry); sandy clay; moist; same as upper horizon.

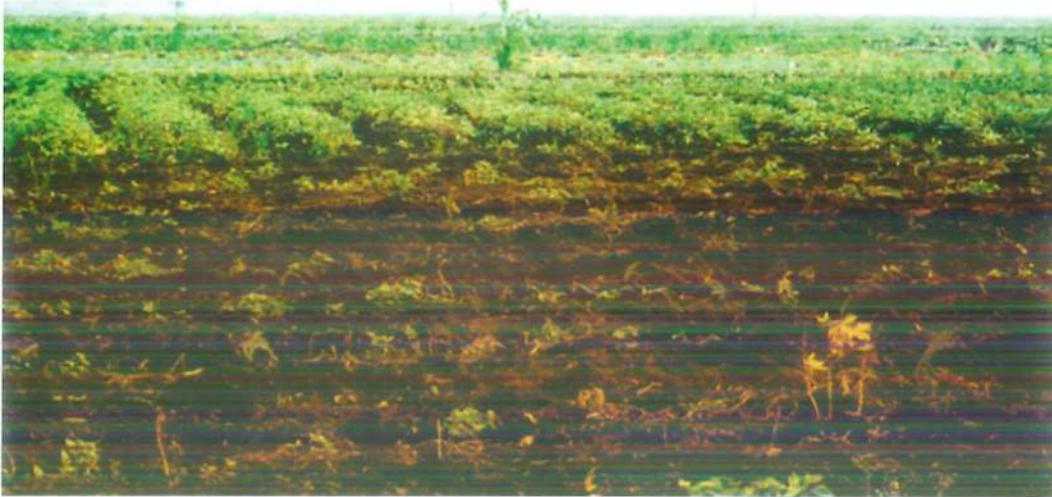
Soil properties:

Soil Horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle sizes, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 20	0.74	2.63	72.0	42.4	0.2	6.2	46.4	47.2
20 - 40	1.16	2.63	56.1	30.5	0.5	31.4	36.8	31.3
40 - 80	1.27	2.67	52.6	28.0	0.0	16.8	40.2	43.0
80 - 110	1.05	2.59	59.4	34.9	0.9	49.5	26.7	22.9
110 - 150	1.07	2.64	59.4	35.6	0.0	44.6	37.4	18.0

Soil Horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 20	1.79	0.27	0.05	1.58	12.87	9.03	1.12	2.48	5.6	5.0
20 - 40	1.70	0.20	0.03	1.75	5.65	9.03	0.16	0.72	6.0	5.6
40 - 80	1.40	0.16	0.02	1.23	0.50	9.03	0.40	1.25	5.8	5.0
80 - 110	3.16	0.13	0.02	0.84	3.99	9.03	0.32	1.12	5.7	5.1
110 - 150	3.30	0.11	0.04	1.12	12.21	7.53	0.64	1.12	5.5	5.1

Soil Horizon thickness, cm	Exchangeable Cation, cmol(+)/kg đất					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 20	5.12	1.00	0.19	0.15	6.46	16.0	20.5	40.4
20 - 40	6.09	0.86	0.19	0.24	7.38	11.6	19.7	63.6
40 - 80	3.96	1.00	0.19	0.21	5.36	10.0	18.3	53.6
80 - 110	3.64	0.91	0.19	0.18	4.92	11.2	20.1	43.9
110 - 150	4.18	0.92	0.16	0.22	5.48	12.4	20.6	44.2

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 29



Location:

- Commune: Khanh An
- District: U Minh
- Province: Ca Mau

Soil name:

- VIETNAMESE: *Peat potential acid sulphate soils*
- FAO-UNESCO: *Protothionic Histosols*
- USDA (Soil Taxonomy): *Sulfohemists*

THE INFORMATION OF SOIL PROFILE VN 29

Location: Khanh An Commune, U Minh District, Ca Mau Province

Latitude: 09° 16' 00" N; **Longitude:** 104° 50' 00" E; **Elevation:** 2 m (ASL)

Parent materials: Aluvium; **Topography:** Flat; **Slope:** 0-3°

Present land use: Just harvested sweet potato

Soil name: Vietnamese: Peat soils (1976); Peat potential acid sulphate soils (1985; 1996)

Peat potential acid sulphate soils

FAO-UNESCO-WRB: Protothionic Histosols

USDA (Soil Taxonomy): Sulfohemists

Soil profile description:

- H1 (0 - 15 cm): Brownish black (5YR 2/1.5 dry); dry; sand; dust of mixed surface; some sweet potato roots; many small crushed dry plant residues; some small dark black mottles; gradual smooth boundary.
- H2 (15 - 35 cm): Brownish black (5YR 2/1.5 moist; 5YR 2/2 dry); peat layer; moist; sand; many decomposed plant residues; hard connection; gradual smooth boundary.
- H3 (35 - 70 cm): Black (5YR 1.7/1 moist; 5YR 1.7/1 dry); fine peat layer; moist; loamy sand; wet in the lower part; some decomposed plant residues; clear smooth boundary.
- H4 (70 - 95 cm): Dark reddish brown (5YR 3/2 moist; 5YR 5/1.5 dry); some bright brown clay mottles (5YR 4/2 moist; 5YR 5/2 dry); wet; clay loam; pasty; plastic; sticky; many plant decomposing residues; gradual smooth boundary.
- Her1 (95 - 130 cm): Brownish black (5YR 2/2.5 moist; 10 YR 5/1 dry); wet; clay loam; pasty; slightly sticky; finer but less plant decomposing residues than upper horizon.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	-	-	-	-	70.5	14.4	6.8	8.3
15 - 35	0.12	1.66	92.8	80.6	61.9	22.5	2.4	13.2
35 - 70	0.14	1.13	87.6	83.7	66.2	18.3	4.6	10.9
70 - 95	0.48	2.20	78.2	60.8	8.7	27.7	28.7	34.9
95 - 130	0.41	2.33	82.4	66.5	12.4	29.8	25.7	32.1

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 15	29.47	1.64	0.06	0.04	8.68	12.05	0.87	123.27	4.1	3.2
15 - 35	32.70	1.21	0.05	0.06	3.81	18.07	0.95	116.15	4.5	3.1
35 - 70	31.94	1.25	0.04	0.07	1.31	8.43	0.48	62.88	4.8	4.0
70 - 95	11.72	0.14	0.04	1.50	1.31	14.46	7.29	49.15	4.0	3.5
95 - 130	14.25	0.14	0.05	1.37	1.80	1.00	5.12	41.81	2.5	2.3

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol (+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 15	6.10	19.50	0.25	1.04	26.89	55.90	41.12	48.1
15 - 35	2.73	13.53	0.38	1.54	18.18	55.30	47.31	32.9
35 - 70	4.62	21.51	0.17	3.31	29.61	41.60	40.21	71.2
70 - 95	2.94	16.36	0.30	3.23	22.83	31.76	44.60	71.9
95 - 130	1.84	17.48	0.02	1.42	20.76	28.42	53.99	38.5

2.5. The Alluvial soils:

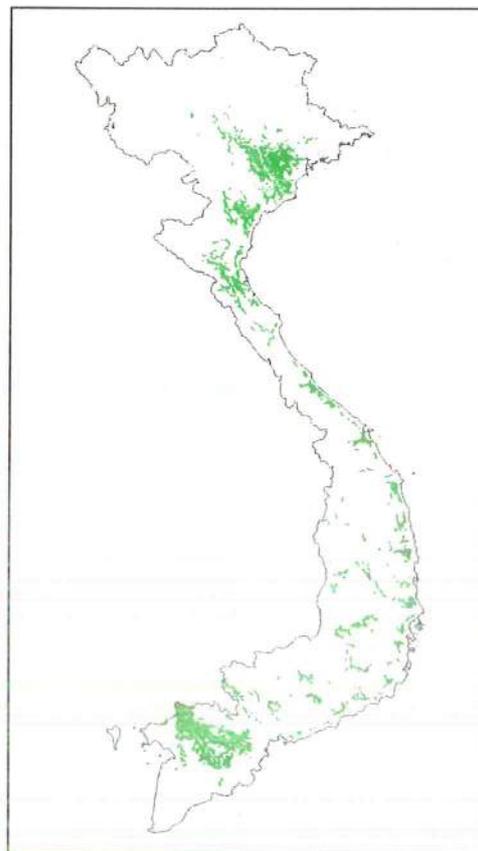
The alluvial soils are formed from different river alluvial deposit that made the basins or coastal flat plains. These are main soils for food and cash crop production thank to the flat topography and favorable irrigation.

There are approximately 3.5 millions hectares of alluvial soils national-wide (more than 10% of total natural area). The alluvial soil in Vietnam is mainly concentrated in the Red River and Mekong River Deltas and in other small area along the seashore.

Depending on geology and topography, the alluvial soils nearby the sea is affected by impact of rivers and seawater.

The alluvial soils are divided into 3 units as follows:

- Alluvial soils of the Red River system;
- Alluvial soils of the Mekong River system;
- and
- Alluvial soils of other river system.



- Alluvial soils of the Red River Delta:

The Alluvial soils of the Red River Delta have an area around 600,000 hectares, distribute mainly in Ha Tay, Hanoi, Hung Yen, Ha Nam, Nam Dinh, Thai Binh, Phu Tho, Vinh Phuc, etc.... Provinces.

Red River system has many characteristics influenced to Red river basin forming and properties: Irregular water regime, high alluvium contain and quality. Because of irregular water regime, alluvial soils of the Red River Delta have different texture by profile and plain surface. In some provinces such as Hanoi, Ha Tay, interposed clay, silt or sand layers can be found. The soils distributed nearby rivers are usually on higher topography and have sandy texture but the soils are far from rivers have finer texture (silt or clay).

In general, the alluvial soils of the Red River Delta are good soils. Soils have a medium texture, bright brown colour, neutral reaction, high base saturation, OC and total Nitrogen are medium and both total phosphorus and potassium are rather high.

The alluvial soils of the Red River Delta are good soils for annual crop production such as rice, maize, bean, tomato, vegetable and fruit trees.

In the intensive regions, rice yield can reach 14 - 15 tons/hectare/year, corn yield can reach 3 - 4 tons/hectare/season, potato yield can reach 20 - 25 tons/hectare/season.

Soil profile **VN 03** is characterized for this soil unit.

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 03



Location:

- Commune: Van Tao
- District: Thuong Tin
- Province: Ha Tay

Soil name:

- VIETNAMESE: *Alluvial soils of the Red River Delta*
- FAO-UNESCO: *Eutric Fluvisols*
- USDA (Soil Taxonomy): *Udifuvents*



THE INFORMATION OF SOIL PROFILE VN 03

Location: Van Tao Commune, Thuong Tin District, Ha Tay Province

Latitude: 20° 52' 00" N; **Longitude:** 105° 57' 00" E; **Elevation:** 3 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Summer rice just harvested

Soil name: *Vietnamese:* Alluvial soils of the Red River Delta (1976); Alluvial soils (1996)

Alluvial soils of the Red River Delta

FAO-UNESCO-WRB: Eutric Fluvisols

USDA (Soil Taxonomy): Udifluvents

Soil profile description:

Ap (0 - 27 cm):	Dull reddish brown (5YR 4/3 moist; 7.5YR 6/3 dry); clay loam; moist; many rice roots; many small cracks along profile; clear smooth boundary.
Aw (27 - 56 cm):	Brown (7.5YR 4/4 moist; 7.5YR 6/3 dry); sandy loam; thin layer of slightly coarse sand at the bottom thickness of 1-2 cm; moist; some rice roots; few dark brown mottles; gradual smooth boundary.
B (56 - 76 cm):	Brown (7.5YR 4/6 moist; 7.5YR 6/4 dry); few black brown mottles (7.5YR 3/2 moist; 7.5YR 4/3 dry); sandy loam; porous; friable; moist; gradual smooth boundary.
BC1 (76 - 97 cm):	Brown (7.5YR 4/4 moist; 7.5YR 6/4 dry); sandy loam; friable; porous; moist; many black brown mottles; gradual smooth boundary.
BC2 (97 - 112 cm):	Brown (7.5YR 4/6 moist; 7.5YR 6/4 dry); few black brown mottles (7.5YR 3/2 moist; 7.5YR 4/3 dry); sandy loam; moist; gradual smooth boundary.
BC3 (112 - 131 cm):	Brown (7.5YR 4/4 moist; 7.5YR 6/4 dry); few black brown mottles (7.5YR 3/2 moist; 7.5YR 4/3 dry); sand; moist.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 16	1.40	2.61	46.4	22.9	0.8	42.7	35.3	21.2
16 - 27	1.32	2.70	51.1	23.1	0.5	56.2	34.4	8.9
56 - 76	1.39	2.60	46.5	22.1	0.6	59.4	29.1	10.9
76 - 97	1.50	2.56	41.4	20.0	0.3	66.5	25.3	7.9
112 - 131	1.30	2.59	49.8	27.6	0.5	92.1	2.4	5.0

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 16	0.96	0.12	0.04	1.69	4.70	7.06	0.04	0.56	8.1	7.1
16 - 27	0.81	0.09	0.03	1.58	3.30	6.12	Trace	0.38	8.4	6.7
56 - 76	0.78	0.08	0.02	1.29	3.15	5.65	Trace	0.35	8.7	7.1
76 - 97	0.67	0.06	0.02	1.38	3.20	5.65	Trace	0.38	8.7	6.9
112 - 131	0.52	0.05	0.04	1.24	2.70	6.12	Trace	0.42	8.8	7.1

Soil horizon thickness, cm	Exchangeable Cation, cmol(+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 16	6.60	0.43	0.15	0.32	7.50	13.52	24.46	55.4
16 - 27	8.55	0.43	0.13	0.26	9.37	11.48	20.86	81.6
56 - 76	6.65	0.41	0.12	0.27	7.45	10.57	13.33	70.4
76 - 97	6.47	0.46	0.12	0.21	7.32	10.82	14.93	67.6
112 - 131	5.13	0.48	0.13	0.30	6.04	9.49	15.31	63.6

- Alluvial soils of the Mekong River Delta:

The Mekong River is the one of big rivers in the World, flows through 6 countries (China, Myanmar, Laos, Thailand, Cambodia and Vietnam) and flows to the sea in Vietnam territory by 9 estuaries (Local name is Nine Dragons). Unlike Red River, Mekong River has regular water regime. That is why there is no dam in Mekong Delta. Suspended alluvium contain is small, even in the rainy flooding season it reaches 250 g/cm³ but total water is very big (around 1,400 milliards cubic meters) that makes very high of total suspended alluvium (around 1 - 1.5 milliards cubic meters). This alluvium spreads equally in the plain through 3,000 km of the dense system of small rivers, ditches and canals and makes plain more flatly compared with Red River Delta. In comparison with Red River Delta, soils of Mekong Delta have more heavy texture and unclear horizon stratification.

Because of without dams and very dense system of canals and ditches, there is very complicated interposition between acid sulfate, saline and alluvial soils. Generally, alluvial soils that distribute in higher land strips are usually nonsaline-affected or nonacid-affected. In addition, because of low process of silt deposit and long dry season, the alluvial soils of Mekong Delta are strongly changed with more acid and occurrence of Cambic horizon.

Alluvial soils of the Mekong Delta have an area about 850,000 hectares distributed in almost Provinces of the Mekong River Delta, lengthening along 2 banks of Hau Giang and Tien Giang rivers. They are also good soils with neutral or weakly acid pH. OC and total N content are medium; total potassium is quite high but total phosphorus is low. Colour of soil is normally greyish brown.

Alluvial soils of Mekong Delta are suitable for paddy, annual crops and fruit trees. In the intensive areas, rice yield can reach 12 - 13 tons/hectare/year. It is necessary to apply new high yield crop varieties, complete irrigation system and balance fertilizers (especially phosphorus fertilizers) in order to have high and stable yields.

Soil profiles **VN 32** and **VN 36** are characterized for alluvial soils of the Mekong Delta.

- Alluvial soil of the other rivers:

Excluding alluvial soils of the Red and Mekong River Deltas, there are alluvial soils of the other rivers in Vietnam such as: Thai Binh river (about 300,000 hectares), Ma river (about 230,000 hectares), Lam river (about 250,000 hectares), Ba river (about 70,000 hectares), Dong Nai river (about 35,000 hectares), etc...

Except for alluvial soils of the Thai Binh and Ba rivers, texture of alluvial soils of the other rivers is lower than alluvial soils of the Red River and Mekong River. Total OC, nitrogen, phosphorus and potassium contents are also lower than that above mentioned.

In spite of lower soil fertility, these soils are also suitable for rice, cash crops and fruit trees. In order to have high and stable yields, it is necessary to apply advanced technologies of irrigation and crop varieties. Organic mixed with mineral fertilizers and biofertilizers should be used in balanced proportion.

Soil profiles **VN 05**, **VN 26**, **VN 24**, **VN 51**, **VN 55** and **VN 58** are characterized for alluvial soils of the other rivers.

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 32



Location:

- *Village:* No 11
- *Town:* Cao Lanh
- *Province:* Dong Thap

Soil name:

- *VIETNAMESE:* Alluvial soils of the Mekong River
- *FAO-UNESCO:* Eutric Fluvisols
- *USDA (Soil Taxonomy):* Ustifluvents

THE INFORMATION OF SOIL PROFILE VN 32

Location: Village No 11, Cao Lanh Town, Dong Thap Province

Latitude: 10° 29' 45" N; **Longitude:** 105° 35' 00" E; **Elevation:** 2 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Rice

Soil name: *Vietnamese:* Alluvial soils of the Mekong River (1976); Eutric Fluvisols (1996)

Alluvial soils of the Mekong River

FAO-UNESCO-WRB: Eutric Fluvisols

USDA (Soil Taxonomy): Ustifluvents

Soil profile description:

- Ap1 (0 - 10 cm): Dull reddish brown (5YR 4/3 moist; 7.5YR 5/3 dry); silty loam; moist; plastics; slightly firm; many rice roots; few vertical cracks; gradual smooth boundary.
- Ap2 (10 - 20 cm): Greyish brown (5YR 4/2 moist; 7.5YR 6/2 dry); clay loam; moist; plastics; sticky; firm; many white rice roots; some black organic mottles; some cracks; clear smooth boundary.
- Bw1 (20 - 55 cm): Brown (7.5YR 4/6 moist; 7.5YR 5/6 dry); greyish brown mottles (5YR 4/2 moist; 7.5YR 4/6 dry); clay; moist; slightly firm; some rice roots; some brownish black iron mottles and reddish brown concretions; gradual smooth boundary.
- Bw2 (55 - 95 cm): Brown (7.5YR 4/6 moist; 7.5YR 5/6 dry); dull reddish brown mottles (5YR 5/2.5 moist; 7.5YR 5/2 dry); clay; moist; plastic; slightly firm; some blackish brown concretions in lower part; clear smooth boundary.
- BC1 (95 - 130 cm): Yellowish grey (2.5Y 6/1 moist; 2.5Y 7/1 dry); clay; wet; slightly firm; yellow brown mottles (7.5YR 5/6 moist; 7.5YR 5/8 dry).

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 10	1.06	2.56	58.6	26.6	1.2	15.3	42.4	41.1
10 - 20	1.44	2.69	46.5	21.3	0.2	12.6	41.4	45.8
20 - 55	1.39	2.61	46.7	24.0	0.2	17.5	34.7	47.6
55 - 95	1.37	2.61	47.5	24.1	0.2	10.5	38.5	50.8
95 - 130	1.41	2.56	44.9	23.4	0.2	6.8	35.1	57.9

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 10	1.93	0.10	0.13	2.10	2.73	5.65	0.04	0.31	4.5	4.0
10 - 20	0.77	0.04	0.08	2.21	1.06	5.65	Trace	0.15	6.2	5.7
20 - 55	0.52	0.04	0.08	2.21	0.72	5.65	Trace	0.15	6.6	6.0
55 - 95	0.45	0.02	0.07	1.74	0.32	4.71	Trace	0.17	6.5	6.0
95 - 130	0.23	0.02	0.06	1.74	0.30	3.76	0.02	0.27	6.5	6.0

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 10	6.05	1.75	0.12	0.27	8.19	13.04	22.03	62.8
10 - 20	9.64	3.31	0.12	0.25	13.32	14.16	26.40	94.1
20 - 55	8.45	3.27	0.12	0.21	12.05	13.20	21.80	91.3
55 - 95	7.57	3.08	0.10	0.19	10.94	16.80	26.60	65.1
95 - 130	8.02	2.34	0.08	0.14	10.58	13.76	23.25	76.9

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 36



Location:

- Commune: Thoi Thanh
- District: O Mon
- Province: Can Tho

Soil name:

- VIETNAMESE: *Alluvial soils of the Mekong Delta with cambic horizon*
- FAO-UNESCO: *Cambic Fluvisols*
- USDA (Soil Taxonomy): *Ustifluvents*

THE INFORMATION OF SOIL PROFILE VN 36

Location: Thoi Thanh Commune, O Mon District, Can Tho Province

Latitude: 10° 04' 33" N; **Longitude:** 105° 35' 30" E; **Elevation:** 1 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Summer rice

Soil name: *Vietnamese:* Alluvial soils of the Mekong Delta (1976);

Alluvial soils with cambic horizon (1996);

Alluvial soils of the Mekong Delta with cambic horizon

FAO-UNESCO-WRB: Cambic Fluvisols

USDA (Soil Taxonomy): Ustifluvents

Soil profile description:

- Ap (0 - 10 cm): Reddish gray (2.5YR 4/1.5 moist; 2.5Y 6/2 dry); clay; wet; pasty at the top; harder at the bottom; many yellowish brown iron mottles along rice roots; many roots and straw residues; some black organic mottles; gradual smooth boundary.
- AB (10 - 35 cm): Brownish black (7.5YR 2/2 moist; 5Y 6/2 dry); clay; wet; plastic; sticky; slightly firm; some yellow brown iron mottles in upper part and some greyish olive clay mottles (5Y 6/2 moist; 5Y 7/2 dry) in lower; many rice roots; some small black mottles; gradual smooth boundary.
- Bw1 (35 - 80 cm): Dull orange (7.5YR 5/5 moist; 10YR 7/1 dry); clay; wet; slightly firm; fine; some brownish yellow (7.5YR 4/6 moist; 7.5YR 6/8 dry) hard concretion mottles in the middle of the horizon; friable; gradual smooth boundary.
- Bw2 (80 - 130 cm): Reddish gray (2.5Y 4/1 moist; 2.5Y 6/2 dry); clay; wet; some yellow iron mottles and concretions along the roots and organic residues.

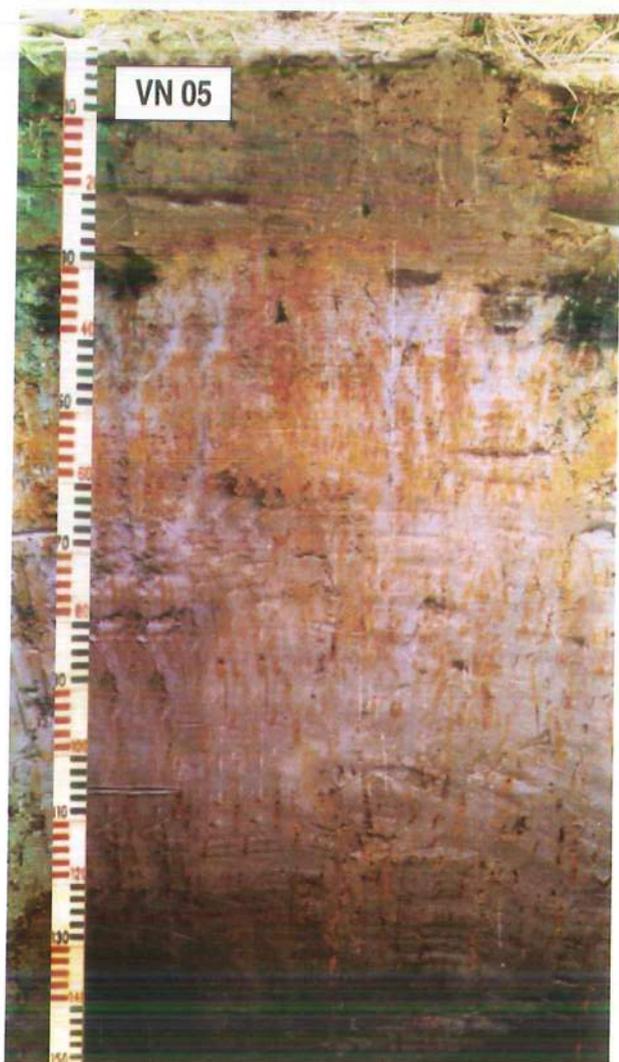
Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 10	0.79	2.41	68.7	41.0	0.2	10.8	26.8	62.3
10 - 35	1.07	2.49	49.0	28.0	0.2	10.5	21.6	67.7
35 - 80	1.10	2.59	51.3	30.8	1.2	9.8	37.2	51.8
80 - 130	0.94	2.58	53.3	30.0	0.2	12.5	31.6	55.7

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 10	2.64	0.12	0.09	1.99	2.17	7.23	1.66	10.89	4.7	4.2
10 - 35	1.55	0.09	0.06	1.99	0.67	6.03	1.25	9.15	5.4	5.2
35 - 80	0.28	0.07	0.05	2.02	0.35	8.44	0.08	3.48	5.6	5.3
80 - 130	0.76	0.05	0.07	2.10	0.81	9.64	0.12	4.02	5.3	5.1

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 10	6.45	3.91	0.15	0.28	10.79	17.20	24.03	62.7
10 - 35	7.95	8.07	0.12	0.51	16.65	16.72	21.40	99.6
35 - 80	5.86	8.81	0.17	0.56	15.40	18.56	23.80	82.9
80 - 130	4.29	8.34	0.20	0.82	13.65	18.16	21.90	75.2

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 05



Location:

- Commune: Thai Hoc
- District: Cam Binh
- Province: Hai Duong

Soil name:

- VIETNAMESE: *Alluvial soils of the Thai Binh River with cambic horizon*
- FAO-UNESCO: *Cambic Fluvisols*
- USDA (Soil Taxonomy): *Udifluvents*

THE INFORMATION OF SOIL PROFILE VN 05

Location: Thai Hoc Commune, Cam Binh District, Hai Duong Province

Latitude: 20° 52' 00" N; **Longitude:** 106° 10' 00" E; **Elevation:** 10 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0-3°

Present land use: Just harvested spring rice

Soil name: *Vietnamese:* Alluvial soils of the other rivers (1976); Dystric Fluvisols (1996)

Alluvial soils of the Thai Binh River with cambic horizon

FAO-UNESCO-WRB: Cambic Fluvisols

USDA (Soil Taxonomy): Udifluvents

Soil profile description:

- Ap1 (0 - 15 cm): Brown (7.5YR 4/3 moist; 10YR 7/3 dry); clay; moist; plastic; fine; many rice roots; gradual smooth boundary.
- Ap2 (15 - 23 cm): Dull brown (7.5YR 5/4 moist; 10YR 7/3 dry); clay; moist; firm, hard; fine; few rice roots; some black cracks; clear smooth boundary.
- Bw (23 - 58 cm): Bright brown (7.5YR 5/8 moist; 7.5YR 7/6 dry); many brown cracks (7.5YR 4/6 moist; 7.5YR 6/8 dry); crumble concretions with greyish yellow brown colour (10YR 5/2 moist; 10YR 8/2 dry); clay; moist; friable structure; clear smooth boundary.
- Cgw (58 - 100 cm): Greyish yellow brown (10YR 6/2 moist; 10YR 8/2 dry); few yellowish brown (10YR 5/6 moist; 10YR 7/6 dry); clay; wet; gley; gradual smooth boundary.
- Cg1 (100 - 150 cm): Greyish yellow brown (10YR 6/2 moist; 10YR 8/2 dry); few yellow colour mottles mixed concretions (7.5YR 4/6 moist; 7.5YR 7/6 dry); brightly yellow brown mottles (10YR 7/6 moist; 10YR 6/6 dry); clay; wet; gley.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	1.17	2.41	51.5	31.9	0.7	32.9	20.9	45.5
15 - 23	1.44	2.41	40.2	22.3	0.6	17.4	39.3	42.7
23 - 58	1.09	2.48	56.0	35.7	2.9	20.7	33.6	42.8
58 - 100	1.14	2.42	52.9	32.1	1.4	16.8	30.2	51.6
100 - 150	1.04	2.46	57.7	35.1	1.1	19.9	37.9	41.1

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 15	1.20	0.12	0.03	1.24	7.80	3.05	2.00	7.70	5.4	4.5
15 - 23	1.00	0.11	0.03	1.24	7.60	4.52	0.70	4.00	5.2	4.1
23 - 58	0.90	0.09	0.03	1.65	0.90	6.02	10.61	17.60	4.9	4.0
58 - 100	0.87	0.09	0.02	1.54	0.70	6.02	9.50	18.80	4.7	3.8
100 - 150	0.80	0.08	0.02	1.48	0.80	7.53	8.20	16.32	4.7	3.8

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 15	4.43	0.47	0.12	0.36	5.38	8.26	13.96	65.1
15 - 23	5.51	1.29	0.15	0.43	7.38	8.56	14.46	86.2
23 - 58	1.15	0.47	0.24	0.90	2.76	10.88	18.38	25.4
58 - 100	1.14	0.49	0.26	0.95	2.84	9.26	15.65	30.7
100 - 150	0.98	0.44	0.33	1.09	2.84	10.67	18.03	26.6

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 24



Location:

- Commune: Hung Xa
- District: Hung Nguyen
- Province: Nghe An

Soil name:

- VIETNAMESE: *Alluvial soils of the Lam River*
- FAO-UNESCO: *Dystric Fluvisols*
- USDA (Soil Taxonomy): *Udifluvents*

THE INFORMATION OF SOIL PROFILE VN 24

Location: Hung Xa Commune, Hung Nguyen District, Nghe An Province.

Latitude: 18° 37' 00" N; **Longitude:** 105° 36' 00" E; **Elevation:** 4 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Rice just harvested

Soil name: *Vietnamese:* Alluvial soils of the other rivers (1976); Dystric Fluvisols (1996)

Alluvial soils of the Lam River

FAO-UNESCO-WRB: Dystric Fluvisols

USDA (Soil Taxonomy): Udifluvents

Soil profile description:

- Apl (0 - 20 cm): Olive brown (2.5Y 4/3 moist; 2.5Y 8/2 dry); clay loam; moist; many roots; clear smooth boundary.
- Ap2 (20 - 28 cm): Yellowish brown (2.5Y 5/3 moist; 2.5YR 7/3 dry); clay; moist; fine; firm; clear smooth boundary.
- AB (28 - 50 cm): Yellowish brown (2.5Y 5/4 moist; 2.5Y 7/4 dry); clay loam; moist; fine; few dark brown colour concretions mottles; clear smooth boundary.
- Bw1 (50 - 80 cm): Olive brown (2.5Y 4/6 moist; 2.5Y 7/4 dry); clay loam; moist; few dark brown concretions mottles; clear smooth boundary.
- Bw2 (80 - 105 cm): Dark grayish (2.5Y 4/2 moist; 2.5Y 7/3 dry); silty clay; moist; firm; few dark brown concretions mottles; gradual smooth boundary.
- Bw3 (105 - 130 cm): Olive brown (2.5Y 4/4 moist; 10YR 7/4 dry); silty clay loam; moist; some yellow brown mottles.

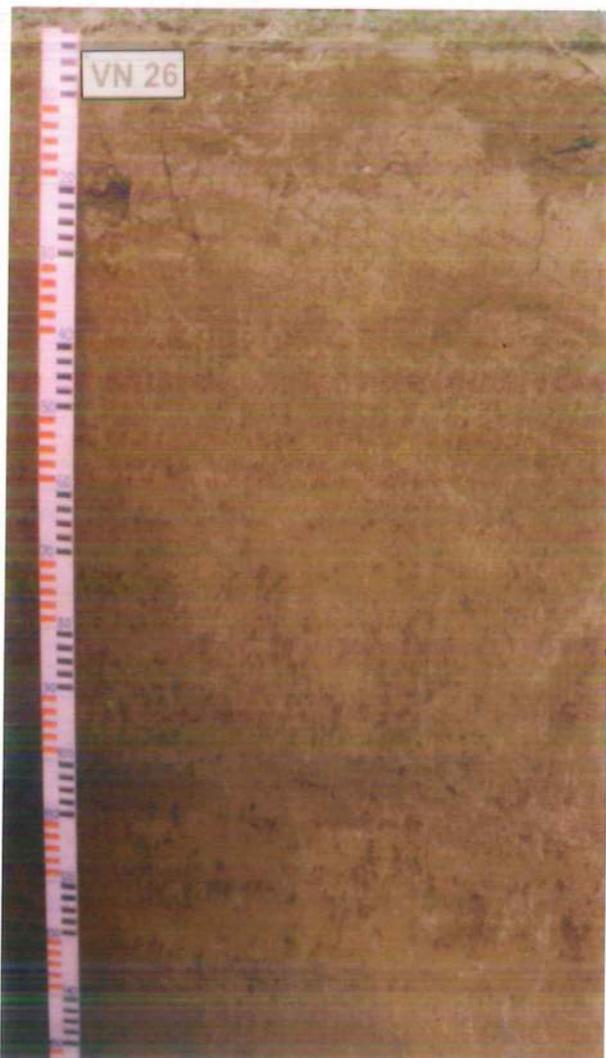
Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 20	0.70	2.52	72.2	84.8	2.5	29.7	35.9	31.9
20 - 28	1.51	2.65	63.8	26.9	2.8	28.7	30.1	37.4
28 - 50	1.54	2.66	42.1	24.6	1.1	22.5	37.5	38.9
50 - 80	1.46	2.67	45.3	30.1	2.0	17.7	46.2	34.1
80 - 105	1.50	2.77	45.8	28.2	2.0	9.8	46.2	42.0
105 - 130	1.51	2.70	44.0	29.7	2.4	16.4	47.1	34.1

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 20	1.93	0.19	0.14	1.77	5.50	12.24	0.10	12.00	5.6	4.6
20 - 28	0.31	0.06	0.07	1.92	6.00	7.06	0.04	4.00	7.5	6.1
28 - 50	0.22	0.04	0.08	2.32	2.00	4.71	0.03	3.50	7.9	6.2
50 - 80	0.38	0.06	0.07	2.64	3.75	4.71	0.03	4.00	7.5	5.8
80 - 105	0.26	0.05	0.10	2.61	3.13	2.35	0.04	5.00	7.6	5.9
105 - 130	0.21	0.05	0.07	2.85	3.00	2.35	0.03	4.00	7.4	5.8

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 20	2.32	0.63	0.26	0.11	3.32	6.40	14.59	51.9
20 - 28	2.50	1.05	0.15	0.11	3.81	6.50	12.50	58.6
28 - 50	3.95	1.76	0.10	0.11	5.56	6.28	10.61	88.5
50 - 80	4.22	2.90	0.10	0.20	7.42	7.76	19.94	95.6
80 - 105	5.09	1.95	0.05	0.11	7.21	10.82	18.93	66.6
105 - 130	4.41	3.32	0.05	0.11	7.98	8.12	20.87	98.3

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 26



Location:

- *Commune:* Dinh Tan
- *District:* Yen Dinh
- *Province:* Thanh Hoa

Soil name:

- *VIETNAMESE:* Alluvial soils of the Ma River
- *FAO-UNESCO:* Dystric Fluvisols
- *USDA (Soil Taxonomy):* Udifluvents

THE INFORMATION OF SOIL PROFILE VN 26

Location: Dinh Tan Commune, Yen Dinh District, Thanh Hoa Province

Latitude: 20° 00' 00" N; **Longitude:** 105° 38' 00" E; **Elevation:** 3 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0- 3°;

Present land use: Rice just harvested

Soil name: *Vietnamese:* Alluvial soils of the other rivers (1976); Dystric Fluvisols (1996)

Alluvial soils of the Ma River

FAO-UNESCO-WRB: Dystric Fluvisols

USDA (Soil Taxonomy): Udifluvents

Soil profile description:

- Ap1 (0 - 10 cm): Olive brown (2.5Y 5/4 moist; 2.5Y 6/3 dry); clay loam; dry; firm, hard; many cracks; many grass roots; gradual smooth boundary.
- Ap2 (10 - 30 cm): Olive brown (2.5Y 4/3 moist; 2.5Y 6/3 dry); silty clay; moister than over lying horizon; plastic; firm; some cracks; some grass roots; some iron mottles; gradual smooth boundary.
- B1 (30 - 70 cm): Olive brown (2.5Y 4/4 moist; 2.5Y 6/4 dry); silty clay; moist; firm; plastic; iron and black concretion mottles; gradual smooth boundary.
- B2 (70 - 100 cm): Brown (10YR 4/4 moist; 2.5Y 6/4 dry); silty clay; moist; more sticky and plastic than upper horizon; more iron and black concretion mottles than upper horizon; gradual smooth boundary.
- BC1 (100-130cm): Dull yellowish brown (10YR 5/3 moist; 2.5Y 7/2 dry); yellowish brown (10YR 6/6 moist; 2.5Y 6/4 dry); clay; moist; plastic; sticky; few concretions.

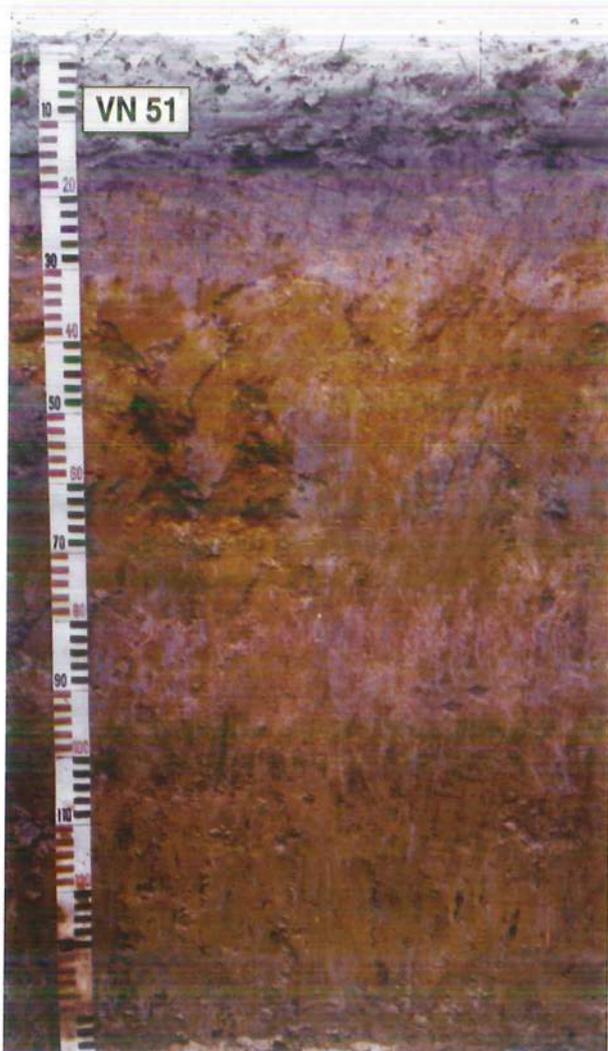
Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 10	1.31	2.65	50.5	26.3	2.9	22.4	39.9	34.8
10 - 30	1.49	2.74	45.6	27.2	1.8	16.2	40.2	42.1
30 - 70	1.46	2.69	45.7	29.2	3.2	9.0	46.6	41.2
70 - 100	1.39	2.75	49.4	33.2	5.6	13.4	41.0	40.0
100 - 130	1.22	2.71	54.6	43.4	3.2	13.8	32.7	50.3

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 10	1.15	0.15	0.10	1.48	7.25	3.76	0.12	8.50	6.2	4.7
10 - 30	0.61	0.08	0.13	1.92	31.0	3.76	0.03	5.50	7.0	6.1
30 - 70	0.38	0.06	0.14	2.17	7.50	4.71	0.03	6.00	7.7	5.8
70 - 100	0.39	0.06	0.17	2.20	12.00	6.12	0.03	7.00	7.6	5.6
100 - 130	0.41	0.06	0.11	1.62	3.25	3.76	0.03	10.50	7.6	5.3

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 10	2.83	0.57	0.08	0.09	3.57	17.40	21.76	20.5
10 - 30	4.82	1.40	0.08	0.17	6.47	10.56	27.85	61.3
30 - 70	4.19	2.03	0.10	0.17	6.49	15.60	24.07	41.6
70 - 100	5.33	1.19	0.13	0.23	6.88	14.60	24.00	47.1
100 - 130	3.78	1.22	0.08	0.17	5.25	17.32	19.27	30.3

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 51



Location:

- Commune: Hoa Thang
- District: Tuy Hoa
- Province: Phu Yen

Soil name:

- VIETNAMESE: Alluvial soils of the Ba River
- FAO-UNESCO: Dystric Fluvisols
- USDA (Soil Taxonomy): Ustifluvents

THE INFORMATION OF SOIL PROFILE VN 51

Location: Hoa Thang Commune, Tuy Hoa District, Phu Yen Province

Latitude: 13° 01' 50" N; **Longitude:** 109° 14' 45" E; **Elevation:** 10 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Rice just harvested

Soil name: *Vietnamese:* Alluvial soils of the other rivers (1976); Dystric Fluvisols (1996)

Alluvial soils of the Ba River

FAO-UNESCO-WRB: Dystric Fluvisols

USDA (Soil Taxonomy): Ustifluvents

Soil profile description:

- Ap (0 - 15 cm): Grayish brown (5YR 5/2 moist; 5Y 6/1 dry); silt loam; moist; many rice roots; clear smooth boundary.
- AB (15 - 30 cm): Reddish gray (2.5YR 5/1 moist; 7.5Y 7/1 dry); sandy clay loam; moist; firm; some rice roots; many small brown concretions; many sand mottles; clear smooth boundary.
- Bt1 (30 - 50 cm): Dull brown (7.5YR 5/4 moist; 10YR 6/8 dry); sandy loam; moist; slightly firm; fine granular structure; many iron brown crack; some dark gray clay mottles; gradual smooth boundary.
- Bt2 (50 - 75 cm): Gray (5 Y 5/1 moist; 2.5YR 5/2 dry); moist; sandy clay loam; firm; yellow brown mottles on upper horizon; brown crack mottles; gradual smooth boundary.
- Bt3 (75 - 110 cm): Brown (7.5 YR 4/3 moist; 2.5Y 6/1 dry); sandy clay loam; moist; firm; many gray and yellow clay; some black brown mottles; gradual smooth boundary.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	0.91	2.75	38.0	39.3	4.70	57.6	11.9	25.8
15 - 30	1.61	2.59	38.0	19.3	15.4	57.9	12.0	14.7
30 - 50	1.56	2.54	39.0	20.5	2.60	51.7	14.8	30.9
50 - 75	1.57	2.59	40.0	20.0	3.30	49.1	17.7	29.9
75 - 110	1.59	2.58	38.0	18.9	10.9	38.6	17.1	33.4

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 15	1.00	0.10	0.053	2.42	2.14	10.83	1.40	6.61	5.8	4.5
15 - 30	0.58	0.05	0.037	2.93	0.76	2.00	0.08	1.98	5.3	4.1
30 - 50	0.90	0.06	0.035	2.29	0.57	3.76	0.02	1.27	5.8	4.8
50 - 75	0.87	0.09	0.035	2.27	1.31	3.76	0.16	2.34	6.0	4.3
75 - 110	0.58	0.04	0.052	2.20	0.63	3.76	0.02	1.03	6.1	4.1

Soil horizon thickness, cm	Exchangeable Cation, cmol(+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 15	3.40	1.72	0.23	0.21	5.56	10.00	35.2	55.6
15 - 30	3.04	1.70	0.05	0.10	4.89	14.48	51.8	33.7
30 - 50	4.81	2.70	0.08	0.22	6.81	15.36	30.9	39.7
50 - 75	3.60	2.40	0.08	0.23	6.31	13.32	31.6	47.3
75 - 110	3.70	2.62	0.08	0.40	7.80	14.52	28.2	53.7

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 55



Location:

- Commune: Thanh Luong
- District: Dien Bien
- Province: Lai Chau

Soil name:

- VIETNAMESE: *Alluvial soils of the Nam Rom River*
- FAO-UNESCO: *Dystric Fluvisols*
- USDA (Soil Taxonomy): *Ustifluvents*

THE INFORMATION OF SOIL PROFILE VN 55

Location: Thanh Luong Commune, Dien Bien District, Lai Chau Province.

Latitude: 21° 19' 30" N; **Longitude:** 102° 59' 05" E; **Elevation:** 480 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Rice

Soil name: *Vietnamese:* Alluvial soils of the other rivers (1976); Dystric Fluvisols (1996)

Alluvial soils of the Nam Rom River

FAO-UNESCO-WRB: Dystric Fluvisols

USDA (Soil Taxonomy): Ustifluvents

Soil profile description:

- Ap (0 - 15 cm): Dull yellow (2.5Y 6/3 moist; 2.5Y 7/2 dry); loam; moist; yellow iron layer on surface; some organic remains; clear smooth boundary.
- AB (15 - 25 cm): Yellowish gray (2.5Y 5/1 moist; 2.5Y 7/1 dry); sandy clay loam; firm; plastic; stick; many small roots; Yellowish brown (2.5Y 5/4 moist; 2.5Y 6/4 dry); many yellow brown iron mottles; gradual smooth boundary.
- Bt1 (25 - 40 cm): Bright yellowish brown (2.5Y 5/4 moist; 2.5Y 7/4 dry); Yellowish brown (2.5Y 5/4 moist; 2.5Y 6/4 dry); clay loam; moist; firm; many rice roots; gradual smooth boundary.
- Bt2 (40 - 75 cm): Bright yellowish brown (10 YR 6/6 moist; 10YR 7/6 dry); Red (7.5R 4/8 moist; 2.5YR 5/8 dry); Gray olive (5 Y 4/2 moist; 5Y 8/2 dry); clay loam; moist; firm; some rice roots; some cracks; gradual smooth boundary.
- Bw (75 - 105 cm): Reddish brown (2.5YR 4/6 moist; 2.5YR 5/6 dry); Grayish olive (2.5Y 6/2 moist; 2.5Y 8/1 dry); Dark reddish (7.5R 3/6 moist; 10R 4/6 dry); clay loam; moist; firm; some cracks.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	0.81	2.55	68.2	21.4	5.8	29.2	38.5	26.5
15 - 25	1.28	2.58	50.4	24.2	10.6	35.8	22.7	30.9
25 - 40	1.56	2.65	42.6	20.5	9.3	28.6	32.4	29.7
40 - 75	1.44	2.62	45.0	21.8	1.6	26.0	36.2	36.2
75 - 105	1.46	2.64	44.7	25.3	2.8	24.8	35.7	36.7

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 15	1.76	0.20	0.09	1.82	4.53	3.62	0.84	5.54	6.3	5.5
15 - 25	1.71	0.14	0.05	2.22	1.40	2.41	0.08	1.82	6.5	5.9
25 - 40	1.40	0.13	0.05	2.40	0.58	2.41	0.08	1.78	6.9	5.9
40 - 75	1.21	0.11	0.05	2.23	0.40	3.62	0.93	3.38	6.7	5.8
75 - 105	1.09	0.11	0.05	2.27	0.32	4.82	0.64	3.01	6.7	5.7

Soil horizon thickness, cm	Exchangeable Cation, cmol(+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 15	1.75	0.30	0.08	0.05	2.18	10.60	12.77	20.6
15 - 25	2.10	0.63	0.05	0.05	2.83	9.08	10.48	31.2
25 - 40	1.85	0.93	0.05	0.06	2.89	9.40	13.88	30.7
40 - 75	2.89	0.65	0.08	0.05	3.67	9.80	11.49	37.4
75 - 105	1.36	1.19	0.10	0.06	2.71	10.00	13.52	27.1

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 58



Location:

- Commune: Tan Binh
- District: Vinh Cuu
- Province: Dong Nai

Soil name:

- VIETNAMESE: *Alluvial soils of the Dong Nai River*
- FAO-UNESCO: *Dystric Fluvisols*
- USDA (Soil Taxonomy): *Ustifluvents*

THE INFORMATION OF SOIL PROFILE VN 58

Location: Tan Binh Commune, Vinh Cuu District, Dong Nai Province

Latitude: 10° 59' 30" N; **Longitude:** 106° 47' 00" E; **Elevation:** 30 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Grape fruit planted in 1997

Soil name: *Vietnamese:* Alluvial soils of the other rivers (1976); Dystric Fluvisols (1996)

Alluvial soils of the Dong Nai River

FAO-UNESCO-WRB: Dystric Fluvisols

USDA (Soil Taxonomy): Ustifluvents

Soil profile description:

Ap (0 - 10 cm):	Bright brown (7.5YR 4/6 moist; 10YR 5/6 dry); sandy clay loam; moist; tender; many black organic mottles; many animal cavernous; some fragments rock; gradual smooth boundary.
AB (10 - 20 cm):	Bright brown (7.5YR 4/6 moist; 10YR 5/6 dry); clay loam; moist; slightly firm; many small roots; many animal cavernous; some small black organic mottles; some red concretions diameter of 3 cm; gradual smooth boundary.
Btc1 (20 - 70 cm):	Brown (7.5Y 5/6 moist; 7.5Y 5/6 dry); clay; moist; slightly firm; many roots; many red concretions diameter of 1 cm; some animal cavernous; gradual smooth boundary.
Btc2 (70 - 120 cm):	Bright brown (7.5YR 5/6 moist; 7.5YR 5/6 dry); clay; moist; porous; many small roots; many black concretions mottles; many animal cavernous; gradual smooth boundary.
BC (120 - 150 cm):	Bright brown (7.5YR 5/6 moist; 7.5YR 6/6 dry); clay; moist; porous; many brown concretion mottles; many animal caves.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 10	1.29	2.69	52.1	25.0	7.7	39.5	24.2	28.6
10 - 20	1.39	2.72	49.0	22.7	6.8	32.2	25.5	35.5
20 - 70	1.30	2.74	52.6	25.4	4.8	28.0	23.1	44.1
70 - 120	1.27	2.73	53.4	25.6	3.3	33.1	18.4	45.2

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 10	1.21	0.11	0.21	1.07	2.33	19.28	0.20	4.67	6.3	5.7
10 - 20	1.19	0.12	0.18	1.18	2.24	14.46	0.76	4.87	6.1	5.6
20 - 70	0.48	0.06	0.17	1.06	0.55	4.82	1.16	4.55	6.3	5.6
70 - 120	0.40	0.04	0.16	1.09	0.53	3.62	2.04	6.18	6.0	5.5

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 10	3.76	1.41	0.41	0.05	5.63	14.08	24.54	40.0
10 - 20	3.72	1.74	0.31	0.04	5.81	11.92	22.88	48.7
20 - 70	2.25	2.19	0.10	0.09	4.63	11.28	19.06	41.0
70 - 120	1.91	2.74	0.08	0.08	4.81	12.40	20.96	38.8

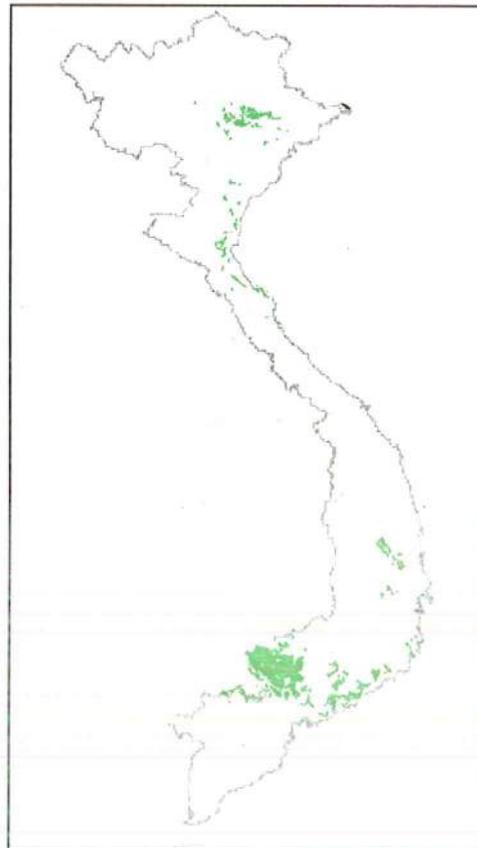
2.6. The Grey Degraded soils:

Local name of these soils is “Bac mau” because of 2 meanings: (i) OC and Fe contents are very low that made soil colour white, grey white; (ii) strongly leaching leads soils to become very poor in nutrients. These soils have an area of around 3 millions hectares.

Grey degraded soils are usually distributed in high topography, easy for process of leaching; soils have a light texture. Grey degraded soils are found mainly in the Southeast, High Plateau (Tay Nguyen) and in the midlands of the North.

There are 3 soil units in this soil group:

- Grey degraded soils on old alluviums.
- Grey degraded gleyic soils on old alluviums.
- Grey degraded soils derived from acid magmatic rocks and sandstones.



- *Grey degraded soils on old alluviums:*

These soils concentrate mainly in the East of the South Vietnam such as Tay Ninh Province and spread in some Provinces of the North Vietnam such as Vinh Phuc, Bac Giang, Bac Ninh, Thai Nguyen...Provinces. They occupy some 1.4 million hectares national-wide.

The grey degraded soils are derived from old alluvium terraces with elevation around 15 - 20 meters that have flat or slightly terrace topography without flooding. They have light texture of all horizons, usually varies from loam to sand. In spite of low fertility, grey degraded soils can give high crop yield if there were advanced technology applications.

Although nutrient lacking, grey degraded soils have many advantages: (i) Flat topography; (ii) Fresh and shallow underground water, easy to exploit for irrigation; (iii) High porosity, airy; and (iv) Low input for soil preparation.

In these soils, a lot of crops have been cultivated such as rubber, fruit trees, sugarcane, banana, maize, cassava and soybean.

Major technical measures are using organic fertilizers (especially green manure) in combination with inorganic fertilizers with balanced proportion; providing water in dry season.

Soil profile **VN 06** is characterized for this soil unit.

- Grey degraded gleyic soils on old alluviums:

The forming process of these soils is the same as above-mentioned grey degraded soils but these soils are usually derived on lower topography than that and flooded in rainy season. There are some 400,000 hectares of these soils.

Typical crop system on these soils is one rice-one cash crop (sweet potato, peanut, beans, tobacco, etc...) that characterized for North region and paddy fields of Trang Bang, Tay Ninh, Dong Nai Provinces in the South.

The topsoil is normally loamy fine with blue white colour. The plough horizon is slightly firm and gleyic property can be found in this layer. In comparison with grey degraded soils on old alluviums, these soils have higher OC content, and another nutrients are higher too.

Good regime of water supply and application of organic fertilizers and green manure in combination with mineral fertilizers based on balanced proportion is effective soil conservation measures.

- Grey degraded soils derived from acid magmatic rocks and sandstones.

These soils are concentrated mainly the Central High Plateau (Tay Nguyen) and scattered in along the seashore of Central region, in Quang Ninh, Thai Nguyen Provinces. The soil forming process resembles as on grey degraded soils on old alluviums but derived from acid magmatic rocks and sandstones. These soils occupy an area around 1.3 million hectares.

Soils are acid, have a low fertility, easy to become droughty. Except for some small areas in low terrace topography can be use for agricultural production, other in high topography should be used for forestry.

Soil profiles **VN 12** and **VN 34** are characterized for this soil unit.

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 06



Location:

- Commune: Thanh Xuan
- District: Soc Son
- City: Ha Noi

Soil name:

- VIETNAMESE: Gray degraded soils on old alluviums with plinthic horizon
- FAO-UNESCO: Plinthic Acrisols
- USDA (Soil Taxonomy): Plinthaquults

THE INFORMATION OF SOIL PROFILE VN 06

Location: Thanh Xuan Commune, Soc Son District, Ha Noi Capital

Latitude: 21° 14' 00" N; **Longitude:** 105° 46' 00" E; **Elevation:** 10 m (ASL)

Parent materials: Alluvium; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Just harvested glutinous sticky rice

Soil name: Vietnamese: Grey degraded soil on old alluviums (1976);

Grey degraded soils with plinthic horizon (1996);

Grey degraded soil on old alluviums with plinthic horizon

FAO-UNESCO-WRB: Plinthic Acrisols

USDA (Soil Taxonomy): Plinthaquults

Soil profile description:

Apl (0 - 13 cm):	Dull brown (7.5YR 5/4 moist; 10YR 7/3 dry); sandy clay loam; porous; slightly moist; many rice roots; clear smooth boundary.
Ap2 (13 - 22 cm):	Dull brown (7.5YR 6/3 moist; 7.5YR 6/3 dry); sandy clay loam; porous; firmer than above lying horizon; many brown cracks vertically profile; clear smooth boundary.
AB (22 - 31 cm):	Dull brown (10YR 6/4 moist; 10YR 8/4 dry); some white cracks (10YR 8/2 moist; 10YR 8/2 dry); sandy clay; slightly moist; firm; clear boundary.
Btw (31 - 60 cm):	Dull orange (7.5YR 7/3 moist; 7.5YR 8/2 dry); many brown red cracks (10YR 4/8 moist; 10YR 5/6 dry); silty clay; slightly moist; clear smooth boundary.
Btv1 (60 - 100 cm):	Dark reddish brown (7.5YR 3/6 moist; 10YR 5/6 dry); bright grey (2.5YR 8/2 moist; 10YR 8/1 dry); loamy; moist; plastic; firm; gradual boundary.
Btv2 (100 - 125 cm):	Dark reddish brown (7.5YR 3/6 moist; 10YR 5/6 dry); bright grey (2.5YR 8/2 moist; 10YR 8/1 dry); loamy; moist.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 13	1.20	2.52	52.4	18.9	1.0	58.7	29.7	10.6
13 - 22	1.70	2.68	36.6	12.1	1.1	58.3	29.4	11.2
22 - 31	1.60	2.67	40.1	14.9	0.5	53.8	36.3	9.4
31 - 60	1.60	2.60	38.5	19.9	0.9	40.4	28.2	30.5
60 - 100	1.40	2.56	45.3	25.2	1.0	36.9	10.9	51.2
100 - 125	1.40	2.53	44.7	25.8	0.5	37.3	11.9	50.3

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 13	1.20	0.10	0.03	0.18	0.90	5.65	0.40	3.51	5.1	4.2
13 - 22	0.39	0.04	0.03	0.21	7.60	3.76	0.04	1.38	5.8	4.9
22 - 31	0.13	0.02	0.02	0.21	0.70	2.82	0.04	0.84	6.6	5.7
31 - 60	0.13	0.03	0.02	0.59	1.00	3.76	2.63	8.77	5.1	3.6
60 - 100	0.11	0.04	0.02	0.98	0.40	4.23	10.11	27.41	4.8	3.3
100 - 125	0.06	0.03	0.02	1.11	0.50	4.71	9.50	28.90	4.6	3.3

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 13	1.68	0.28	0.12	0.90	2.98	5.62	19.89	53.0
13 - 22	1.70	0.30	0.08	0.46	2.54	3.79	10.57	67.0
22 - 31	1.32	0.22	0.06	0.23	1.83	2.68	7.47	68.3
31 - 60	1.70	0.06	0.08	0.49	2.73	7.05	18.12	38.7
160 - 100	0.78	0.31	0.09	0.45	1.63	10.74	18.15	15.2
100 - 125	0.38	0.36	0.10	0.44	1.28	16.08	27.17	8.0

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 12



Location:

- Commune: Hong Tien
- District: Pho Yen
- Province: Thai Nguyen

Soil name:

- VIETNAMESE: *Grey degraded soils on sandstones*
- FAO-UNESCO: *Haplic Acrisols*
- USDA (Soil Taxonomy): *Hapludults*

THE INFORMATION OF SOIL PROFILE VN 12

Location: Hong Tien Commune, Pho Yen District, Thai Nguyen Province

Latitude: 21° 26' 00" N; **Longitude:** 105° 52' 00" E; **Elevation:** 30 m (ASL)

Parent materials: Sandstones; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Just harvested summer rice

Soil name: *Vietnamese:* Grey degraded soils on acid magmatic rocks and sandstones (1976);

Grey degraded soils (1996)

Grey degraded soils on sandstones

FAO-UNESCO-WRB: Haplic Acrisols

USDA (Soil Taxonomy): Hapludults

Soil profile description:

- Ap (0 - 16 cm): Dark reddish brown (7.5YR 4/1 moist; 7.5YR 6/1 dry); loamy sand; moist; many rice roots; undecomposed of organic remains; clear smooth boundary.
- ABt (16 - 40 cm): Greyish brown (7.5YR 4/2 moist; 7.5YR 6/2 dry); loamy sand (firmer and harder than above lying horizon); moist; many rice roots; few small concretions; few yellow mottles; gradual smooth boundary.
- Bt1 (40 - 85 cm): Light grey (7.5YR 8/1 moist; 7.5YR 8/2 dry); sandy loam; many yellowish red cracks; sandy (60%); some concretions; clear smooth boundary.
- Bt2 (85 - 110 cm): Bright yellowish brown (10YR 6/8 moist; 10YR 7/6 dry); light grey (7.5YR 8/1 moist; 7.5YR 8/2 dry); some pieces of hard red concretions (7.5R 4/8 moist); and few yellow red concretions; sandy loam; gradual smooth boundary.
- BCv (110 - 160 cm): Red (7.5R 4/8 moist; 10YR 5/6 dry); sandy clay loam; bright grey (7.5YR 8/1 moist; 7.5YR 8/2 dry); red colour (70 - 80 %) is dominant; many bigger and harder pieces of yellowish red; few small gravels.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 16	1.31	2.66	50.8	22.8	7.0	75.3	16.3	1.4
16 - 40	1.90	2.71	29.9	10.9	6.3	70.0	22.1	1.6
40 - 85	1.93	2.96	28.3	10.1	6.7	61.6	25.5	6.2
85 - 110	1.76	2.69	34.6	17.4	7.4	51.3	29.4	11.9
110 - 160	1.70	2.70	37.0	19.7	11.3	45.5	18.2	25.0

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 16	1.02	0.06	0.06	0.02	41.20	3.76	0.05	1.60	6.1	5.4
16 - 40	0.21	0.02	0.01	0.01	5.50	6.00	Trace	0.50	6.3	5.4
40 - 85	0.06	0.01	0.01	0.04	2.90	3.00	0.43	0.50	5.4	4.1
85 - 110	0.05	0.01	0.02	0.09	2.60	1.88	1.78	2.50	4.8	3.7
110 - 160	0.04	0.01	0.02	0.25	1.60	3.76	3.90	7.25	4.5	3.5

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 16	1.64	0.53	0.08	1.18	3.43	7.16	16.99	47.9
16 - 40	0.69	0.26	0.12	0.61	1.68	3.44	7.88	48.8
40 - 85	0.32	0.19	0.06	0.83	1.40	4.11	6.81	34.1
85 - 110	0.41	0.36	0.04	0.78	1.59	4.43	6.78	35.9
110 - 160	0.36	0.25	0.08	0.93	1.62	5.13	13.18	31.6

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 34



Location:

- Commune: Truong Hoa
- District: Hoa Thanh
- Province: Tay Ninh

Soil name:

- VIETNAMESE: Grey degraded soils
on acid magmatic rocks
- FAO-UNESCO: Haplic Acrisols
- USDA (Soil Taxonomy): Haplustults

THE INFORMATION OF SOIL PROFILE VN 34

Location: Truong Hoa Commune, Hoa Thanh District, Tay Ninh Province

Latitude: 11° 17' 00" N; **Longitude:** 106° 09' 30" E; **Elevation:** 18 m (ASL)

Parent materials: Sandstones; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Cashew planted 1990

Soil name: *Vietnamese:* Grey degraded soils on acid magmatic rocks and sandstones (1976);
Grey degraded soils (1996)

Grey degraded soils on acid magmatic rocks

FAO-UNESCO-WRB: Haplic Acrisols

USDA (Soil Taxonomy): Haplustults

Soil profile description:

- Ap (0 - 20 cm): Light brownish grey (7.5YR 7/2 moist; 7.5YR 7/1 dry); sandy loam; dry; hard; firm; many grass and cashew roots; some small coal mottles; gradual smooth boundary.
- AB (20 - 35 cm): Dull brown (7.5YR 6/3 moist; 7.5YR 7/2 dry); sandy loam; some dull orange mottles (7.5YR 7/3.5 moist; 7.5YR 6/8 dry); moist; very hard and firm; many grass roots; gradual smooth boundary.
- BA (35 - 60 cm): Dull orange (7.5YR 6/4 moist; 7.5YR 7/2 dry); sandy clay loam; moist; less hard and firm than above lying horizon; some cashew roots diameter of 2 mm; some yellowish brown iron; gradual smooth boundary.
- Bt1 (60 - 105 cm): Dull orange (7.5YR 7/3 moist; 7.5YR 7/1 dry); sandy clay loam; moist; some coal mottles; many bright reddish brown iron mottles (5YR 5/8 moist; 5YR 6/6 dry); some animal channels; gradual smooth boundary.
- Bt2 (105 - 160 cm): Dull orange (7.5YR 7/2.5 moist; 7.5YR 8/1 dry); loamy sand; moist; many roots diameter of 2 mm; more brown mottles than over lying horizon.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 20	1.38	2.69	48.7	2.2	28.6	43.1	20.7	7.6
20 - 35	1.62	2.65	38.9	7.1	30.0	50.3	1.8	17.9
35 - 60	1.59	2.67	40.4	7.6	30.1	45.0	1.9	23.0
60 - 105	1.65	2.58	36.0	10.6	29.2	39.0	2.8	29.0
105 - 160	1.67	2.60	35.8	10.9	30.2	41.3	4.7	23.8

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 20	1.10	0.10	0.03	0.07	3.05	1.21	0.86	3.53	4.5	3.7
20 - 35	0.80	0.05	0.03	0.77	3.81	2.41	1.68	5.48	4.3	3.7
35 - 60	0.70	0.03	0.02	0.05	1.52	2.41	1.96	6.12	4.8	4.2
60 - 105	0.30	0.02	0.02	0.05	0.74	2.41	2.12	6.42	4.7	4.2
105 - 160	0.30	0.01	0.00	0.06	0.53	3.62	2.30	6.80	4.5	4.3

Soil horizon thickness, cm	Exchangeable Cation, cmol(+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ^{**}	Mg ^{**}	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 20	0.07	0.03	0.03	0.03	0.16	1.00	3.54	16.0
20 - 35	0.09	0.00	0.05	0.00	0.14	2.00	5.14	7.0
35 - 60	0.12	0.00	0.05	0.03	0.20	2.08	5.34	0.9
60 - 105	0.10	0.00	0.05	0.00	0.15	2.24	5.75	6.7
105 - 160	0.11	0.00	0.07	0.00	0.18	2.08	6.12	8.7

2.7. The Brownish Grey soils in semi-arid region:

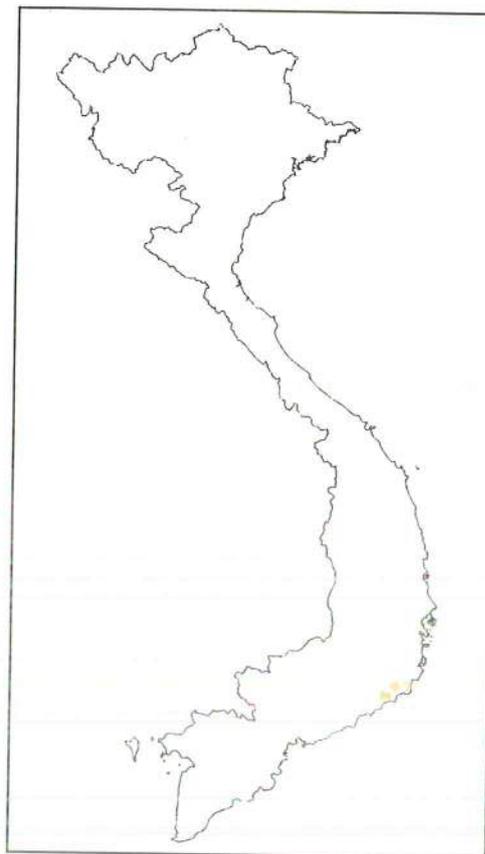
Brownish Grey soils in semi-arid region have a very small area, around 30,000 hectares and concentrate mainly in Ninh Thuan and Binh Thuan Provinces.

These soils are formed in special condition of dry climate with the annual rainfall is lower than the evaporation. The erosion and leaching in these soils are weak. Soils have the process of accumulation of alkaline, Fe and Al. Therefore, soils are normally neutral or low acidic with high base saturation.

This soil group has only one unit: Brown grey in semi-arid region.

Natural vegetation cover is very characterized for semi-arid region: thin forest, savanna...

The soils are suitable for many crops such as sugarcane, cashew, tobacco, cotton, beans, etc... if water for irrigation is solved.



Due to low rainfall, applying of countermeasures for keeping of soil moisture, building irrigation system in flat areas and covering vegetation in barren hills should be carried out.

Soil profile VN 47 is characterized for this soil unit.

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 47



Location:

- Commune: Xuan Hai
- District: Ninh Hai
- Province: Ninh Thuan

Soil name:

- VIETNAMESE: *Brownish grey soils on the semi-arid region*
- FAO-UNESCO: *Chromic Lixisols*
- USDA (Soil Taxonomy): *Paleargids*



THE INFORMATION OF SOIL PROFILE VN 47

Location: Xuan Hai Commune, Ninh Hai District, Ninh Thuan Province

Latitude: 11° 38' 20" N; **Longitude:** 108° 58' 45" E; **Elevation:** 20 m (ASL)

Parent materials: Granite; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Maize just harvested

Soil name: Vietnamese: Brownish grey soils in semi-arid region (1976, 1996)

Brownish grey soils in semi-arid region

FAO-UNESCO-WRB: Chromic Lixisols

USDA (Soil Taxonomy): Paleargids

Soil profile description:

- Ap (0 - 15 cm): Brown (7.5YR 4/4 moist; 7.5YR 6/3 dry); sandy loam; dry; firm; many small roots; many bright brown piece (7.5YR 5/8 moist; 7.5YR 6/4 dry); some black mottles; clear smooth boundary.
- AB (15 - 40 cm): Dull reddish brown (5YR 4/3.5 moist; 7.5YR 5/3 dry); sandy clay loam; slightly moist; slightly firm; many small roots; some sand mottles; some black coal mottles; clear smooth boundary.
- Btw1 (40 - 90 cm): Dull brown (7.5YR 5/4 moist; 7.5YR 8/6 dry); sandy clay loam; moist; firm granular structure; many bright brown color clay mottles (7.5YR 5/6 moist; 10R 5/8 dry); brownish gray (10YR 5/1.5 moist; dry); many yellow sand mottles; gradual smooth boundary.
- BC (90 - 130 cm): Dull brown (7.5YR 5/4 moist; 7.5YR 6/8 dry); sandy clay loam; moist; firm; porous.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	1.54	2.70	43.0	4.3	41.6	37.1	5.7	15.6
15 - 40	1.84	2.63	31.0	9.9	36.3	26.4	8.6	28.7
40 - 90	1.77	2.64	33.0	11.8	30.6	26.5	8.0	34.9
90 - 130	1.69	2.64	36.0	12.3	29.7	27.0	10.3	33.0

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 15	1.00	0.03	0.07	3.52	4.59	5.03	0.20	1.15	4.6	4.1
15 - 40	0.87	0.02	0.03	2.98	3.66	4.13	0.10	2.23	5.7	4.8
40 - 90	0.87	0.01	0.13	2.98	3.80	2.08	0.10	2.54	6.8	6.0
90 - 130	0.70	0.01	0.04	2.17	4.54	2.23	0.10	1.87	6.8	6.1

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 15	2.30	1.30	0.10	1.07	4.77	5.40	12.96	88.3
15 - 40	3.40	2.30	0.09	4.35	10.14	11.04	21.69	91.8
40 - 90	3.60	2.13	0.04	6.83	12.60	15.64	23.14	80.5
90 - 130	3.60	2.20	0.04	7.66	13.5	15.32	39.37	88.1

2.8. The Tropical Black soils:

These soils are formed in high topography and have 2 main processes: The process of accumulation of organic matter and the process of alkali accumulation in condition of rich alkali parent rocks weathering such as limestones and basic rocks.

Total area is approximately more than 100,000 hectares that distributes mainly in mountainous areas of Northern and Central regions.

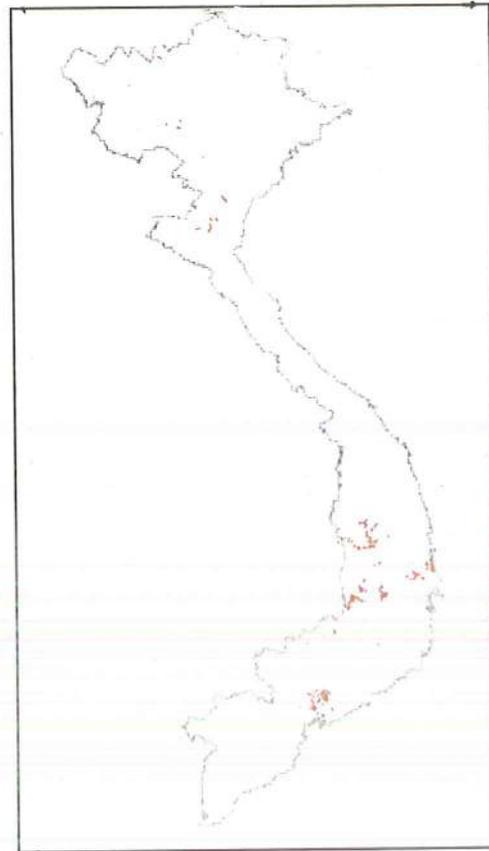
This soil group has following units:

- Carbonates black soils
- Black soils on basaltic deposit
- Black soils on basaltic tuff

These soils are suitable for beans, maize, sugar cane and fruit trees.

In flat topography with less drainage, rice and some adaption trees are recommended.

It is noted to use fertilizers, which is suitable for alkaline or neutral medium and rich in Ca^{++} and Mg^{++} in these soils.



Soil profile **VN 14** is characterized for Carbonates black soils derived from limestones.
Soil profile **VN 20** is characterized for Black soils derived from basaltic deposit.

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 14



Location:

- Commune: Co Noi
- District: Mai Son
- Province: Son La

Soil name:

- VIETNAMESE: *Carbonate black soils*
- FAO-UNESCO: *Calcic Luvisols*
- USDA (Soil Taxonomy): *Paleustalfs*

THE INFORMATION OF SOIL PROFILE VN 14

Location: Co Noi Commune, Mai Son District, Son La Province

Latitude: 21° 08' 00" N; **Longitude:** 104° 12' 00" E; **Elevation:** 400 m (ASL)

Parent materials: Limestones; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Sugar cane just harvested

Soil name: Vietnamese: Black soils (1976); Carbonate black soils (1996)

Carbonate black soils

FAO-UNESCO-WRB: Calcic Luvisols

USDA (Soil Taxonomy): Paleustalfs

Soil profile description:

- Ap1 (0 - 15 cm): Dull yellowish brown (10YR 4/3 moist; 2.5Y 4/3 dry); clay; dry; hard; clear smooth boundary.
- Ap2 (15 - 30 cm): Dull yellowish brown (10YR 4/3 moist; 2.5Y 4/3 dry); clay loam; dry; hard; fine; some roots; grey mottles (7.5YR 8/2 moist); many cracks; gradual smooth boundary.
- AB (30 - 45 cm): Greyish yellow brown (10YR 4/2 moist; 2.5Y 4/2 dry); clay loam; granular structure; moist; some roots; few white mottles; gradual smooth boundary.
- Bw1 (45 - 75 cm): Dull yellowish brown (10YR 5/3 moist; 2.5Y 4/4 dry); clay; fine granular structure; slightly plastic; moist; gradual smooth boundary.
- Bw2 (75 - 95 cm): Dull yellowish brown (10YR 5/4 moist; 2.5Y 4/4 dry); many red mottles and cracks; clay; fine granular structure; plastic; clear smooth boundary.
- Bw3 (95 - 140 cm): Bright yellowish brown (10YR 6/6 moist; 10YR 6/8 dry); many small red cracks; clay; moist; sticky; gradual smooth boundary.

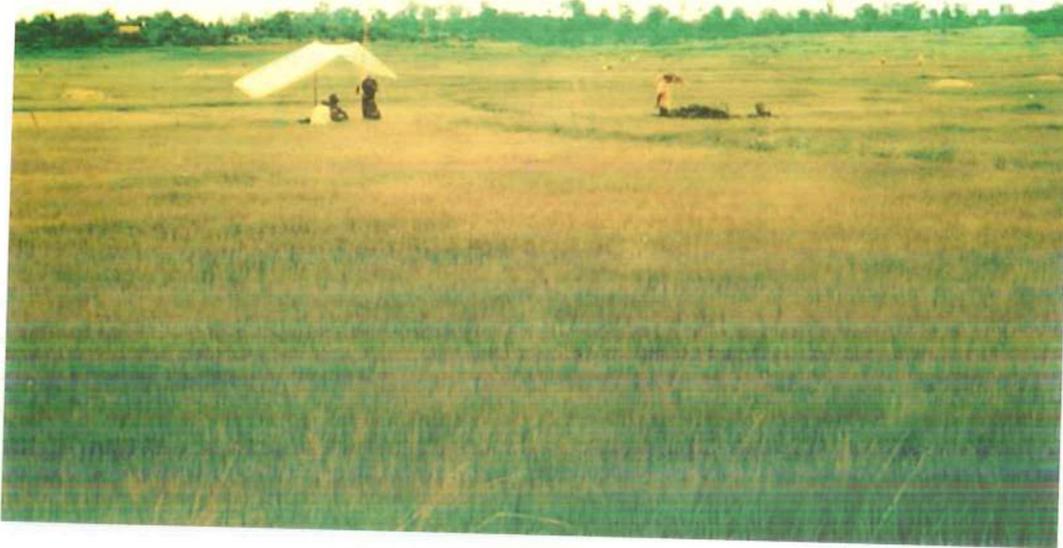
Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	1.18	2.51	53.0	11.3	7.7	23.1	26.3	42.9
15 - 30	1.48	2.59	42.9	16.9	7.7	31.4	30.0	30.9
30 - 45	1.37	2.60	43.3	18.4	5.7	31.4	30.1	32.8
45 - 75	1.12	2.59	56.8	29.0	6.9	20.7	21.6	50.8
75 - 95	1.26	2.62	51.9	27.9	10.0	18.0	20.6	51.4
95 - 140	1.30	2.64	50.8	32.1	9.4	13.1	15.3	62.2

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 15	2.22	0.25	0.16	0.20	5.9	6.59	0.04	0.27	8.2	7.1
15 - 30	1.96	0.17	0.17	0.16	3.5	8.95	Trace	0.15	8.4	7.5
30 - 45	1.22	0.17	0.11	0.20	3.4	8.48	Trace	0.15	8.4	7.5
45 - 75	1.52	0.13	0.12	0.25	3.1	6.12	Trace	0.17	8.5	7.2
75 - 95	0.70	0.08	0.09	0.27	1.7	6.12	0.02	0.25	8.4	7.0
95 - 140	0.30	0.06	0.13	0.31	1.8	6.00	0.02	0.31	7.8	6.9

Soil horizon thickness, cm	Exchangeable Cation, cmol(+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 15	11.34	1.24	0.14	0.82	13.54	17.34	28.26	78.1
15 - 30	8.00	0.85	0.19	0.83	9.87	13.08	29.82	75.5
30 - 45	8.79	1.07	0.18	0.60	10.64	13.04	33.51	81.6
45 - 75	10.00	0.93	0.13	0.50	11.56	14.76	24.94	78.3
75 - 95	9.20	1.26	0.13	0.77	11.36	13.76	23.25	82.6
95 - 140	9.23	1.52	0.12	0.98	11.85	14.25	24.08	83.2

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 20



Location:

- Commune: Ea Phe
- District: Krong Pach
- Province: Dac Lac

Soil name:

- VIETNAMESE: *Black soils on basaltic deposit*
- FAO-UNESCO: *Gleyic Luvisols*
- USDA (Soil Taxonomy): *Haplustolls*

Location: Ea Phe Commune, Krong Pach District, Dac Lac Province
Latitude: 12° 44' 00" N; **Longitude:** 108° 22' 00" E; **Elevation:** 470 m (ASL)
Parent materials: Basalt; **Topography:** Flat; **Slope:** 0 - 3°
Present land use: Rice

Soil name: Vietnamese: Black soils (1976); Gleyic Black soils (1996)
Black soils on basaltic deposit
 FAO-UNESCO-WRB: Gleyic Luvisols
 USDA (Soil Taxonomy): Haplustolls

Soil profile description:

Ap (0 - 20 cm): Black (10YR 2/1 moist; 10YR 4/1 dry); clay; wet; sticky; some iron mottles; many rice roots; clear smooth boundary.
 AB (20 - 40 cm): Brownish black (10Y 3/1 moist; 10YR 3/1 dry); brighter than upper horizon; clay; slightly firm; sticky; some small friable concretions; some brownish black organic mottles; gradual smooth boundary.
 B1 (40 - 80 cm): Light yellowish grey (2.5Y 4/1 moist; 10Y 3/1 dry); clay; slightly porous; fine granular structure; some rice roots; some roots diameter of 10 - 15 cm; some friable concretion mottles; gradual smooth boundary.
 B2 (80 - 130 cm): Yellowish grey (2.5Y 5/1 moist; 10Y 4/1 dry); clay; wet; slightly firm; sticky; some small roots; some iron mottles; gradual smooth boundary.
 BC (130 - 160 cm): Yellowish grey (2.5Y 4/1 moist; 10YR 4/1 dry); clay; wet; granular structure; sticky; plastic; some brown iron mottles.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 20	0.80	2.54	68.5	68.1	6.2	9.7	32.7	51.4
20 - 40	0.87	2.49	65.1	72.1	4.6	7.0	24.3	64.1
40 - 80	1.18	2.74	56.8	11.7	6.4	17.2	10.2	66.2
80 - 130	1.10	2.56	57.1	48.2	6.7	10.5	18.4	64.4
130 - 160	1.16	2.61	56.1	42.6	4.8	8.3	14.7	72.2

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 20	3.20	0.22	0.21	0.04	4.80	6.12	0.25	35.37	5.7	4.5
20 - 40	1.66	0.12	0.16	0.04	2.80	4.71	0.23	31.50	5.8	4.5
40 - 80	0.36	0.04	0.14	0.04	2.00	4.71	0.23	26.70	6.1	4.5
80 - 130	0.10	0.02	0.12	0.04	2.10	6.12	1.16	30.90	5.1	3.5
130 - 160	0.02	0.01	0.20	0.04	3.20	4.71	0.42	26.80	5.7	3.9

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 20	6.11	4.53	0.13	0.29	11.06	15.20	60.64	72.7
20 - 40	8.11	5.47	0.10	0.37	14.05	16.00	54.08	87.8
40 - 80	8.01	6.40	0.10	0.71	15.31	17.05	69.29	89.7
80 - 130	11.06	9.36	0.13	0.13	20.68	23.05	87.61	89.7
130 - 160	11.30	9.67	0.10	1.40	22.47	25.12	86.39	89.4

2.9. The Ferralitic soils:

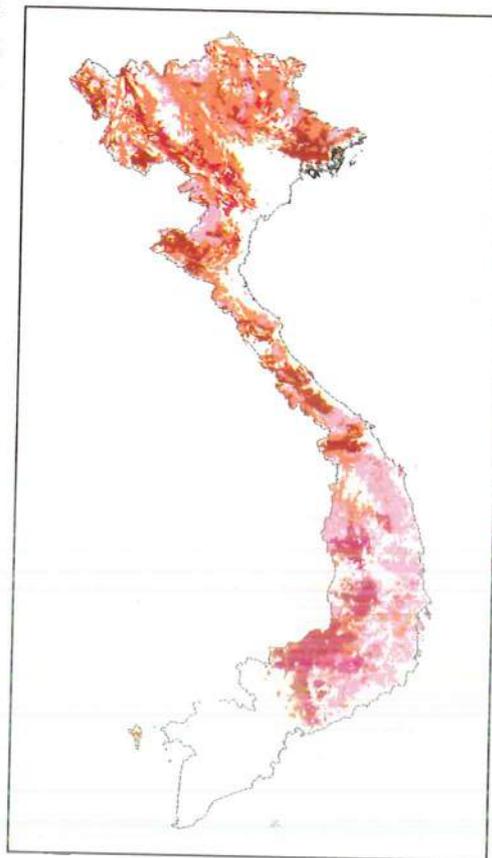
Distributing in almost midland and mountainous Provinces throughout country, covering the largest area (approximate 20 millions hectares national-wide) and playing an important role in agricultural and socio-economic development.

Differing from those soils in plain regions, soil formation process in mountainous regions is strongly affected by topography, parent rocks and forest.

In Vietnam, ferralitic soil forming processes is characterized by: (i) The process of absolute accumulation of Fe, Al or lateritic (petroferric) process; and (ii) The process of relative accumulation of Fe, Al or ferralitic process (in this process, some base elements and SiO₂ are leached and resulted in accumulation of Fe and Al).

The Ferralitic soils are divided into 8 soil units:

- Violet brown soils derived from basic and intermediate magmatic rocks;
- Reddish brown soils derived from basic and intermediate magmatic rocks;
- Yellowish brown soils on derived from basic and intermediate magmatic rocks;
- Brownish red soils derived from limestone;
- Yellowish red soils derived from clay shale and metamorphic rocks;
- Reddish yellow soils derived from acid magmatic rocks;
- Light yellow soils derived from sandstone;
- Yellowish brown soils derived from old alluvium.



- Violet brown soils derived from basic and intermediate magmatic rocks:

These soils cover an approximate area of 80,000 hectares throughout country. Normally found at foothills and inserted into regions of reddish brown soils by narrow belts. Their properties are similar as that of reddish brown soils except have lower acidity and higher potential fertility.

Soil profile **VN 19** is characterized for this soil unit.

- Reddish brown soils derived from basic and intermediate magmatic rocks:

Reddish brown soils derived from basic and intermediate magmatic rocks (such as basalt, spilite, diabase, andesite, porphyrite, etc...) have total area of over 2 millions hectares and distribute mainly in Dong Nai, Binh Duong, Binh Phuoc, Quang Tri, Nghe An Provinces and High plateau (Tay Nguyen) region. Some small areas are found in Thanh Hoa, Hoa Binh, Thai Nguyen, Son La, Lang Son, etc... These soils are normally found on flat or undulating hills (Xuan Loc, Gio Linh, and Phu Quy) or flat plateaus (Tay Nguyen, Son La).

Reddish brown soils have a very thick and homogeneous layer (even more than 10 m). Soils are very acidic, pH ranges from 4 to 4.5. The potential contents of organic carbon, nitrogen, and phosphorus are quite high. Although having very fine texture, reddish brown soils are very porous and airy because of good soil structure. In general, these are precious soils. When using for agricultural production it is necessary to maintain their good characteristics such as a big fine earth thickness, porosity, high organic carbon content, etc.... and improve some disadvantage characteristics such as low potential and available phosphorus contents, easily becoming waterless.

Some measures must be paid attention:

1. Erosion controlling;
2. Covering soil and keeping moisture in dry season;
3. Restraining earthworking to keep soil structure; and
4. Applying N, P, K fertilizer with balanced proportion, especially P and K fertilizers.

Soil profiles **VN 08** is characterized for Reddish brown soils derived from basaltic rocks in the North; **VN 18** and **VN 21** are characterized for that in the Tay Nguyen region. Soil profile **VN 40** is characterized for soils derived from porphyrite and **VN 49** for soils derived from andesite.

- Yellowish brown soils derived from basic and intermediate magmatic rocks:

These soils have a small area, about 530,000 hectares; concentrate mainly in the Bao Loc Plateau (Lam Dong Province, where is at 900 m height ASL with the total rainfall of 2,800 mm, which arranges equally the year round) and in Dac Lak Province.

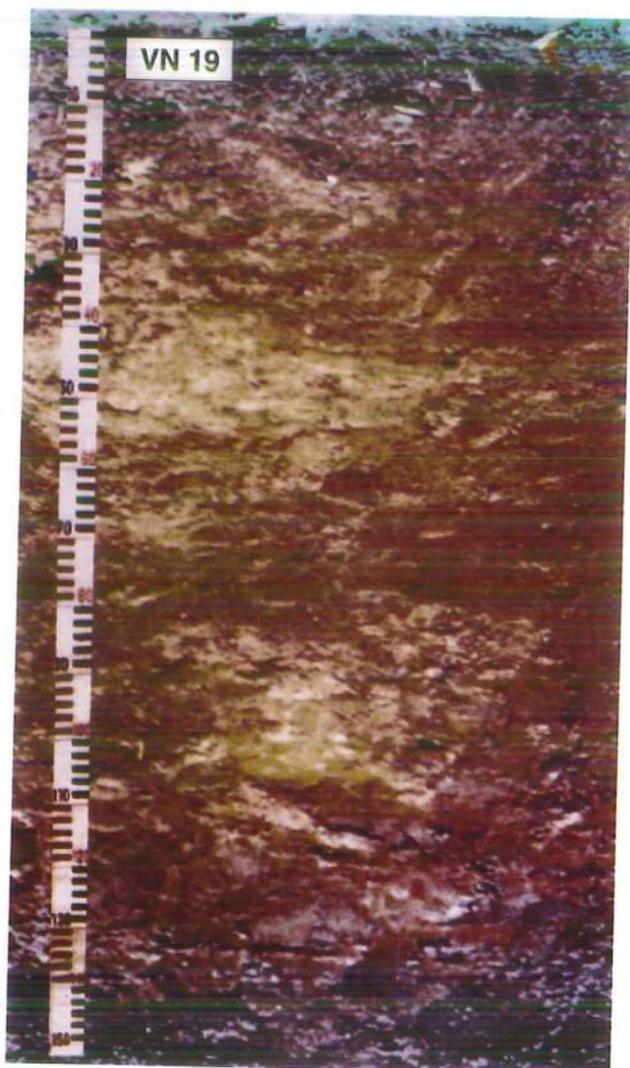
Yellowish brown soils have all good characteristics similar as that of Reddish brown soils. In addition, because distributing in wet climate regions, humidity of these soils is higher than that of Red brown soils.

On yellowish brown soils, can be developed industrial crops, fruit trees, food crops etc. but some countermeasures should be paid attention to:

1. Erosion controlling;
2. Restraining earth working to keep soil structure; and
3. Applying N, P, K fertilizer with balanced proportion, especially P and K fertilizers.

Soil profile **VN 38** is characterized for this soil unit.

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 19



Location:

- Commune: Eak Tua
- District: Krong Ana
- Province: Dac Lac

Soil name:

- VIETNAMESE: *Violet brown soils on basalt*
- FAO-UNESCO: *Rhodic Nitisols*
- USDA (Soil Taxonomy): *Haplustolls*

THE INFORMATION OF SOIL PROFILE VN 19

Location: Eak Tua Commune, Krong Ana District, Dac Lac Province

Latitude: 12° 37' 00" N; **Longitude:** 108° 08' 00" E; **Elevation:** 500 m (ASL)

Parent materials: Basalt; **Topography:** Undulating; **Slope:** 8° - 10°

Present land use: Coffee mixed with Eucalyptus (1994)

Soil name: *Vietnamese:* Violet brown soils on basic and intermediate magmatic rocks (1976)

Violet brown soils on Basalt

FAO-UNESCO-WRB: Rhodic Nitisols

USDA (Soil Taxonomy): Haplustolls

Soil profile description:

- Ap1 (0 - 10 cm): Very dark reddish brown (2.5YR 2/2 moist; 7.5YR 3/2 dry); clay; moist; porous; fine granular structure; many grass roots; clear smooth boundary.
- Ap2 (10 - 35 cm): Very dark reddish brown (2.5YR 2/3 moist; 2.5YR 3/3 dry); clay; moist; fine granular structure; slightly firm; many roots diameter of 1.5 - 2 cm and animal channels; few red concretions; gradual smooth boundary.
- Bw (35 - 55 cm): Dark reddish brown (2.5YR 2/4 moist; 5YR 3/3dry); clay; fine granular structure; plastic; firm; many roots; some weathering rocks with reddish brown colour (10YR 5/3 moist); reddish yellow (7.5 YR 6/8 moist); gradual smooth boundary.
- BC1 (55 - 80 cm): Dark reddish brown (2.5YR 3/3 moist; 2.5YR 3/3dry); clay; moist; plastic; subangular structure; some roots; many weathering rock fragments (2.5 YR 2/1 moist); clear smooth boundary.
- BC2 (80 - 105 cm): Dark brown (10YR 3/3 moist; 7.5YR 3/3.5 dry); sandy clay loam; firm; some rice roots; some weathering rock fragments diameter of 10 - 25 cm.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 10	1.03	2.70	61.9	33.8	5.0	18.7	33.9	42.4
10 - 35	0.93	2.72	65.8	33.1	1.4	10.9	24.5	63.2
35 - 55	1.20	2.70	56.0	34.1	4.3	15.7	22.8	57.2
55 - 80	1.09	2.69	59.5	43.2	5.4	15.5	24.4	54.7
80 - 105	1.11	2.70	59.1	40.4	31.7	29.1	17.6	21.6

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 10	2.55	0.17	0.38	0.54	108.0	57.00	0.10	29.12	5.9	4.8
10 - 35	0.90	0.08	0.28	0.48	65.8	6.12	0.15	25.80	5.9	4.2
35 - 55	0.61	0.06	0.15	0.35	39.2	45.70	0.10	21.40	6.2	4.5
55 - 80	0.38	0.07	0.15	0.28	27.5	32.50	0.10	22.30	6.2	4.6
80 - 105	0.14	0.02	0.14	0.29	167.3	45.00	0.12	21.30	6.5	4.5

Soil horizon thickness, cm	Exchangeable Cation, cmol(+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 10	8.91	5.64	1.21	0.14	15.90	29.44	47.99	54.0
10 - 35	4.50	4.28	0.26	0.14	9.18	21.79	41.84	42.0
35 - 55	4.20	4.62	0.97	0.14	9.93	20.32	34.34	48.9
55 - 80	4.62	4.85	0.69	0.14	10.30	20.40	34.48	50.5
80 - 105	4.32	4.05	0.90	0.23	9.50	18.64	47.90	51.0

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 08



Location:

- Tay Hieu Farm No 3
- District: Nghia Dan
- Province: Nghe An

Soil name:

- VIETNAMESE: *Reddish brown soils on basaltic rocks*
- FAO-UNESCO: *Rhodic Ferralsols*
- USDA (Soil Taxonomy): *Hapludox*

THE INFORMATION OF SOIL PROFILE VN 08

Location: Tay Hieu Farm No 3, Nghia Dan District, Nghe An Province

Latitude: 19° 30' 00" N; **Longitude:** 105° 22' 00" E; **Elevation:** 80 m (ASL)

Parent materials: Basalt; **Topography:** Flat; **Slope:** 3° - 8°

Present land use: Rubber tree planted in 1959-1960

Soil name: *Vietnamese:* Reddish brown soils on basic and intermediate magmatic rocks (1976);

Reddish brown soils (1996)

Reddish brown soils on basaltic rocks

FAO-UNESCO-WRB: Rhodic Ferralsols

USDA (Soil Taxonomy): Hapludox

Soil profile description:

- Ap1 (0 - 15 cm): Dark reddish brown (2.5YR 3/4 moist; 2.5YR 4/6 dry); clay; fine; porous; many grass roots; clear smooth boundary.
- Ap2 (15 - 30 cm): Dark reddish brown (2.5YR 3/6 moist; 5YR 4/8 dry); moister than above horizon; clay; fine; some small roots; few animal channels; gradual smooth boundary.
- Bs1 (30 - 70 cm): Dark reddish brown (2.5YR 3/6 moist; 5YR 4/8 dry); clay; moist; finer than above horizon; gradual smooth boundary.
- Bs2 (70 - 110 cm): Dark reddish brown (2.5YR 3/6 moist; 5YR 4/8 dry); clay; similar as above horizon; porous; fine; some roots; gradual smooth boundary.
- Bs3 (110 - 150 cm): Dark reddish brown (2.5YR 3/6 moist; 5YR 4/8 dry); clay; similar as above horizon; moister than above horizon.

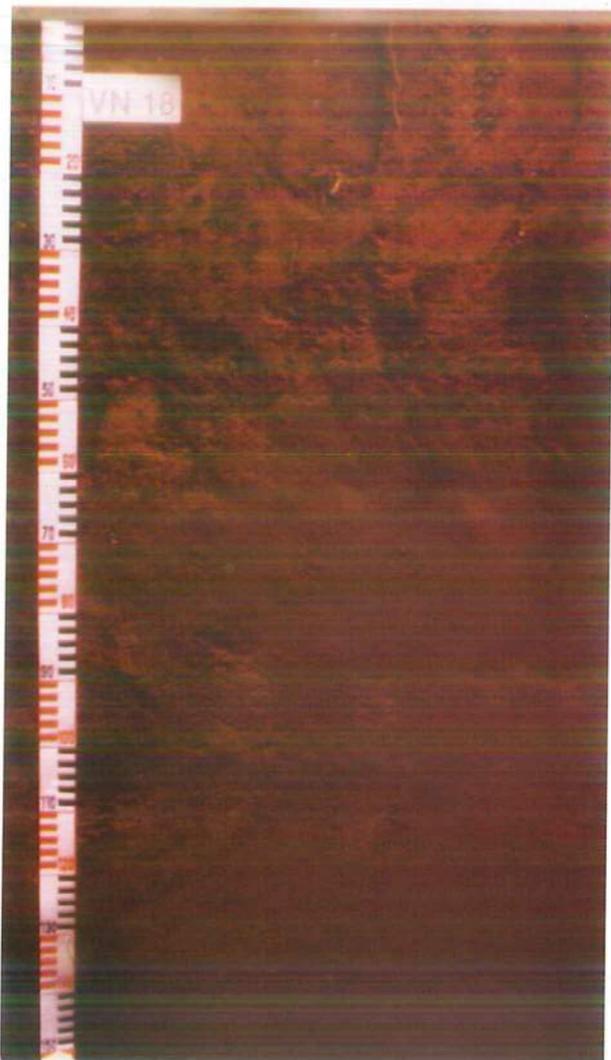
Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	0.97	2.51	61.4	28.5	1.8	10.2	9.1	78.9
15 - 30	0.90	2.60	65.4	32.1	2.0	10.6	13.6	73.8
30 - 70	0.82	2.69	69.5	33.0	1.8	12.2	12.2	73.8
70 - 110	0.83	2.70	69.5	32.5	1.3	9.4	15.0	74.3
110 - 150	0.83	2.72	69.5	31.3	1.1	8.9	15.4	74.6

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 15	1.73	0.15	0.17	0.52	9.33	6.12	2.70	20.05	4.5	3.7
15 - 30	0.96	0.10	0.21	0.50	8.20	2.35	2.04	15.60	4.6	3.8
30 - 70	0.61	0.07	0.20	0.43	8.17	3.06	1.30	12.00	4.8	3.9
70 - 110	0.46	0.07	0.26	0.34	7.33	3.76	0.80	12.90	4.7	4.0
110 - 150	0.36	0.05	0.30	0.34	6.37	2.35	0.56	11.25	5.2	4.1

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 15	0.46	0.06	0.13	0.04	0.69	11.60	19.60	5.9
15 - 30	0.34	0.04	0.05	Trace	0.43	8.94	17.17	4.8
30 - 70	0.46	0.08	0.06	0.04	0.64	8.58	14.50	7.5
70 - 110	0.90	0.14	0.08	0.12	1.24	8.61	14.55	14.4
110 - 150	0.79	0.17	0.05	0.14	1.15	8.04	13.59	14.3

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 18



Location:

- *Commune:* Hoa Thang
- *District:* Tuy Hoa
- *Province:* Phu Yen

Soil name:

- *VIETNAMESE:* Alluvial soils of the Ba River
- *FAO-UNESCO:* Dystric Fluvisols
- *USDA (Soil Taxonomy):* Ustifluvents

THE INFORMATION OF SOIL PROFILE VN 18

Location: Hoa Thang Commune, Buon Ma Thuot City, Dac Lac Province

Latitude: 12° 40' 00"N; **Longitude:** 108° 07' 00" E; **Elevation:** 480 m (ASL)

Parent materials: Basalt; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Rubber tree diameter of 20 - 30 cm

Soil name: *Vietnamese:* Reddish brown soils on basic and intermediate magmatic rocks (1976);

Reddish brown soils (1996)

Reddish brown soils on basaltic rocks

FAO-UNESCO-WRB: Rhodic Ferralsols

USDA (Soil Taxonomy): Haplustox

Soil profile description:

- Ap (0 - 30 cm):** Very dark reddish brown (2.5YR 2/4 moist; 5YR 4/7 dry); clay; moist; fine granular structure; many grass roots and organic mottles throughout; many black mottles of coal; many small pores; more slightly firm at the lower part of horizon; some animal (termite) caves; clear smooth boundary.
- Bs1 (30 - 70 cm):** Dark reddish brown (2.5YR 3/4 moist; 2.5YR 4/8 dry); clay; moist; fine granular structure; slightly firm; fine roots throughout; few small red mottles (2 - 3 mm); gradual smooth boundary.
- Bs2 (70 - 150 cm):** Dark red (10YR 3/6 moist; 2.5YR 4/8 dry); clay; porous; friable; fine granular structure; few rubber roots (10 - 15 mm) and small grass roots; few coal mottles; homogenous colour throughout.

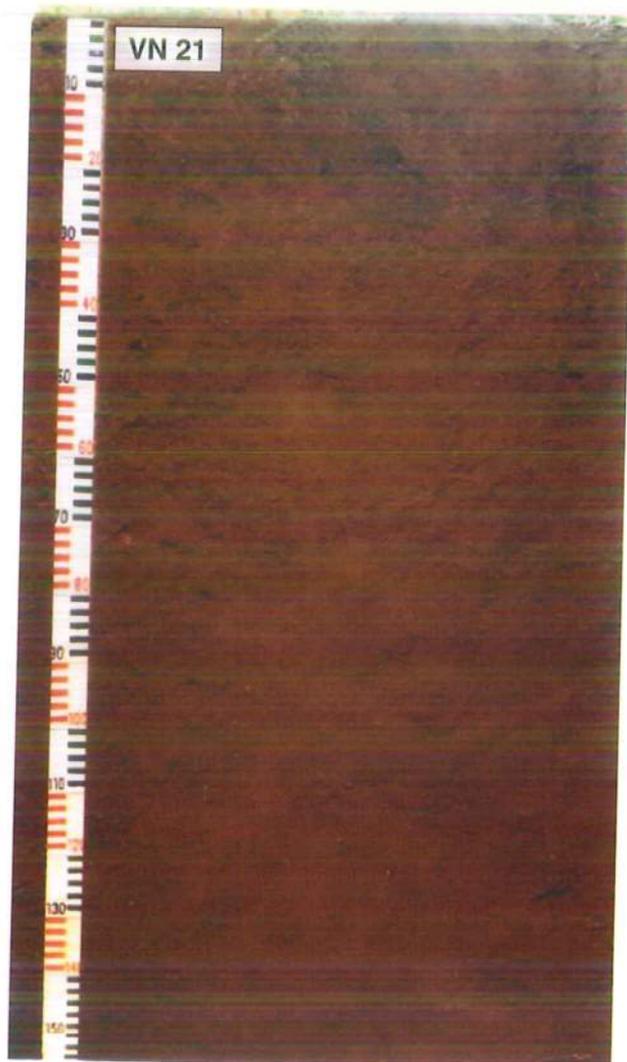
Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2,0 - 0,2 mm	0,2 - 0,02 mm	0,02 - 0,002 mm	< 0,002 mm
0 - 30	0.80	2.50	68.0	43.7	3.6	11.6	32.6	52.2
30 - 70	1.04	2.71	61.6	44.5	2.5	8.2	24.0	65.3
70 - 90	0.90	2.73	67.1	43.0	0.0	7.9	17.7	74.4
90 - 120	0.92	2.17	66.0	44.3	0.3	7.6	17.2	74.9

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 30	3.51	0.21	0.18	0.08	5.88	16.00	3.18	38.00	4.2	3.7
30 - 70	1.79	0.11	0.18	0.08	6.36	13.00	1.21	23.93	4.2	3.9
70 - 90	0.72	0.06	0.17	0.06	6.15	15.00	0.10	15.10	5.2	4.1
90 - 120	0.45	0.05	0.16	0.05	7.12	14.00	0.08	13.50	5.2	4.2

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 30	0.35	0.09	0.33	0.06	0.83	18.00	29.34	4.6
30 - 70	0.44	0.11	0.27	0.03	0.85	10.00	19.90	8.5
70 - 90	0.53	0.39	0.31	0.03	1.26	8.36	14.13	15.1
90 - 120	0.34	0.23	0.29	0.03	0.89	5.83	9.85	15.2

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 21



Location:

- Hoa Binh Rubber Farm
- Mang Giang Rubber Company
- Province: Gia Lai

Soil name:

- VIETNAMESE: *Reddish brown soils on basaltic rocks*
- FAO-UNESCO: *Rhodic Ferralsols*
- USDA (Soil Taxonomy): *Haplustox*

THE INFORMATION OF SOIL PROFILE VN 21

Location: Hoa Binh Rubber Farm, Mang Giang Rubber Company, Gia Lai Province

Latitude: 13° 56' 00" N; **Longitude:** 108° 07' 00" E; **Elevation:** 700 m (ASL)

Parent materials: Basalt; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Rubber

Soil name: *Vietnamese:* Reddish brown soils on basic and intermediate magmatic rocks (1976);

Reddish brown soils (1996)

Reddish brown soils on basaltic rocks

FAO-UNESCO-WRB: Rhodic Ferralsols

USDA (Soil Taxonomy): Haplustox

Soil profile description:

- Ap (0 - 20 cm): Dark brown (7.5R 2/3 moist; 10R 3/3 dry); clay; moist; fine granular structure; many grass roots; few animal (termite) channels; few black coal mottles; gradual smooth boundary.
- BA (20 - 55 cm): Dark brown (7.5R 3/4 moist; 10R 3/4 dry); clay; moist; slightly firm; fine granular structure; some rice roots; few black coal mottles (N 2/0); gradual smooth boundary.
- Bs1 (55 - 110 cm): Reddish brown (7.5R 3/4 moist; 10R 3/6 dry); clay; firmer than above lying horizon; some grass roots diameter of 5-10mm; some animal channels; gradual smooth boundary.
- Bs2 (110 - 150 cm): Reddish brown (7.5R 3/4 moist; 10R 3/6dry); clay; slightly firm; fine granular structure; some rubber and corn roots; gradual smooth boundary.
- Bs3 (150 - 160 cm): Reddish brown (7.5R3/4 moist; 10 R 3/6dry); clay; granular structure.

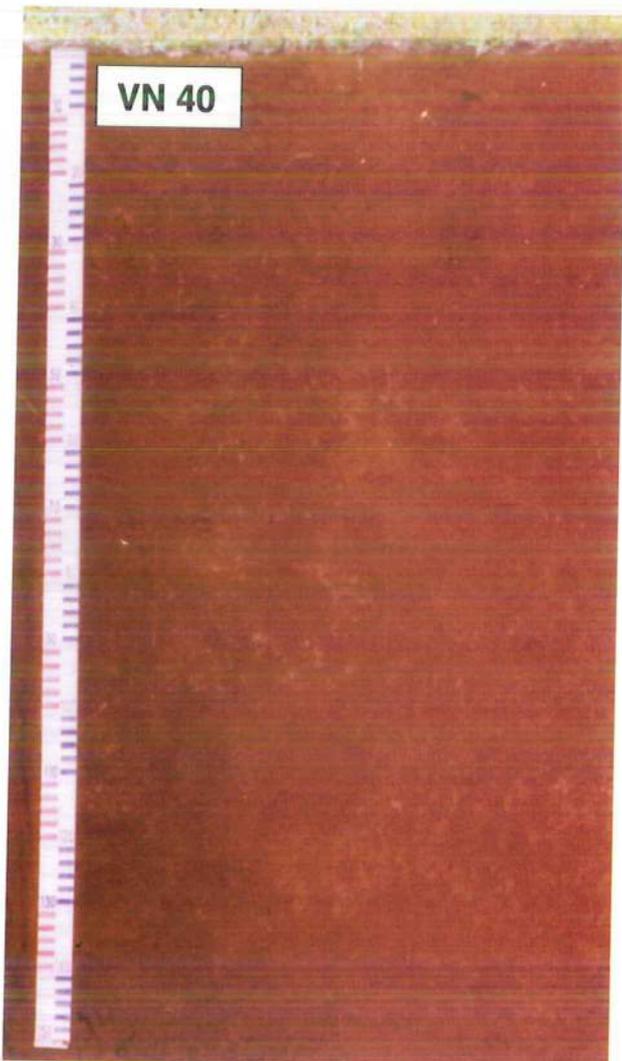
Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 20	1.04	2.76	62.4	37.2	2.7	9.4	14.1	73.8
20 - 55	0.92	2.77	66.8	39.0	1.8	7.8	13.3	78.0
55 - 110	0.92	2.86	67.9	39.7	1.3	5.6	13.6	79.5
110 - 150	1.01	2.96	65.9	39.9	1.3	6.8	11.9	80.0
150 - 160	1.08	2.65	59.3	39.8	1.3	8.1	11.5	79.1

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 20	3.07	0.18	0.44	0.50	15.80	3.76	2.92	31.25	4.2	3.7
20 - 55	1.59	0.11	0.38	0.52	7.30	2.35	1.69	19.74	4.7	3.9
55 - 110	0.45	0.04	0.38	0.48	9.20	2.35	0.63	15.10	5.0	4.1
110 - 150	0.30	0.04	0.34	0.41	8.20	2.25	0.64	13.30	4.8	4.1
150 - 160	0.19	0.03	0.31	0.39	8.80	2.40	0.58	13.20	4.2	4.1

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 20	0.60	0.18	0.08	Trace	0.86	14.16	23.08	6.6
20 - 55	0.58	0.14	0.05	Trace	0.77	12.16	14.94	7.8
55 - 110	0.40	0.10	0.05	Trace	0.55	14.14	7.17	4.9
110 - 150	0.40	0.10	0.05	Trace	0.55	10.24	10.28	5.4
150 - 160	0.38	0.06	0.04	Trace	0.48	10.01	16.90	4.8

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 40



Location:

- Commune: Kien Tho
- District: Ngoc Lac
- Province: Thanh Hoa

Soil name:

- VIETNAMESE: *Reddish brown soils on porphyrite rocks*
- FAO-UNESCO: *Rhodic Ferralsols*
- USDA (Soil Taxonomy): *Eutrudox*

THE INFORMATION OF SOIL PROFILE VN 40

Location: Kien Tho Commune, Ngoc Lac District, Thanh Hoa Province

Latitude: 20° 02' 00" N; **Longitude:** 105° 22' 00" E; **Elevation:** 50 m (ASL)

Parent materials: Porphyrite; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Sugar cane

Soil name: *Vietnamese:* Reddish brown soils on basic and intermediate magmatic rocks (1976);
Reddish brown soils (1996)

Reddish brown soils on porphyrite rocks

FAO-UNESCO-WRB: Rhodic Ferralsols

USDA (Soil Taxonomy): Eutrudox

Soil profile description:

- Ap (0 - 30 cm): Bright brown (2.5YR 3/6 moist; 2.5YR 5/8 dry); clay; moist; porous; friable; fine granular structure; many small grass; gradual smooth boundary.
- Bs1 (30 - 70 cm): Bright brown (2.5YR 3/6 moist; 2.5YR 5/8 dry); clay; moist; porous; friable; some small roots; gradual smooth boundary.
- Bs2 (70 - 120 cm): Bright brown (2.5YR 3/6 moist; 2.5YR 5/8 dry); clay; moist; porous; friable; gradual smooth boundary.
- Bs3 (120 - 160 cm): Bright brown (2.5YR 3/6 moist; 2.5YR 5/8 dry); clay; moister than upper horizon; porous; friable.

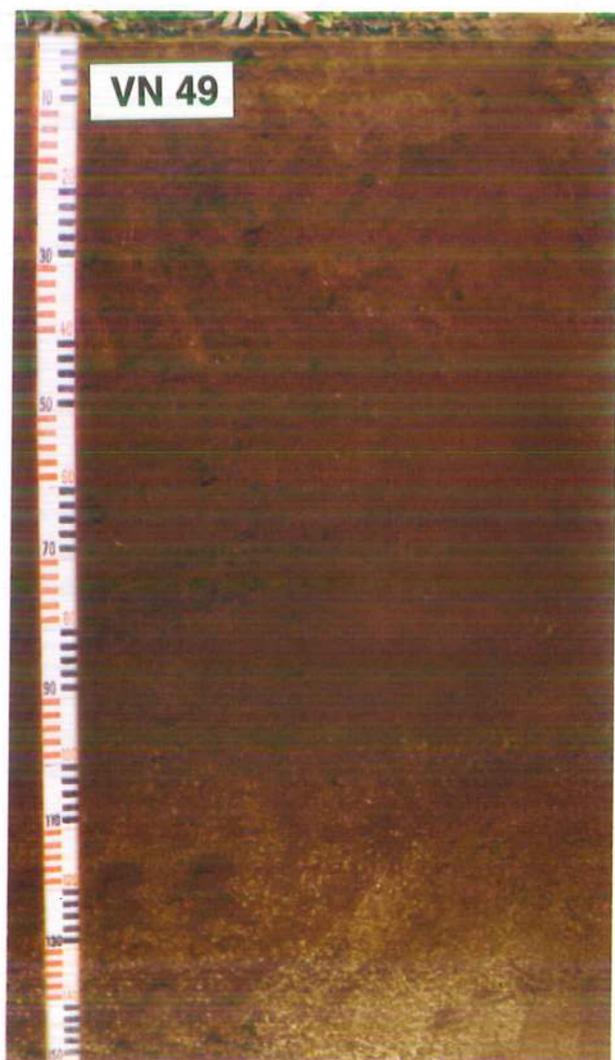
Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 30	0.76	2.90	74.0	29.9	2.4	9.0	29.2	59.4
30 - 70	0.95	2.85	67.0	31.1	2.2	7.4	25.2	65.2
70 - 120	1.03	2.81	63.0	32.1	1.9	6.5	32.0	59.6
120 - 160	0.95	2.85	67.0	32.7	1.8	6.4	19.5	72.3

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 30	1.30	0.12	0.29	0.07	3.71	4.52	1.44	17.10	4.5	3.8
30 - 70	0.74	0.07	0.30	0.06	6.76	3.10	0.88	13.30	4.7	3.9
70 - 120	0.45	0.05	0.22	0.06	6.47	4.52	0.88	13.30	4.6	3.8
120 - 160	0.37	0.05	0.12	0.05	6.47	3.01	0.48	10.00	4.7	3.9

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 30	2.14	1.21	0.09	0.03	3.47	6.08	11.67	57.0
30 - 70	2.14	0.89	0.06	0.08	3.17	5.68	22.20	55.8
70 - 120	2.05	0.85	0.09	0.17	3.16	7.40	24.34	44.5
120 - 160	1.31	0.94	0.06	0.03	2.34	6.84	20.00	46.9

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 49



Location:

- Commune: My Son
- District: Ninh Son
- Province: Ninh Thuan

Soil name:

- VIETNAMESE: *Reddish brown soils on andesite rocks*
- FAO-UNESCO: *Rhodic Ferralsols*
- USDA (Soil Taxonomy): *Eutrustox*

THE INFORMATION OF SOIL PROFILE VN 49

Location: My son Commune, Ninh Son District, Ninh Thuan Province

Latitude: 11° 41' 50" N; **Longitude:** 108° 41' 50" E; **Elevation:** 50 m (ASL)

Parent materials: Andezite; **Topography:** Flat; **Slope:** 3° - 8°

Present land use: Maize

Soil name: *Vietnamese:* Reddish brown soils on basic and intermediate magmatic rocks (1976);
Reddish brown soils (1996)

Reddish brown soils on andesite rocks

FAO-UNESCO-WRB: Rhodic Ferralsols

USDA (Soil Taxonomy): Etrustox

Soil profile description:

- Ap (0 - 10 cm): Dark reddish brown (2.5YR 3/4 moist; 2.5YR 3/6 dry); sandy clay; dry; porous; friable; many roots; thin sand layer on surface; clear smooth boundary.
- AB (10 - 35 cm): Dark reddish brown (2.5YR 3/4 moist; 2.5YR 3/4 dry); sandy clay; slightly moist; hard; firm; many animal channels; some small roots; some small black animal mottles; gradual smooth boundary.
- Bs (35 - 80 cm): Dark reddish brown (2.5YR 3/5 moist; 10R 4/8 dry); sandy clay; moist; slightly firm; porous; some gravels diameter of >1 mm; many animal channels; gradual smooth boundary.
- BC1 (80 - 100 cm): Dark reddish brown (2.5 YR 3/5 moist; 10R 4/8 dry); sandy clay; moist; firm; many gravels than upper horizon; some small animals; clear smooth boundary.
- BC2 (100 - 125 cm): Dark reddish brown (2.5 YR 3/5 moist; 2.5YR 4/6 dry); sandy clay loam; moist; mixed yellow gravels of 20-30%; clear smooth boundary.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 10	1.30	2.71	52.0	8.3	22.2	31.1	9.5	37.2
10 - 35	1.50	2.62	43.0	14.8	18.1	26.1	9.1	46.7
35 - 80	1.50	2.62	44.0	15.9	21.3	22.9	9.5	46.3
80 - 100	1.60	2.63	40.0	15.0	20.7	30.9	7.4	41.0
100 - 125	1.50	2.73	45.0	14.2	28.7	29.8	11.6	29.9

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 10	1.00	0.07	0.04	1.82	0.39	6.12	0.03	1.59	6.4	5.4
10 - 35	0.85	0.05	0.03	1.60	0.33	3.76	0.04	1.62	6.5	5.3
35 - 80	0.80	0.04	0.04	1.60	0.31	3.76	0.06	1.17	6.5	5.0
80 - 100	0.72	0.03	0.03	1.65	0.25	23.50	0.04	1.58	6.7	5.0
100 - 125	0.65	0.03	0.04	1.67	0.88	23.50	0.04	1.43	6.3	5.0

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 10	2.80	1.46	0.13	0.05	4.44	9.52	16.08	46.6
10 - 35	2.54	1.81	0.08	0.05	4.48	11.24	31.40	39.8
35 - 80	2.27	2.01	0.08	0.08	4.44	10.24	26.00	43.3
80 - 100	2.55	1.91	0.51	0.17	5.14	10.16	26.00	50.5
100 - 125	3.12	1.87	0.51	0.32	5.82	10.80	27.76	53.8

- Brownish red soils derived from limestones:

Limestones are very common in the North of Vietnam such as limestone mountains in Cao Bang, Lang Son, Ha Giang, Tuyen Quang, Bac Kan, Son La, Ninh Binh, Nghe An ... provinces with total area of around 250,000 hectares.

Topography form of limestone mountains, called Karsts one, is very complicated. In these regions are abrupt rocky mountains with many caves interposed valleys. The main components of limestones are CaCO_3 , little sediment, and some others. When weathered, CaCO_3 is dissolved; sediment is not dissolved and accumulated forming brownish red soils. Because of little sediment, soils derived from limestone are normally very little in volume and agglomerated mainly at foothills, in valleys, or in mountain gorges. Because of this complex relationship, on limestone are found many soil types interposed together. For instance, at foothills, where topography is quite slopped, are normally found intermediate brownish red soils. On the same topography but far from rocky mountains are acid soils; in low and wet place are moderate acid yellow soils; as for hollow place are black soils.

Many crops can be grown on these soils such as maize, soybean, tea, pineapple, sugarcane, etc... It is suggested to using measures for erosion controlling and keeping soil moisture.

Soil profiles **VN 15** and **VN 27** are characterized for these soils.

- Yellowish red soils derived from clay shales and metamorphic igneous rocks:

These soils cover the biggest area in Vietnam (about 7.14 millions hectares), distribute in almost provinces of midland and mountainous regions on hilly topography forms with different slope degree that are strongly separated. In Phu Tho Province mica schist and paragneiss stones with plump hilly topography forms are dominant. In Cao Bang, Lang Son, and Bac Giang Provinces there are clay shales with hilly range topography forms. In Northwest region (from Hoa Binh to Lai Chau Provinces) there are clay shales and violet shale stones with high hilly or plateau topography forms.

Soil properties of yellowish red soils on clay shales and metamorphic rocks are various, but in general are as follows:

1. Fine earth thickness is about 0.60 - 1.2 m. The highest value is found on mica schist in Phu Tho, 2 m in average.
2. Soil horizon boundary is very smoothly.
3. Soil porosity is lower in comparison with that of basalt reddish brown soils. Soil structure and soil porosity is better and better following the order of soils derived on shale stones, violet shale stones, and mica schist.
4. These soils, in general, are very acidic, pH_{KCl} ranges from 4 to 4.5.
5. Soil texture normally is very fine, sometimes found quartz fragments in the fine part.
6. Organic carbon content is very various with humus layer is not thick. Both potential and available phosphorus are low, potassium is normally medium but higher than that soils derived from mica schist.

On these soils perennial crops such as tea, wax-tree, etc... and annual crops such as pineapple, maize, cassava, sugarcane, etc... can be cultivated. On high place are mainly forest trees. Because of thin fine earth thickness and low fertility, soils would be degenerate quickly if they are not improved and protected from erosion.

Soil profiles **VN 10**, **VN 13**, **VN 45**, and **VN 09** are characterized for this soil unit.

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 38



Location:

- Commune: Loc Son
- District: Bao Loc
- Province: Lam Dong

Soil name:

- VIETNAMESE: Yellowish brown soils on basaltic rocks
- FAO-UNESCO: Xanthic Ferralsols
- USDA (Soil Taxonomy): Hapludox

THE INFORMATION OF SOIL PROFILE VN 38

Location: Loc Son Commune, Bao Loc District, Lam Dong Province

Latitude: 11° 31' 20" N; **Longitude:** 107° 49' 00" E; **Elevation:** 830 m (ASL)

Parent materials: Basalt; **Topography:** Flat; **Slope:** 3° - 8°

Present land use: Perennial industrial crops (Coffee, Tea)

Soil name: Vietnamese: Yellowish brown soils on basic and intermediate magmatic rocks (1976);
Yellowish brown soils (1996)

Yellowish brown soils on basaltic rocks

FAO-UNESCO-WRB: Xanthic Ferralsols

USDA (Soil Taxonomy): Hapludox

Soil profile description:

- Ap (0 - 20 cm):** Dark brown (7.5YR 3/4 moist; 7.5YR 4/4 dry); clay; moist; very porous and friable; granular structure; many grass roots; organic black mottles and many animal channels (termite, ant); gradual smooth boundary.
- Bs1 (20 - 65 cm):** Brown (7.5YR 4/6 moist; 7.5YR 5/6 dry); clay; moist; porous; friable; fine granular structure; many animal channels, grass roots and rotten tea roots diameter of 1 - 2 cm; few small dark brown rock fragments; gradual boundary.
- Bs2 (65 - 100 cm):** Brown (7.5YR 4/6 moist; 7.5YR 5/6 dry); clay; moist; porous; friable; fine granular structure; firm; some termite and ant channels; some mixed white and red rock fragments; gradual smooth boundary.
- Bs3 (100 - 145 cm):** Brown (7.5YR 4/6 moist; 7.5YR 5/7 dry); clay; moist; friable; porous; fine granular structure; some mixed white and red rock fragments; few small brownish pink clay mottles; gradual smooth boundary.
- BC (145 - 165 cm):** Reddish brown (5YR 4/8 moist; 7.5YR 5/8 dry); clay; moist; many rock fragments diameter of less than 2 cm (5 - 10%).

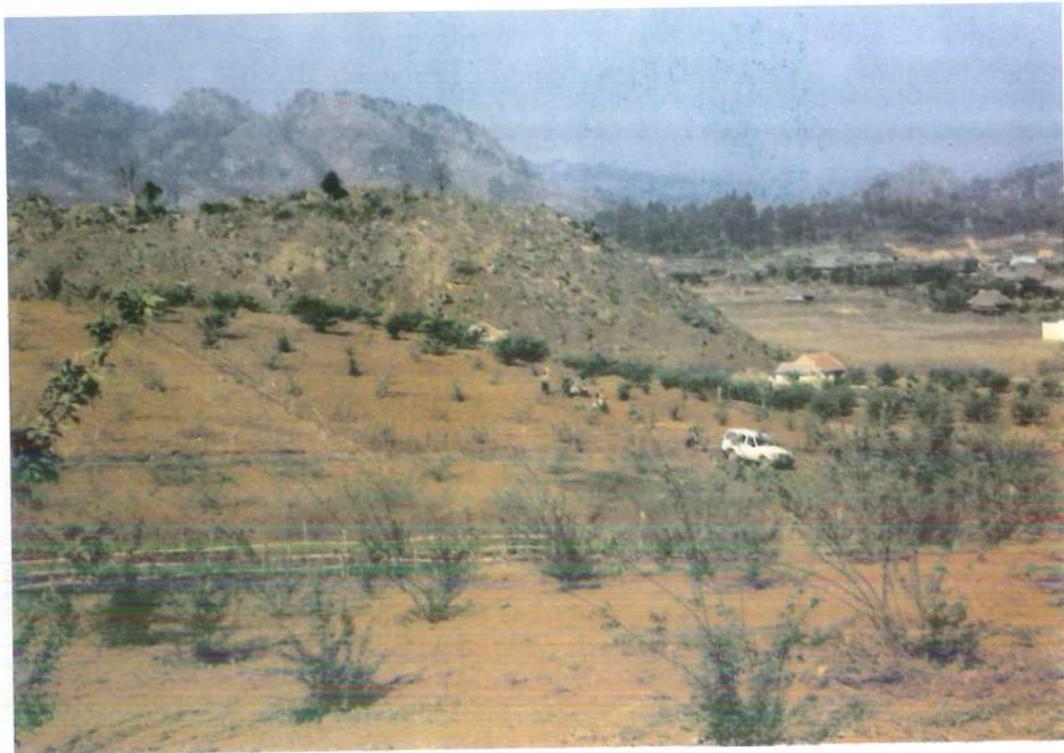
Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 20	0.81	2.53	68.0	24.8	7.7	21.7	3.3	67.3
20 - 65	0.83	2.66	68.8	29.0	7.4	13.5	4.7	74.4
65 - 100	1.01	2.73	63.0	29.2	6.6	19.9	1.9	71.6
100 - 145	0.94	2.70	65.2	30.2	6.5	17.8	0.2	75.5
145 - 165	1.05	2.73	61.5	29.7	6.5	18.0	1.8	73.7

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 20	4.15	0.53	0.21	0.08	1.73	4.82	3.92	16.83	4.7	4.0
20 - 65	1.57	0.18	0.18	0.06	0.23	4.82	1.00	5.46	4.9	4.2
65 - 100	0.34	0.08	0.14	0.05	0.14	1.00	0.06	1.11	4.9	4.2
100 - 145	0.34	0.05	0.11	0.04	0.14	2.41	0.06	1.11	4.9	4.1
145 - 165	0.30	0.04	0.12	0.04	0.14	2.41	0.04	0.87	4.7	4.1

Soil horizon thickness, cm	Exchangeable Cation, cmol(+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 20	0.29	0.06	0.10	0.05	0.50	13.28	18.40	3.8
20 - 65	0.34	0.04	0.10	0.00	0.48	5.28	14.10	9.1
65 - 100	0.16	0.00	0.02	0.00	0.18	3.92	18.60	4.6
100 - 145	0.06	0.00	0.05	0.00	0.11	3.28	15.54	3.4
145 - 165	0.22	0.00	0.05	0.00	0.27	3.14	17.34	8.6

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 15



Location:

- Commune: Muong Sang
- District: Moc Chau
- Province: Son La

Soil name:

- VIETNAMESE: *Brownish red soils on limestones*
- FAO-UNESCO: *Haplic Ferralsols*
- USDA (Soil Taxonomy): *Hapludox*



THE INFORMATION OF SOIL PROFILE VN 15

Location: Muong Sang Commune, Moc Chau District, Son La Province

Latitude: 20° 50' 00" N; **Longitude:** 104° 35' 00" E; **Elevation:** 900 m (ASL)

Parent materials: Limestones; **Topography:** Undulating; **Slope:** 8° - 15°

Present land use: Plum mixed with apricot trees

Soil name: Vietnamese: Brownish red soils on limestones (1976); Reddish brown soils (1996)

Brownish red soils on limestones

FAO-UNESCO-WRB: Haplic Ferralsols

USDA (Soil Taxonomy): Hapludox

Soil profile description:

- Ap (0 - 20 cm): Bright reddish brown (5YR 5/6 moist; 7.5YR 4/6 dry); clay; dry; fine; many small grass roots; clear smooth boundary.
- Bs1 (20 - 45 cm): Reddish brown (5YR 4/8 moist; 5YR 4/8 dry); some black mottles; clay; dry; fine granular structure; many cracks; some roots; some animal channels; gradual smooth boundary.
- Bs2 (45 - 110 cm): Reddish brown (5YR 4/8 moist; 5YR 4/8 dry); clay; moister than above horizon; fine granular structure; some grass roots; gradual clear smooth boundary.
- BC (110 - 160 cm): Reddish brown (5YR 4/8 moist; 5YR 5/8 dry); clay; moister than upper horizon; some small concretions; fine granular structure.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 20	1.26	2.57	51.0	17.6	7.1	24.8	10.9	57.2
20 - 45	1.16	2.60	55.4	26.8	6.4	20.4	8.6	64.6
45 - 110	1.18	2.67	55.8	29.2	5.6	20.5	10.8	63.1
110 - 160	1.33	2.69	50.6	30.9	5.1	18.8	11.1	65.0

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 20	1.62	0.15	0.14	0.20	4.10	4.71	3.22	19.37	5.5	3.9
20 - 45	0.81	0.09	0.12	0.17	2.50	4.24	2.56	14.50	5.3	4.0
45 - 110	0.46	0.07	0.12	0.22	1.80	4.24	2.74	14.00	5.4	3.9
110 - 160	0.38	0.08	0.12	0.22	1.60	5.65	2.98	13.00	5.2	3.9

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 20	0.96	0.36	0.10	0.89	2.31	6.77	11.44	34.1
20 - 45	0.77	0.25	0.09	0.51	1.62	7.99	13.50	20.3
45 - 110	0.52	0.42	0.09	0.76	1.79	6.79	11.46	26.4
110 - 160	0.91	0.39	0.12	0.65	2.07	6.92	11.70	29.9

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 27



Location:

- Commune: Dong Giao
- District: Tam Diep
- Province: Ninh Binh

Soil name:

- VIETNAMESE: Yellowish brown soils on limestones
- FAO-UNESCO: Xanthic Ferralsols
- USDA (Soil Taxonomy): Hapludox



THE INFORMATION OF SOIL PROFILE VN 27

Location: Dong Giao Farm No 1, Tam Diep District, Ninh Binh Province.

Latitude: 20° 10' 00'' N; **Longitude:** 105° 52' 00'' E; **Elevation:** 15 m (ASL)

Parent materials: Limestones; **Topography:** Flat; **Slope:** 0 - 3°

Present land use: Pineapple just harvested

Soil name: *Vietnamese:* Brownish red soils on limestones (1976); Reddish brown soils (1996)
Yellowish brown soils on limestones

FAO-UNESCO-WRB: Xanthic Ferralsols

USDA (Soil Taxonomy): Hapludox

Soil profile description:

- Ap (0 - 25 cm): Yellowish brown (10YR 5/6 moist; 10YR 4/6 dry); clay; fine granular structure; dry; hard; many small grass roots; some small termite channels; clear smooth boundary.
- Bs1 (25 - 50 cm): Bright brown (7.5YR 5/8 moist; 7.5YR 6/7 dry); clay; moister than upper horizon; firm; fine granular structure; some animal channels; few roots; clear smooth boundary.
- Bs2 (50 - 100 cm): Bright brown (7.5YR 5/8 moist; 7.5YR 6/8 dry); clay; moister than above lying horizon; more porous than above lying horizon; fine granular structure; gradual smooth boundary.
- BC (100 - 160 cm): Orange (7.5YR 6/8 moist; 10YR 6/8 dry); clay; moist; friable; porous; fine granular structure.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 25	1.24	2.63	52.8	24.1	2.0	17.5	12.9	67.6
25 - 50	1.17	2.80	58.2	31.7	2.1	17.3	11.0	69.6
50 - 100	1.18	2.79	57.7	34.5	1.8	11.0	11.1	76.1
100 - 160	1.14	2.87	60.2	34.0	2.0	15.3	10.3	72.4

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 25	1.77	0.15	0.28	1.10	10.38	5.20	2.07	17.75	5.1	3.9
25 - 50	0.67	0.08	0.21	1.00	4.50	5.00	2.69	14.00	4.8	3.9
50 - 100	0.44	0.06	0.23	0.80	5.50	4.50	1.00	12.00	5.2	4.1
100 - 160	0.29	0.07	0.31	0.70	5.00	4.00	0.78	11.00	4.9	4.2

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 25	0.23	0.14	0.11	0.36	1.32	11.50	19.44	11.4
25 - 50	0.16	0.35	0.10	0.26	0.87	9.99	16.88	8.7
50 - 100	0.13	0.21	0.09	0.20	0.63	7.57	12.79	8.3
100 - 160	0.08	0.14	0.08	0.12	0.42	6.34	10.71	6.6

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 10



Location:

- Phu Ho Tea Research Station
- District: Phu Ninh
- Province: Phu Tho

Soil name:

- VIETNAMESE: *Yellowish red soils on clay shales*
- FAO-UNESCO: *Haplic Acrisols*
- USDA (Soil Taxonomy): *Hapludults*

Location: Phu Ho Tea Research Station, Phu Ninh District, Phu Tho Province

Latitude: 21° 28' 00" N; **Longitude:** 105° 14' 00" E; **Elevation:** 70 m (ASL)

Parent materials: Clay shales; **Topography:** Flat; **Slope:** 3° - 8°

Present land use: Ironwood trees (Latin: *Eurythrophloeumfodii*)

Soil name: Vietnamese: Yellowish red soils on clay shales and metamorphic rocks (1976);

Ferralitic Grey soils (1996)

Yellowish red soils on clay shales

FAO-UNESCO-WRB: Haplic Acrisols

USDA (Soil Taxonomy): Hapludults

Soil profile description:

- Ap1 (0 - 10 cm): brown (7.5YR 4/4 moist; 10YR 5/4 dry); sandy loam; slightly moist; granular structure; slightly porous; some big roots; clear smooth boundary.
- Ap2 (10 - 30 cm): Brown (7.5YR 4/6 moist; 10YR 6/6 dry); sandy clay; slightly moist (moister than above lying horizon); fine granular structure; many different size roots; some animal channels; gradual smooth boundary.
- Bt1 (30 - 75 cm): Bright brown (7.5YR 5/6 moist; 10YR 6/6 dry); sandy clay; fine granular structure; some roots; clear smooth boundary.
- Bt2 (75 - 125 cm): Bright brown (7.5YR 5/6 moist; 10YR 6/6 dry); many small brown yellow concretions (7.5YR 4/6 moist; 10YR 3/4 dry); bright brown (2.5YR 5/8 moist; 10YR 6/6 dry) concretions (> 50%); few rocks diameter of 5-7 cm; dry; sandy clay; granular structure; clear smooth boundary.
- BC (125 - 160 cm): Bright brown (7.5YR 5/6 moist; 10YR 6/6 dry); many white and yellow weathered rocks (10YR 7/6 dry); more friable than above lying horizon; some porous violet concretions (7.5YR 4/6 dry); clay; fine structure.

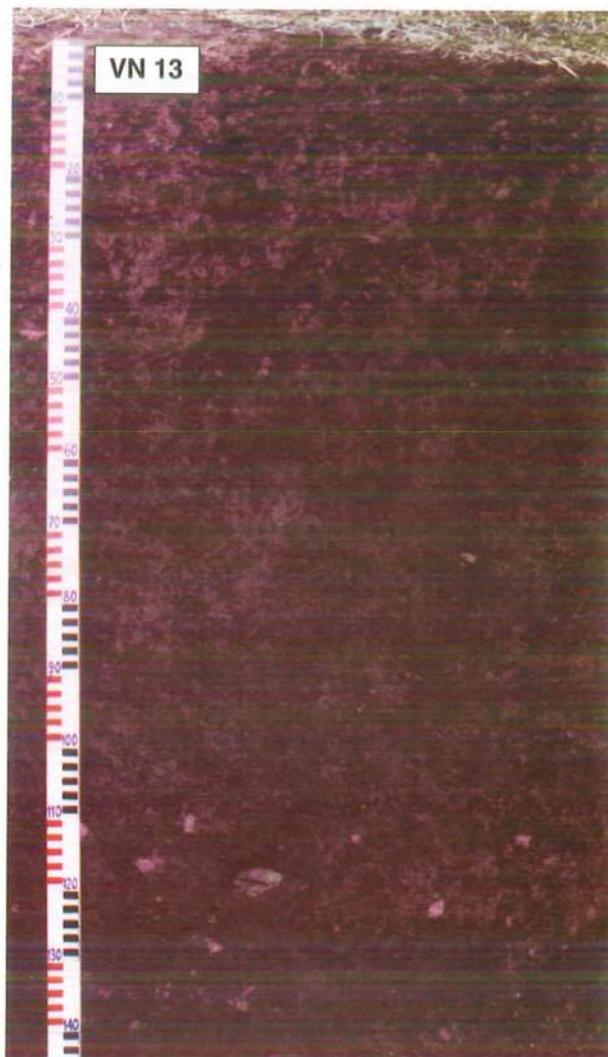
Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 10	1.09	2.56	57.4	30.2	29.8	46.5	5.4	18.3
10 - 30	1.36	2.63	48.3	33.5	21.7	30.9	4.2	43.2
30 - 75	1.31	2.63	50.2	37.5	22.8	27.2	3.0	47.0
75 - 125	1.36	2.72	50.0	32.9	28.3	19.2	8.4	44.1
125 - 160	1.35	2.71	50.2	33.8	18.3	21.8	5.2	54.7

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 10	1.62	0.14	0.04	0.08	4.93	7.06	2.76	10.50	3.9	3.3
10 - 30	0.67	0.06	0.04	0.06	0.90	1.41	2.74	8.50	4.4	3.6
30 - 75	0.54	0.07	0.03	0.05	1.00	1.41	2.25	8.00	4.5	3.7
75 - 125	0.19	0.02	0.03	0.05	0.90	1.41	1.12	8.25	4.6	3.8
125 - 160	0.26	0.02	0.02	0.05	0.70	Trace	2.05	6.25	4.6	3.9

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 10	0.91	0.14	0.15	0.09	1.29	8.84	20.16	14.6
10 - 30	0.57	0.08	0.03	0.07	0.75	6.69	11.31	11.2
30 - 75	0.57	0.09	0.03	0.07	0.76	9.82	16.60	7.7
75 - 125	0.53	0.08	0.03	Trace	0.64	12.46	21.06	5.1
125 - 160	0.35	0.10	Trace	Trace	0.45	12.50	21.12	3.6

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 13



Location:

- Commune: Chieng An
- Town: Son La
- Province: Son La

Soil name:

- VIETNAMESE: *Violet brown soils on clay shales*
- FAO-UNESCO: *Haplic Nitisols*
- USDA (Soil Taxonomy): *Kandiudults*

THE INFORMATION OF SOIL PROFILE VN 13

Location: Chieng An Commune, Son La Town, Son La Province

Latitude: 21° 22' 00''N; **Longitude:** 103° 53' 00''E; **Elevation:** 950 m (ASL)

Parent materials: Clay shales; **Topography:** Hill; **Slope:** 20° - 25°

Present land use: Fruit trees (Plum, banana, pineapple) intercropped with coffee

Soil name: Vietnamese: Yellowish red soils on clay shales and metamorphic rocks 1976);

Ferralitic Grey soils (1996)

Violet brown soils on clay shales

FAO-UNESCO-WRB: Haplic Nitisols

USDA (Soil Taxonomy): Kandiudults

Soil profile description:

Ap (0 - 15 cm):	Dull reddish brown (2.5YR 4/3 moist; 2.5YR 4/3 dry); clay; dry; cubic structure; many roots; many cracks; gradual smooth boundary.
AB (15 - 40 cm):	Dull reddish brown (2.5YR 4/4 moist; 2.5YR 5/4 dry); clay; moister than upper horizon; friable; cubic structure; many roots and some grass roots; many cracks; clear smooth boundary.
Bt1 (40 - 85 cm):	Dull reddish brown (2.5YR 4/4 moist; 2.5YR 5/4 dry); clay; moister than upper horizon; subangular blocky structure; some soft rocks of blackish violet colour; shiny ped face; gradual smooth boundary.
Bt2 (85 - 110 cm):	Dull reddish brown (2.5YR 4/4 moist; 2.5YR 5/4 dry); clay loam; shiny ped face; less rocks fragments than upper horizon; clear smooth boundary.
BC (110 - 150 cm):	Dull reddish brown (2.5YR 4/4 moist; 2.5YR 5/4 dry); clay loam; moist; more friable and porous; some rocks fragments (7.5 R 4/1.5 dry); some soft and small metamorphic rocks at the lower part of horizon.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	1.23	2.78	55.8	27.5	7.2	17.1	20.0	55.7
15 - 40	1.12	2.78	59.7	30.4	4.7	14.1	14.8	66.4
40 - 85	1.20	2.79	57.0	31.0	4.7	11.0	20.8	63.5
85 - 110	1.19	2.80	57.5	29.9	5.1	15.5	25.1	54.3
110 - 150	1.21	2.78	56.5	30.1	4.7	16.2	26.9	52.2

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 15	1.44	0.14	0.67	0.43	6.10	9.42	11.18	30.00	4.8	3.6
15 - 40	1.14	0.11	0.30	0.43	2.60	5.65	8.21	27.50	5.5	3.7
40 - 85	0.87	0.08	0.29	0.40	2.80	6.59	6.86	23.75	5.3	3.8
85 - 110	0.56	0.06	0.32	0.40	3.50	5.65	7.15	22.50	5.7	3.8
110 - 150	0.48	0.05	0.33	0.36	4.00	4.71	6.29	21.75	5.6	3.8

Soil horizon thickness, cm	Exchangeable Cation, cmol(+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 15	1.34	1.10	0.20	0.10	2.74	7.15	13.73	38.3
15 - 40	1.51	1.14	0.12	0.09	2.86	7.51	14.42	38.0
40 - 85	1.91	1.16	0.14	0.07	3.28	7.07	11.95	46.3
85 - 110	2.39	1.13	0.12	0.06	3.70	7.97	13.47	46.4
110 - 150	1.63	0.92	0.11	0.05	2.71	9.06	15.31	29.9

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 45

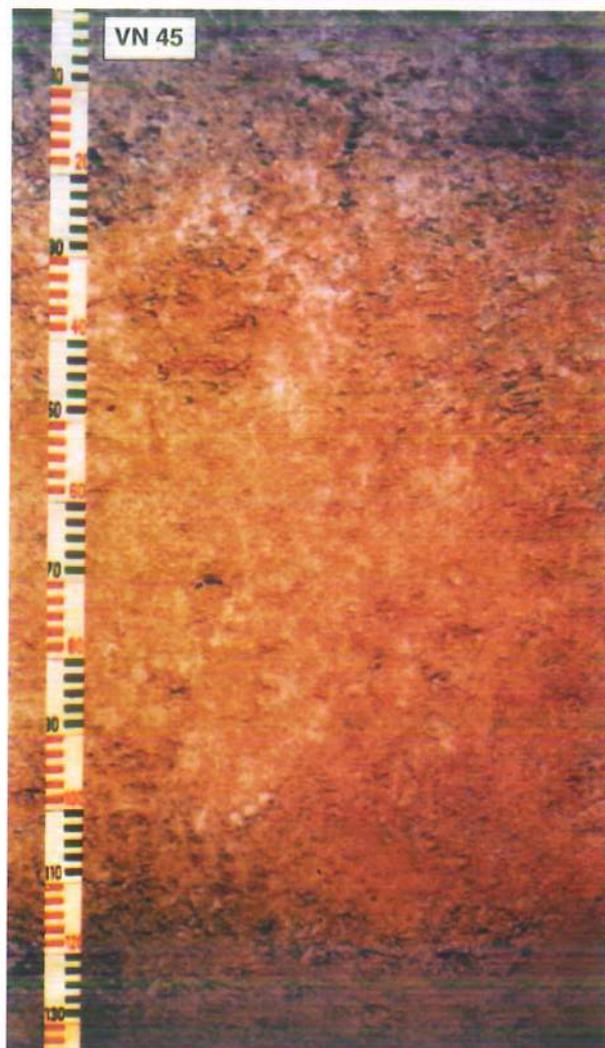


Location:

- Commune: Phu Ho
- District: Phu Ninh
- Province: Phu Tho

Soil name:

- VIETNAMESE: *Yellowish brown soils on mica schist*
- FAO-UNESCO: *Xanthic Ferralsols*
- USDA (Soil Taxonomy): *Hapludox*



THE INFORMATION OF SOIL PROFILE VN 45

Location: Phu Ho Commune, Phu Ninh District, Phu Tho Province

Latitude: 21° 27' 00" N; **Longitude:** 105° 16' 00" E; **Elevation:** 70 m (ASL);

Parent materials: Mica schist; **Topography:** Sloping hill; **Slope:** 8° - 15°;

Present land use: Cassava

Soil name: Vietnamese: Yellowish red soils on clay shales and metamorphic rocks 1976);
Ferralitic Grey soils (1996)

Yellowish brown soils on mica schist

FAO-UNESCO-WRB: Xanthic Ferralsols

USDA (Soil Taxonomy): Hapludox

Soil profile description:

- Ap (0 - 25 cm): Reddish brown (5YR 4/7 moist; 7.5YR 6/6 dry); clay; slightly moist; porous; many small roots; firmer than upper horizon; clear smooth boundary.
- Bws (25 - 60 cm): Bright reddish brown (5YR 5/8 moist; 7.5YR 6/8 dry); clay; moist; firmer than upper horizon; many small roots; porous; friable; gradual smooth boundary.
- Bs (60 - 110 cm): Bright (5YR 5/8 moist; 7.5YR 7/8 dry); clay; slightly moist; many small roots; friable; gradual smooth boundary.
- Bsc (110 - 140 cm): Bright (5YR 5/8 moist; 7.5YR 7/8 dry); clay; slightly moist; many concretions diameter of 1 - 2 mm (30 - 40%).

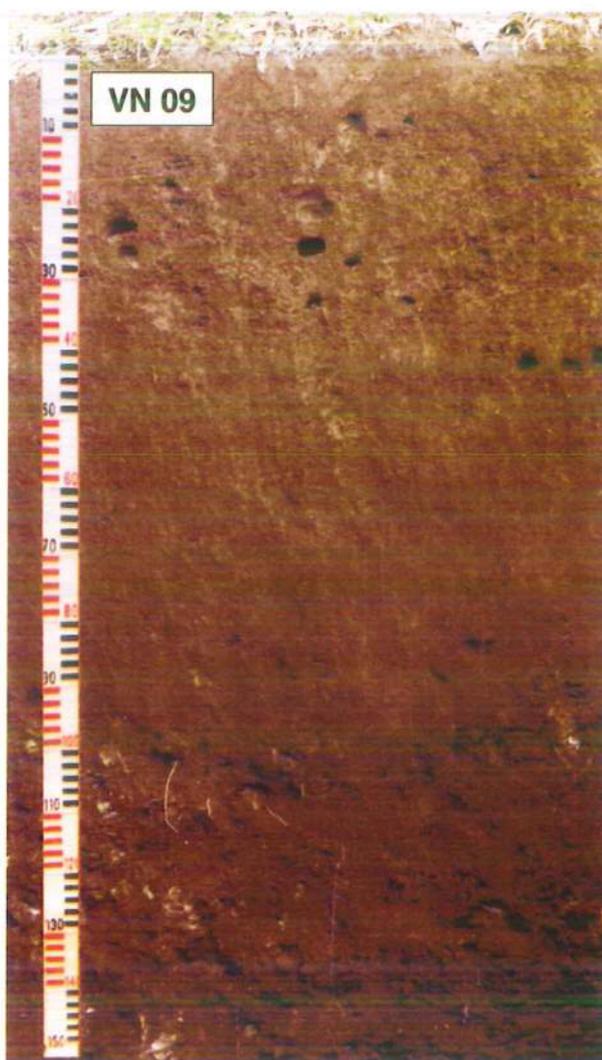
Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 25	1.14	2.77	59.0	22.8	21.2	22.8	11.3	44.7
25 - 60	1.32	2.71	51.0	22.9	31.0	5.6	14.5	48.9
60 - 110	1.35	2.75	51.0	22.9	18.2	17.5	13.7	50.6
110 - 140	-	-	-	-	21.1	15.5	13.5	49.9

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 25	1.78	0.14	0.05	0.06	1.59	7.53	1.68	10.20	4.6	3.8
25 - 60	0.60	0.09	0.05	0.05	1.09	3.01	1.44	7.51	4.7	3.9
60 - 110	0.56	0.06	0.06	0.10	1.24	4.52	1.60	7.63	4.8	4.0
110 - 140	0.30	0.06	0.05	0.10	0.73	3.01	1.36	6.11	4.7	3.9

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 25	0.63	0.32	0.15	0.07	1.17	5.76	9.73	20.3
25 - 60	0.63	0.32	0.06	0.03	1.04	8.64	23.20	12.0
60 - 110	0.16	0.08	0.09	0.04	0.37	6.88	11.62	5.4
110 - 140	0.16	0.08	0.06	0.03	0.33	6.88	11.62	4.8

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 09



Location:

- Commune: Chau Hanh
- District: Quy Chau
- Province: Nghe An

Soil name:

- VIETNAMESE: Yellowish red soils
on the metamorphic granite/gneiss
- FAO-UNESCO: Haplic Acrisols
- USDA (Soil Taxonomy): Kanhapludults

THE INFORMATION OF SOIL PROFILE VN 09

Location: Chau Hanh Commune, Quy Chau District, Nghe An Province

Latitude: 19° 32' 06" N; **Longitude:** 105° 06' 00" E; **Elevation:** 70 m (ASL)

Parent materials: Granite/Gneiss; **Topography:** Sloping hill; **Slope:** 15° - 20°

Present land use: Bamboo mixed with scrubs

Soil name: *Vietnamese:* Reddish yellow soils on acid magmatic rocks 1976);

Ferralitic Grey soils (1996)

Yellowish red soils on the metamorphic granite/gneiss

FAO-UNESCO-WRB: Haplic Acrisols

USDA (Soil Taxonomy): Kanhapludults

Soil profile description:

- Ap (0 - 15 cm): Dull reddish brown (5YR 4/4 moist; 7.5YR 6/4 dry); sandy clay; slightly moist; fine; porous; many grass roots; clear smooth boundary.
- AB (15 - 35 cm): Reddish brown (5YR 4/6 moist; 5YR 6/4 dry); sandy clay; porous; fine; many grass roots and animal channels; gradual smooth boundary.
- Bt1 (35 - 60 cm): Bright reddish brown (5YR 5/8 moist; 5YR 6/6 dry); sandy clay; fine; porous; few roots; clear smooth boundary.
- Bt2 (60 - 100 cm): Bright reddish brown (5YR 5/8 moist; 5YR 6/6 dry); sandy clay; porous; fine; few roots; clear smooth boundary.
- BC (100 - 150 cm): Bright reddish brown (5YR 5/8 moist; 5YR 6/6 dry); clay; moist; many white gneiss rocks; few roots.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	1.16	2.74	57.7	27.6	16.4	40.6	7.3	35.7
15 - 35	1.24	2.71	54.2	26.6	13.0	38.6	8.8	39.6
35 - 60	1.19	2.79	57.3	27.4	12.7	33.2	5.5	48.6
60 - 100	1.26	2.68	53.0	28.1	14.8	31.0	3.6	50.6
100 - 150	1.25	2.79	55.2	2.85	11.5	27.5	9.9	51.1

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 15	2.15	0.20	0.04	0.32	13.00	16.01	2.74	13.74	4.6	3.7
15 - 35	0.96	0.19	0.03	0.30	2.67	9.76	3.61	10.60	4.5	3.6
35 - 60	0.69	0.07	0.03	0.24	1.67	3.76	3.79	10.00	4.5	3.6
60 - 100	0.65	0.07	0.03	0.26	1.43	3.76	3.69	9.50	4.7	3.7
100 - 150	0.34	0.04	0.02	0.24	1.03	4.24	2.93	7.00	5.0	3.7

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 15	1.10	0.18	0.34	0.20	1.82	12.14	19.74	15.0
15 - 35	0.88	0.14	0.08	0.14	1.24	8.74	16.78	14.2
35 - 60	0.84	0.14	0.08	0.14	1.20	8.96	15.14	13.4
60 - 100	0.79	0.13	0.08	0.39	1.39	8.33	14.08	16.7
100 - 150	0.80	0.14	0.09	0.14	1.17	6.79	11.48	17.2

- Reddish yellow soils on acid magmatic rocks:

These soils occupy quite big areas in Vietnam, estimated around 4.5 millions hectares, distributed alternately with different soil units of mountainous regions.

The acid magmatic rocks in Vietnam have many kinds such as: granite, liparite, hyalite, and quartz... The acid magmatic rocks distributed from the North to the South but mainly in the provinces of midland and mountainous region (Lang Son, Vinh Phuc, Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Khanh Hoa, Quang Ngai, etc...).

The soils derived from acid magmatic rocks usually have thin soil layer (less than 1m in average) because acid magmatic rocks are formed in sloping topography and have very weak weathered process.

These soils have a medium texture, but the texture of surface is rather lighter because of leaching. Primary quartz is distributed dispersedly in soil profile. Soil characteristics are the same as that derived from clay shales and metamorphic rocks: soils are very acidic, thin humus horizon, low phosphorus content, etc... These soils are suitable for cultivation of tea, anise, maize, cassava, upland rice, etc.

Because of thin layer and forming on sloping topography these soils are easy to be eroded. Therefore, they should be conserved by afforestation, applying controlled erosion methods and fortification soil fertility.

Soil profiles **VN 50** and **VN 54** are characterized for this soil unit.

- Light yellow soils on sandstones:

There are around 2.5 milions hectares of light yellow soils on sandstones in Vietnam that distribute in the provinces of Northeast and Central regions.

Sandstones contain a high amount of quartz and have high silica content. Sandstones have many kinds such as: mica shist, sandy quartzite rocks. Light yellow soils on sandstones normally have a thin layer (less than 1 m in average) because parent rocks are difficult weathered. The texture of these soils is sandy. Soils are acidic, poor in nutritions (both total and available); content of OC in these soils is low... because of strong erosion and leaching.

Soil profiles **VN 11** and **VN 52** are characterized for this soil unit.

- Yellowish brown soils on old alluvium:

These soils are distributed in the edge of Northern plain regions (Ha Tay Province) and in the Southeast regions with total area of 400,000 hectares national-wide.

Topography of these soils is higher than the plains (about 25 - 30 m) and on the undulating hill form. The soils have yellowish brown colour and they are acidic with major properties of ferralitic soils. Lateritic process is very strong. Rather flat topography and shallow ground water level make the soils having lateritic (petroferic) layers.

In general, soils are poor in nutrient, but favorable for agriculture development with some advantages as follows:

- + Having rather thick layer and porous.
- + Flat topography.
- + Having water resources or next to water resources.
- + Next to the plains, transportation is favorable.

Cash crops and fruit trees can be planted on these soils. It is suggested to apply organic fertilizer, balance nutrient and control degrading.

Soil profile **VN 07** is characterized for this soil unit.

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 50



Location:

- Commune: Ninh Ich
- District: Ninh Hoa
- Province: Khanh Hoa

Soil name:

- VIETNAMESE: Yellowish red soils on granite rocks
- FAO-UNESCO: Haplic Acrisols
- USDA (Soil Taxonomy): Eutrastults

THE INFORMATION OF SOIL PROFILE VN 50

Location: Ninh Ich Commune, Ninh Hoa District, Khanh Hoa Province

Latitude: 12° 23' 10" N; **Longitude:** 109° 10' 30" E; **Elevation:** 85 m (ASL)

Parent materials: Granite; **Topography:** Sloping hill; **Slope:** 15° - 20°

Present land use: Cashew, mango

Soil name: Vietnamese: Reddish yellow soils on acid magmatic rocks (1976);

Ferralitic Grey soils (1996);

Yellowish red soils on granite rocks

FAO-UNESCO-WRB: Haplic Acrisols

USDA (Soil Taxonomy): Eutrastults

Soil profile description:

- Ap (0 - 20 cm): Dark reddish brown (5YR 3/3 moist; 10YR 5/3dry); sandy clay loam; slightly moist; slightly firm; porous; friable; many small rock fragments diameter of 4 - 6 cm on the surface; many roots; some black peat; clear smooth boundary.
- Bws (20 - 50 cm): Reddish brown (5YR 4/8 moist; 7.5YR 6/6 dry); clay loam; moist; porous; many roots diameter of 1 - 5 cm; many rock fragments (20 - 30%); gradual smooth boundary.
- Bts (50 - 95 cm): Bright reddish brown (5YR 5/6 moist; 7.5YR 6/8 dry); clay; moist; porous; some roots; some small rock fragments diameter of < 2 cm; gradual smooth boundary.
- BC (95 - 130 cm): Dark reddish brown (5YR 5/6 moist; 5YR 5/8 dry); sandy clay; moist; some roots; many rock fragments (40 - 50%).

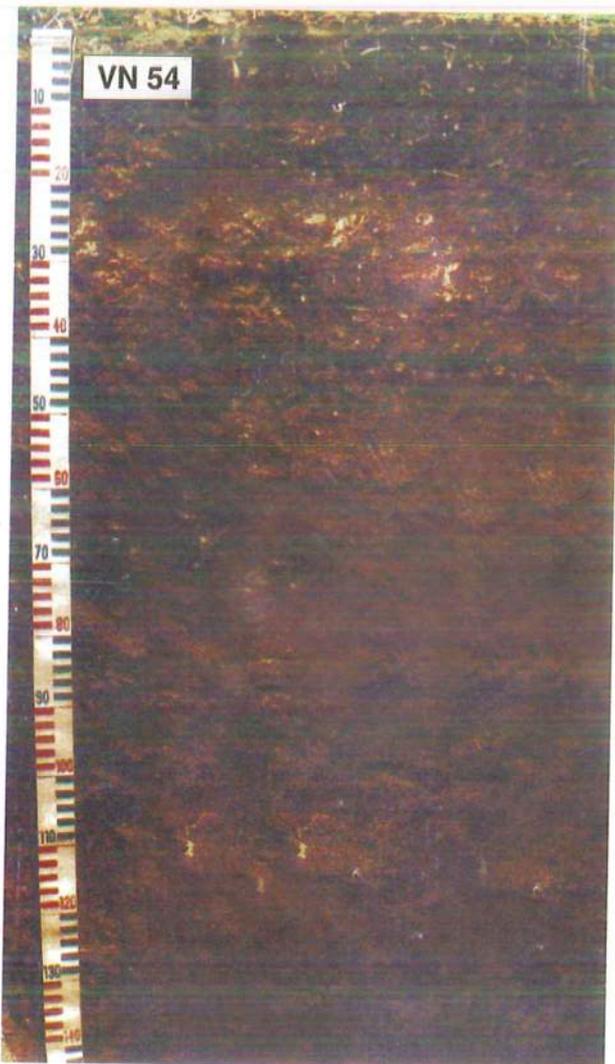
Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 20	1.30	2.71	52.0	12.8	26.3	28.2	25.3	20.2
20 - 50	1.50	2.62	48.0	17.4	22.6	18.2	24.2	35.0
50 - 95	1.50	2.65	48.0	14.4	29.0	13.2	16.5	41.3
95 - 130	1.60	2.64	39.0	12.1	30.8	20.6	10.9	37.7

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 20	2.63	0.13	0.07	4.85	0.04	4.71	0.04	1.78	5.9	5.1
20 - 50	1.36	0.05	0.05	4.03	0.36	3.76	0.36	2.38	5.0	4.3
50 - 95	0.90	0.06	0.03	3.15	0.84	2.82	0.84	3.17	6.0	4.1
95 - 130	1.00	0.05	0.03	3.20	1.28	2.82	1.28	3.60	5.6	3.9

Soil horizon thickness, cm	Exchangeable Cation, cmol(+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 20	3.80	2.10	0.10	0.06	6.06	12.56	23.86	48.2
20 - 50	3.34	2.87	0.08	0.78	7.07	15.52	37.25	45.5
50 - 95	4.43	3.28	0.06	0.26	8.03	18.80	36.09	42.7
95 - 130	4.29	3.61	0.06	0.32	8.28	19.92	38.24	41.5

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 54



Location:

- Commune: Hanh Dung
- District: Nghia Hanh
- Province: Quang Ngai

Soil name:

- VIETNAMESE: Yellowish red soils on granite rocks
- FAO-UNESCO: Arenic Acrisols
- USDA (Soil Taxonomy): Kandiuults

THE INFORMATION OF SOIL PROFILE VN 54

Location: Hanh Dung Commune, Nghia Hanh District, Quang Ngai Province
Latitude: 15° 03' 15" N; **Longitude:** 108° 43' 20" E; **Elevation:** 125 m (ASL)
Parent materials: Granite; **Topography:** Sloping hill; **Slope:** 15° - 25°
Present land use: Grass

Soil name: Vietnamese: Reddish yellow soils on acid magmatic rocks (1976);
 Ferralitic Grey soils (1996);
 Yellowish red soils on granite rocks
 FAO-UNESCO-WRB: Arenic Acrisols
 USDA (Soil Taxonomy): Kandiuults

Soil profile description:

- Ap (0 - 15 cm): Dull reddish brown (5YR 4/3 moist; 7.5YR 6/4 dry); sandy loam; moist; porous; friable; many roots; some animal channels and black mottles; thin organic remains layer on surface; clear smooth boundary.
- AB (15 - 40 cm): Reddish brown (5YR 4/6 moist; 7.5YR 7/6 dry); sandy loam; moist; porous; friable; many roots and animal caves; some rock fragments (30%); gradual smooth boundary.
- Bts1 (40 - 80 cm): Reddish brown (5YR 4/6 moist; 7.5YR 7/6 dry); sandy loam; moist; porous; many roots; some rock fragments; some channels; gradual smooth boundary.
- Bts2 (80 - 120 cm): Reddish brown (2.5YR 4/6 moist; 5YR 4/4 dry); loamy sand; moist; porous; friable; many silt weathering rocks; rocks fragment (30%); some channels; many small roots.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	1.27	2.62	52.0	13.9	37.8	33.2	10.5	18.5
15 - 40	1.47	2.61	54.0	10.2	41.9	22.7	15.4	20.0
40 - 80	1.27	2.69	53.0	11.1	30.8	32.1	13.1	24.0
80 - 120	1.20	2.66	55.0	11.1	47.6	22.5	12.4	17.5

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 15	1.75	0.16	0.09	0.48	1.95	8.44	0.68	5.35	4.8	4.0
15 - 45	1.25	0.07	0.09	0.39	0.64	8.44	0.36	2.97	4.8	3.9
45 - 80	1.00	0.04	0.09	0.42	2.74	7.41	0.36	2.46	4.5	3.9
80 - 120	0.91	0.04	0.07	0.37	0.41	3.62	0.48	2.77	4.5	4.0

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 15	1.57	1.16	0.18	0.22	3.13	5.88	11.17	53.2
15 - 45	0.62	0.11	0.18	0.10	1.01	3.08	7.39	32.8
45 - 80	0.62	0.26	0.19	0.05	1.12	2.68	6.88	41.8
80 - 120	1.07	0.19	0.08	0.08	1.42	3.76	9.66	37.8

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 11



Location:

- Quang Ninh Pine Enterprise
- Town: Hoanh Bo
- Province: Quang Ninh

Soil name:

- VIETNAMESE: *Light yellow soils on conglomerate*
- FAO-UNESCO: *Skeletal Acrisols*
- USDA (Soil Taxonomy): *Kanhapludults*

THE INFORMATION OF SOIL PROFILE VN 11

Location: Quang Ninh Pine Enterprise, Hoanh Bo Town, Quang Ninh Province

Latitude: 21° 04' 00'' N; **Longitude:** 106° 58' 00'' E; **Elevation:** 40 m (ASL)

Parent materials: Sandstones; **Topography:** Sloping hill; **Slope:** 20° - 25°

Present land use: Pines (Latin: *Podocarpus*) mixed with scrubs

Soil name: Vietnamese: Light yellow soils on sandstones (1976); Ferralitic Grey soils (1996);
Light yellow soils on conglomerate

FAO-UNESCO-WRB: Skeletic Acrisols

USDA (Soil Taxonomy): Kanhapludults

Soil profile description:

- Ao (0 - 2 cm):** Brownish black (10YR 3/2 moist; 10YR 4/2 dry); sandy loam; slightly moist; many decomposed pine leaves; many roots; clear smooth boundary.
- Ap (2 - 15 cm):** Dark brown (10YR 3/3 moist; 10YR 4/2 dry); sand; slightly moist; granular structure; porous; fine; many roots of different sizes; clear smooth boundary.
- AB (15 - 40 cm):** Bright brown (7.5YR 5/8 moist; 10YR 5/6 dry); sandy loam; slightly moist; many gravel diameter of 3 - 4 mm (30%); granular structure; sticky; some small grass roots; clear smooth boundary.
- Bt1 (40 - 90 cm):** Bright brown (7.5YR 5/8 moist; 7.5YR 5/8 dry); clay; moist; many gravels (60%) diameter of 3 - 4 mm; granular structure; slightly sticky; clear smooth boundary.
- Bt2 (90 - 160 cm):** Bright reddish brown (5YR 5/8 moist; 7.5YR 5/8 dry); clay; slightly moist; many big gravels diameter of 5 - 6 cm; many small gravels diameter of 4 - 5 mm (> 65%); slightly sticky.

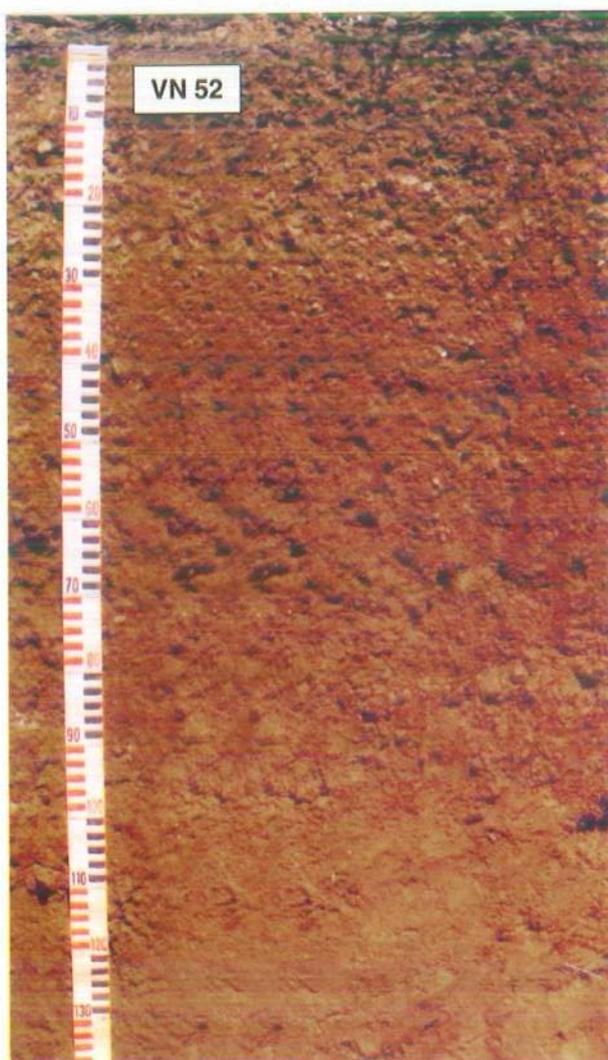
Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
2 - 15	1.05	2.57	59.1	17.2	41.8	34.9	5.5	17.8
15 - 40	1.40	2.61	46.4	9.3	32.3	40.9	9.0	17.8
40 - 90	1.45	2.58	43.8	9.2	20.2	17.3	4.9	57.6
90 - 160	1.43	2.61	45.2	10.5	22.9	15.4	4.9	56.8

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
2 - 15	3.59	0.22	0.04	0.15	9.67	3.29	5.77	22.34	4.2	3.4
15 - 40	0.76	0.04	0.07	0.40	2.47	2.81	6.15	15.00	4.6	3.6
40 - 90	0.46	0.07	0.09	0.49	2.97	2.35	6.88	16.50	4.6	3.6
90 - 160	0.37	0.06	0.08	0.43	2.70	2.35	5.45	14.00	4.8	3.6

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
2 - 15	1.01	0.14	0.07	vết	1.22	12.96	24.62	9.4
15 - 40	0.87	0.11	0.06	0.08	1.12	10.51	17.76	10.7
40 - 90	0.76	0.12	0.05	0.09	1.02	12.55	21.21	8.1
90 - 160	0.99	0.14	0.05	0.09	1.27	10.54	17.81	12.0

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 52



Location:

- Commune: Phong Thu
- District: Phong Dien
- Province: Thua Thien Hue

Soil name:

- VIETNAMESE: *Light yellow soils on the sandstones*
- FAO-UNESCO: *Arenic Acrisols*
- USDA (Soil Taxonomy): *Kanhaplustults*

THE INFORMATION OF SOIL PROFILE VN 52

Location: Phong Thu Commune, Phong Dien District, Thua Thien-Hue Province

Latitude: 16° 35' 24" N; **Longitude:** 107° 19' 38" E; **Elevation:** 50 m (ASL)

Parent materials: Sandstones; **Topography:** Flat; **Slope:** 3° - 8°

Present land use: Forest

Soil name: Vietnamese: Light yellow soils on sandstones (1976); Ferralitic Grey soils (1996);
Light yellow soils on sandstones

FAO-UNESCO-WRB: Arenic Acrisols

USDA (Soil Taxonomy): Kanhaplustults

Soil profile description:

Ap (0 - 15 cm):	Dull reddish brown (10YR 4/3 moist; 10YR 8/3 dry); loamy; moist; porous; many rice roots; many small rock fragments diameter of < 3 cm; gradual smooth boundary.
AB (15 - 30 cm):	Bright brown (7.5YR 5/6 moist; 10YR 8/6 dry); loamy sand; moist; slightly dry; porous; friable; many roots; many fragments (40-50%); clear smooth boundary.
Btw (30 - 55 cm):	Bright brown (2.5YR 5/8 moist; 7.5YR 8/6 dry); sandy clay; moist; some rice roots; rock fragments of upper horizon diameter < 1 cm; mixed big rock fragments diameter of 1 - 6 cm (40 - 50%); gradual smooth boundary.
BC1 (55 - 105 cm):	Bright redish brown (5YR 5/8 moist; 5YR 6/6 dry); sandy clay loam; moist; some roots; rock fragments of upper horizon; clear smooth boundary.
BC2 (105 - 140 cm):	Bright reddish brown (5YR 5/8 moist; 7.5 YR 8/4 dry); clay; moist; some roots; some animal channels; mixed yellow wethering rocks.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	1.60	2.72	41.0	7.5	18.1	59.0	8.7	14.2
15 - 30	1.48	2.76	46.0	7.9	19.4	50.9	5.4	24.3
30 - 55	1.71	2.72	38.0	11.3	20.2	36.2	6.4	37.2
55 - 105	1.48	2.70	45.0	15.9	17.1	36.6	12.3	34.0
105 - 140	1.47	2.65	45.0	17.7	18.6	35.2	9.4	36.8

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 15	1.13	0.08	0.03	0.67	0.82	6.01	2.32	5.54	4.6	3.9
15 - 30	0.75	0.05	0.03	1.02	0.48	3.62	3.28	5.98	4.7	3.8
30 - 55	0.36	0.04	0.02	1.60	0.41	4.82	4.32	8.12	4.7	3.7
55 - 105	0.36	0.04	0.02	1.72	0.27	4.82	2.76	5.35	4.9	3.8
105 - 140	0.40	0.04	0.02	1.92	0.33	4.82	2.24	4.59	4.9	3.8

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 15	0.50	0.15	0.13	0.08	0.86	3.56	7.20	24.2
15 - 30	0.56	0.10	0.08	0.06	0.80	4.16	9.40	19.2
30 - 55	0.53	0.21	0.10	0.07	0.91	6.00	12.00	15.2
55 - 105	0.85	0.14	0.10	0.09	1.18	4.32	9.20	27.3
105 - 140	1.25	0.15	0.10	0.25	1.75	4.08	10.21	42.9

LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 07



Location:

- Commune: Thach Hoa
- District: Thach That
- Province: Ha Tay

Soil name:

- VIETNAMESE: *Yellowish brown soils on old alluviums*
- FAO-UNESCO: *Haplic Acrisols*
- USDA (Soil Taxonomy): *Hapludults*

THE INFORMATION OF SOIL PROFILE VN 07

Location: Thach Hoa Commune, Thach That District, Ha Tay Province
Latitude: 21° 03' 00'' N; **Longitude:** 105° 30' 00'' E; **Elevation:** 20 m (ASL)
Parent materials: Old Aluviums; **Topography:** Flat; **Slope:** 3° - 8°
Present land use: Acasia Mangium
Soil name: Vietnamese: Yellowish brown soils on old alluviums (1976);
 Grey degraded soils (1996);
 Yellowish brown soils on old alluviums
 FAO-UNESCO-WRB: Haplic Acrisols
 USDA (Soil Taxonomy): Hapludults

Soil profile description:

Ap (0 - 15 cm):	Brown (10YR 4/4 moist; 10YR 5/3 dry); few small reddish and yellow concretions; clay; slightly moist; cubic structure; clear smooth boundary.
AB (15 - 35 cm):	Yellowish brown (10YR 5/6 moist; 10YR 6/4 dry); clay; moist; cubic structure; few small animal channels; gradual smooth boundary.
Bt (35 - 85 cm):	Bright brown (10YR 6/8 moist; 10YR 7/6 dry); some concretions; clay; fine granular structure; few fine roots; many dark brown cracks; gradual smooth boundary.
BC (85 - 122 cm):	Yellow orange (10YR 7/8 moist; 10YR 7/4 dry); orange concretions (7.5YR 6/8 moist; 7.5YR 5/6 dry); dark brown (5YR 3/6 moist; 5YR 3/6 dry); clay; few roots; dark brown mottles; clear smooth boundary.
C (122 - 150 cm):	Dark reddish brown (2.5YR 3/6 moist; 2.5YR 6/8 dry) hard concretions (95%); reddish brown (5YR 4/8 moist; 5YR 6/6 dry); some orange cilinder clay mottles (7.5YR 6/6 moist; 10YR 8/4 dry); sandy clay.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	1.15	2.49	53.8	32.2	5.5	23.0	11.1	60.4
15 - 35	1.15	2.55	54.9	25.5	4.5	24.8	7.2	63.5
35 - 85	1.00	2.58	61.2	31.2	3.9	20.6	6.4	69.1
85 - 122	1.13	2.57	56.0	30.7	4.8	16.7	10.4	68.1
122 - 150	1.25	2.61	52.1	31.4	32.4	22.0	7.6	38.0

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 15	2.60	0.17	0.09	0.10	10.30	5.65	3.60	28.33	4.5	3.6
15 - 35	1.23	0.09	0.09	0.10	16.90	5.18	3.25	19.00	4.8	3.7
35 - 85	0.75	0.07	0.09	0.10	14.13	3.62	3.08	17.20	5.1	3.7
85 - 122	0.42	0.05	0.09	0.16	11.87	3.62	2.19	12.26	5.0	3.7
122 - 150	0.18	0.03	0.18	0.10	10.10	3.62	0.30	12.15	4.8	4.3

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 15	0.35	0.04	0.12	0.04	0.55	15.04	24.52	3.7
15 - 35	0.46	0.03	0.11	Trace	0.60	12.65	24.29	4.7
35 - 85	0.34	0.03	0.05	Trace	0.42	9.36	15.82	4.5
85 - 122	0.38	0.03	0.05	Trace	0.46	7.54	12.74	6.1
122 - 150	0.39	0.04	0.05	0.04	0.52	5.46	9.23	9.5

2.10. The Reddish yellow humus soil in mountains:

These soils are found in mountainous regions with the height ranging from 700 - 900 m to 2,000 m above sea level.

Climate is colder and wetter than that of lower mountainous regions. Mean annual temperature is around 15 - 20^oC.

Vegetation covers a larger area in comparison with that of hilly regions.

Reddish yellow humus soils are covered 2.7 millions hectares and distributed in mountainous provinces throughout the country, is the only one soil unit of this soil group.

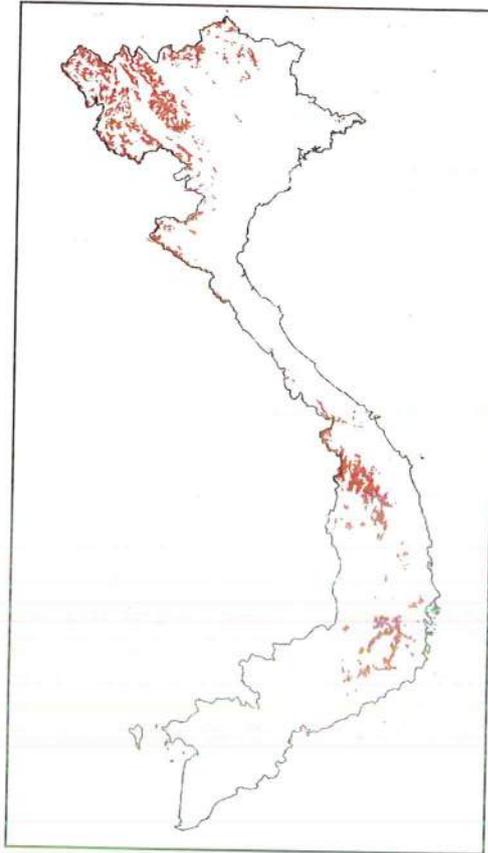
On one hand, because distributing on rugged and inaccessible terrain resulted in strongly erosion, and on other hand, because of weak weathering process resulted in thin fine earth thickness, normally less than 1.5 m.

OC content is high; total and available phosphorus are low to medium. Total potassium is low to medium. Total exchangeable basic cations are low. CEC is also low. OC content of soil is high, but coarse humus is mainly, because of low composition.

This soil unit is suitable for planting forest and using agro-forestry combinations. Medicine plants and temperate fruit-trees can be cultivated in these soils.

In order to use reasonably and sustainable agricultural land, have paid more attention to soil, bio-environment preservation. This is effective measure for erosion control.

Soil profile VN 44 is characterized for this soil unit.



LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 44

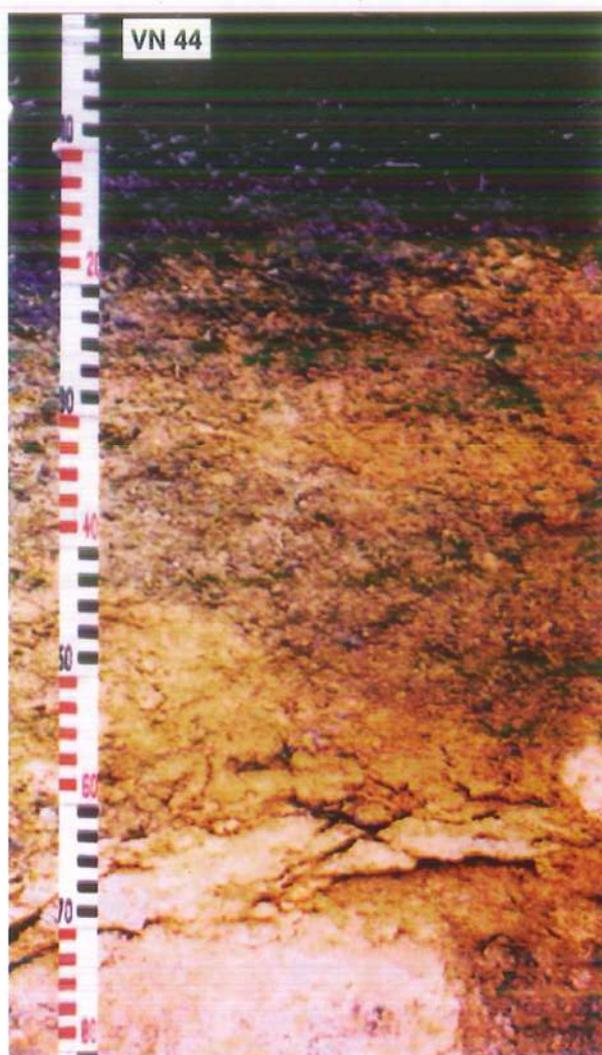


Location:

- Commune: Cao Bo
- District: Vi Xuyen
- Province: Ha Giang

Soil name:

- VIETNAMESE: *Reddish yellow humus soils on the mountains*
- FAO-UNESCO: *Humic Acrisols*
- USDA (Soil Taxonomy): *Haplohumults*



THE INFORMATION OF SOIL PROFILE VN 44

Location: Cao Bo Commune, Vi Xuyen District, Ha Giang Province

Latitude: 22° 47' 00" N; **Longitude:** 104° 50' 00" E; **Elevation:** 1,250 m (ASL)

Parent materials: Metamorphic rocks; **Topography:** Sloping hill; **Slope:** 20° - 25°

Present land use: Forest

Soil name: Vietnamese: Reddish yellow humus soils on the mountain (1976, 1996)

Reddish yellow humus soils on the mountain

FAO-UNESCO-WRB: Humic Acrisols

USDA (Soil Taxonomy): Haplohumults

Soil profile description:

Ah (0 - 20 cm): Brownish black (5YR 2/2 moist; 10YR 5/2 dry); sandy loam; moist; porous; many roots; many vegetation remains decomposed; clear smooth boundary.

Bs (20 - 50 cm): Bright reddish brown (10YR 5/6 moist; 10YR 8/2 dry); sandy loam; moist; porous; many roots; mixed gravels; clear smooth boundary.

C (50 - 120 cm): Wethering material rocks (10YR 6/6 moist; 10YR 8/2 dry).

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 20	0.69	2.58	78.0	25.1	25.3	42.6	12.5	19.6
20 - 50	0.76	2.62	71.0	44.2	24.3	50.2	13.3	12.2

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 20	2.53	0.23	0.08	0.64	5.08	13.56	3.36	19.10	4.5	3.8
20 - 50	0.82	0.09	0.05	0.67	1.24	7.53	2.40	10.68	4.5	3.8

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 20	0.32	0.24	0.28	0.06	0.90	12.96	24.62	6.9
20 - 50	0.08	0.00	0.15	0.06	0.29	6.40	17.85	4.5

2.11. The Humus soils on high mountains:

These soils are normally found at the tops of Hoang Lien Son, Ngoc Linh, Ngoc Ang, Chu Yang Sin, etc... mountains with the height more than 2,000 m ASL.

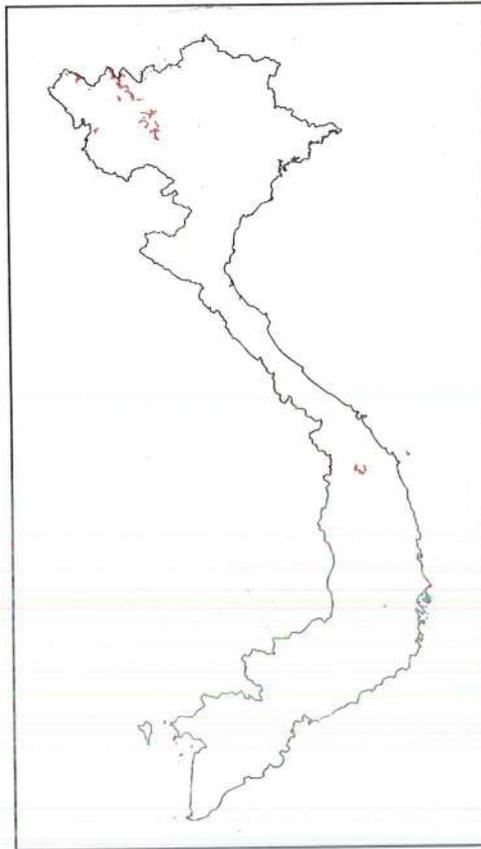
Mean annual temperature is less than 15^o C. Especially at some tops of the mountains in the North, water is frozen in winter.

Vegetation found is water-rail, small bamboo, and some temperate needle trees.

These soils have thin fine earth thickness with many primary rock fragments. The surface horizon is a thin humus or peat layer. So that the soil forming process on these soils is ruled by humus formation.

Because placed on high mountains, these soils seem to be not utility significance for agricultural production in reality.

Soil profile VN 43 is characterized for these soils.



LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 43



Location:

- Commune: O Quy Ho
- District: SaPa
- Province: Lao Cai

Soil name:

- VIETNAMESE: *Humus soils on the high mountains*
- FAO-UNESCO: *Haplic Alisols*
- USDA (Soil Taxonomy): *Haplohemists*

THE INFORMATION OF SOIL PROFILE VN 43

Location: O Quy Ho Commune, Sa Pa District, Lao Cai Province

Latitude: 22° 21' 00" N; **Longitude:** 103° 48' 00" E; **Elevation:** 2.150 m (ASL);

Parent materials: Granite; **Topography:** Sloping hill; **Slope:** > 25°;

Present land use: Bamboo, scrubs

Soil name: *Vietnamese:* Humus soils on high mountains (1976);

Humus Alit soils on high mountains (1976);

Humus soils on high mountains

FAO-UNESCO-WRB: Haplic Alisols

USDA (Soil Taxonomy): Haplohemists

Soil profile description:

O (0 - 2 cm): Organic decompositing; moist; desultory.

OB (2 - 12 cm): Black (10YR 2/1 moist; 5YR 3/1 dry); sandy clay loam; moist; many small roots decompositing; fine granular structure; clear smooth boundary.

BC (12 - 50 cm): Brownish black (5YR 2/2 moist; 5YR 2.5/2 dry); sandy loam; moist; many roots; fine granular structure; many weathering rocks.

C (50 - 70 cm): Dark reddish brown (5YR 3/3 moist; 7.5YR 8/4 dry); sandy loam; many weathering rocks.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
2 - 12	0.79	1.34	66.0	39.2	36.8	35.8	6.0	21.4
12 - 50	0.82	1.42	66.0	35.4	34.7	37.7	13.0	14.6
50 - 70	-	-	-	-	29.8	52.0	2.7	15.5

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
2 - 12	8.44	0.54	0.07	0.06	7.12	13.56	2.32	20.08	4.4	3.8
12 - 50	6.67	0.37	0.06	0.05	4.22	9.04	2.00	12.41	4.5	4.0
50 - 70	0.71	0.07	0.05	0.07	1.74	6.03	3.04	10.21	4.5	3.8

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
2 - 12	1.27	0.40	0.28	0.06	2.01	13.92	26.44	14.4
12 - 50	0.63	0.08	0.19	0.25	0.85	10.24	16.38	11.2
50 - 70	0.08	0.00	0.12	0.10	0.30	5.84	15.00	5.1

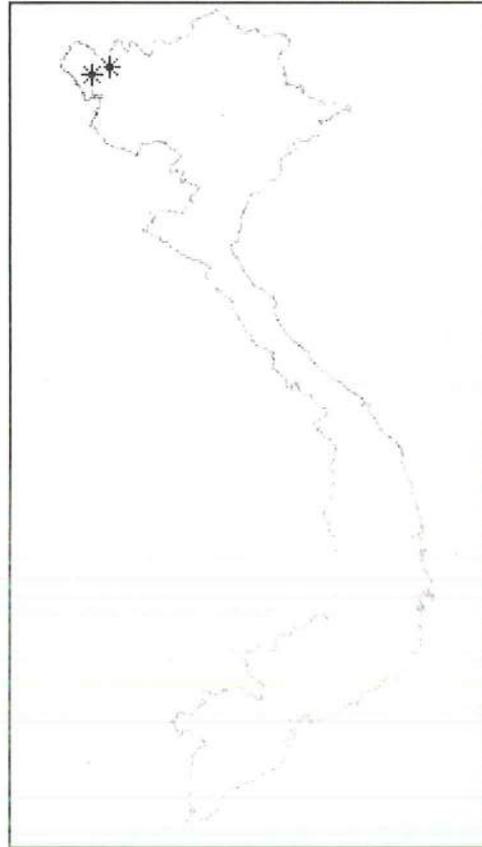
2.12. The Podzols:

In some small areas in Vietnam are found soils with a washy subsurface horizon (A₂ horizon) looked like Podzols in temperate zone.

In 1972, the authors of Soil Map of Northern Vietnam at 1:500,000 scale found a soil type looked like podzol in Sin Ho (Lai Chau Province). In 1975, the authors of Soil Map of Vietnam also found a similar soil profile in the Tay Nguyen plateau.

Because of very small area (not enough to present on map), these soils seem to be not utility significance in reality.

Soil profile **VN 56** is characterized for the Podzols



LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 56

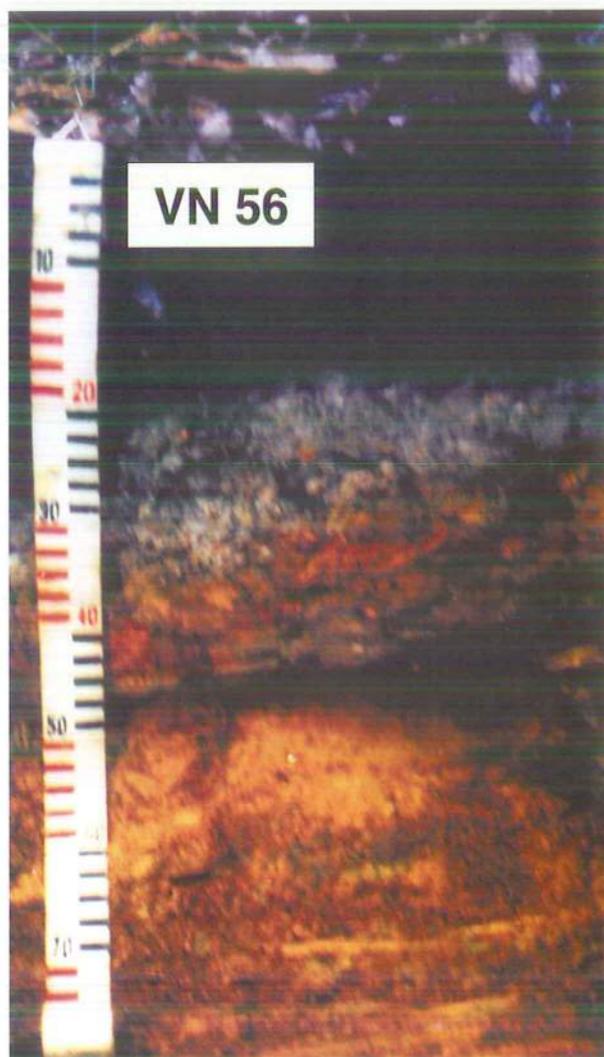


Location:

- Commune: Xa De Phin
- District: Sin Ho
- Province: Lai Chau

Soil name:

- VIETNAMESE: *Podzols*
- FAO-UNESCO: *Histic Podzols*
- USDA (Soil Taxonomy): *Haplorthods*



THE INFORMATION OF SOIL PROFILE VN 56

Location: Xa De Phin Commune, Sin Ho District, Lai Chau Province

Latitude: 22° 18' 00" N; **Longitude:** 103° 13' 00" E; **Elevation:** 1,904 m (ASL)

Parent materials: Granite; **Topography:** Sloping hill; **Slope:** > 25°

Present land use: Forest

Soil name: Vietnamese: Podzols (1976); Dystric Podzols (1996);

Podzols

FAO-UNESCO-WRB: Histic Podzols

USDA (Soil Taxonomy): Haplorthods

Soil profile description:

- Ah (0 - 10 cm): Brownish black (5YR 2/2 moist; 5YR 3/3 dry); sand; moist; fine granular structure; many roots; many plant remains decompositing; clear smooth boundary.
- AB (10 - 20 cm): Black (5YR 1.7/1 moist; 5YR 2/1 dry); sandy loam; moist; porous; plastic; stick; some rice roots; many plant remains; gradual smooth boundary.
- Btw (20 - 30 cm): Yellowish gray (2.5Y 4/1 moist; 2.5Y 6/1 dry); loam; moist; firmer than upper horizon; some rice roots; mixed sime weathering rocks; clear smooth boundary.
- BC (30 - 40 cm): Dull reddish brown (5YR 5/4 moist; 10YR 6/6 dry); clay loam; moist; firm; many rice roots; many sime weathering rocks.
- C (40 - 100 cm): Wethering rocks.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 10	-	-	-	-	68.7	21.2	9.6	0.5
10 - 20	1.21	2.60	53.5	20.2	46.2	30.3	17.6	5.9
20 - 30	0.60	2.41	75.1	47.8	5.8	35.8	43.1	15.3
30 - 40	1.18	2.50	52.8	48.5	8.8	25.2	34.2	31.8

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 10	32.81	1.55	0.17	0.86	31.40	50.96	1.76	98.06	5.7	5.3
10 - 20	25.13	1.50	0.13	0.76	21.10	20.00	6.00	158.40	5.3	5.0
20 - 30	2.28	0.12	0.04	1.22	2.34	2.41	3.80	12.67	5.5	5.1
30 - 40	2.36	0.11	0.03	1.21	0.46	3.62	6.68	17.23	5.6	5.2

Soil horizon thickness, cm	Exchangeable Cation, cmol(+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 10	1.69	1.58	0.31	0.11	3.69	7.98	-	46.2
10 - 20	0.18	0.34	0.51	0.97	2.00	9.22	14.31	21.7
20 - 30	0.13	0.07	0.05	0.02	0.27	6.76	17.60	4.0
30 - 40	0.18	0.07	0.05	0.04	0.34	12.72	37.00	2.7

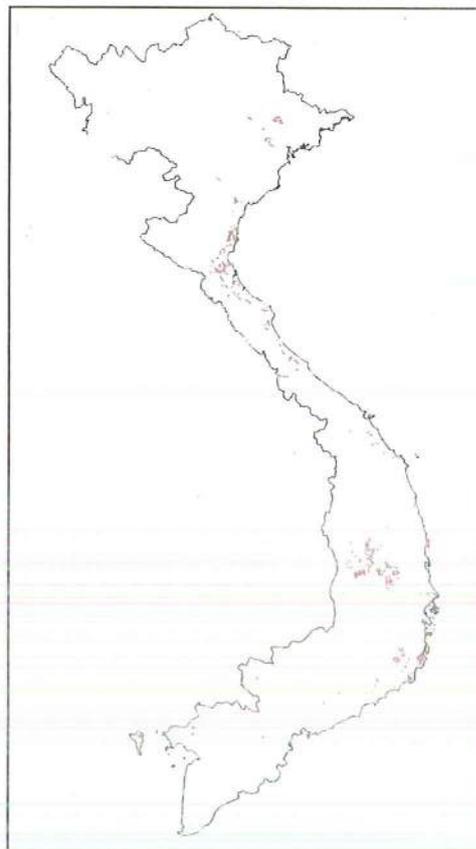
2.13. The Eroded skeletal soils:

These soils cover about 500,000 hectares, concentrate mainly on bare hills in Tay Nguyen plateau, Central region, and Midland and Mountainous regions of the North.

Eroded skeletal soil is the only one soil unit of this group. On these soils are found a thinly vegetation cover, many gravel or other coarse rock fragments on surface, continuous hard rock/concretion/laterite contact at 30 cm from soil surface. With very low nutrient content, this soil is marginally suitable for agricultural production.

It should be afforested on these soils in order to cover bare hills quickly, control erosion, protect soil in low place from bad affection.

Soil profile **VN 61** is characterized for this soil unit.



LANDSCAPE AND SOIL PROFILE MORPHOLOGY VN 61



Location:

- Commune: Van An
- District: Chi Linh
- Province: Hai Duong

Soil name:

- VIETNAMESE: *Eroded soils*
- FAO-UNESCO: *Haplic Leptosols*
- USDA (Soil Taxonomy): *Udorthents*

THE INFORMATION OF SOIL PROFILE VN 61

Location: Van An Commune, Chi Linh District, Hai Duong Province

Latitude: 21° 07' 00" N; **Longitude:** 106° 21' 45" E; **Elevation:** 85 m (ASL)

Parent materials: Sandstones; **Topography:** Undulating; **Slope:** 15° - 25°

Present land use: Cassava, Eucalyptus, Grass

Soil name: Vietnamese: Eroded soils (1976); Haplic Leptosols (1996)

Eroded soils

FAO-UNESCO-WRB: Haplic Leptosols

USDA (Soil Taxonomy): Udorthents

Soil profile description:

- A (0 - 15 cm): Light brown (7.5YR 5/5 moist; 7.5YR 5/4 dry); sand; dry; some gravels and rock fragments on the surface; the gravels are round and white diameter of 2 - 3 cm; the small rock fragments are yellowish brown diameter of less than 1 cm; many small grass roots; clear boundary.
- BC (15 - 65 cm): Many big rocks (90 - 95%); within rocks are small rock fragment and few brownish red clay soil (5YR 5/6 moist; 7.5YR 6/6 dry); sandy loam; dry; some roots; gradual smooth boundary.
- C (65 - 150 cm): The same as upper horizon.

Soil properties:

Soil horizon thickness, cm	Bulk Density, g/cm ³	Particle Density, g/cm ³	Porosity, %	Soil Moisture, %	Particle size, %			
					2.0 - 0.2 mm	0.2 - 0.02 mm	0.02 - 0.002 mm	< 0.002 mm
0 - 15	-	-	-	-	57.3	16.5	9.3	16.9
15 - 65	-	-	-	-	57.2	11.6	5.5	25.7
65 - 150	-	-	-	-	53.4	16.6	7.8	22.2

Soil horizon thickness, cm	Total, %				Available, mg/100g		Acidity, cmol(+)/kg		pH	
	OC	N	P ₂ O ₅	K ₂ O	P ₂ O ₅	K ₂ O	Exchange.	Potential	H ₂ O	KCl
0 - 15	0.43	0.11	0.03	0.47	9.42	22.57	3.44	4.25	5.0	4.6
15 - 65	1.31	0.06	0.02	0.87	0.62	7.53	5.52	6.76	5.1	4.5
65 - 150	0.78	0.06	0.02	0.62	1.12	6.02	4.80	5.71	5.2	4.4

Soil horizon thickness, cm	Exchangeable Cation, cmol (+)/kg					CEC, cmol(+)/kg		BS, %
	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Total	Soil	Clay	
0 - 15	0.36	0.05	0.48	0.12	1.01	5.81	11.51	17.4
15 - 65	0.03	0.02	0.16	0.06	0.28	5.04	10.71	5.6
65 - 150	0.02	0.02	0.13	0.05	0.22	4.82	7.12	4.6

Chapter 3

INTRODUCTION OF VIETNAM SOIL REFERENCE AND INFORMATION CENTER (ViSRIC)

3.1. Establishment of Soil Reference and Information Center:

Soil monoliths were taken the first time in Russia in the decades of the end of 19th Century. It was displayed in the Columbia's exhibition in Chicago (United State) in 1893-1894. These monoliths are taken by vertically putting up an iron boxes along the soil profile, as the methods of Rispoloshensky (1897) and Kubiena (1953) applied in America.

In the first International Soil Conference in Washington in 1927, 19 big monoliths taken in Latvia were displayed. It was put in wooden boxes (Kasakin and Krassynk, 1917; Hodgson, 1918 and Polynov, 1929). In 1925, Miklaszewski proposed the cooperation in soil monoliths and database at international level. In 1927, Vilenski published the document "About organization of exchange soil monoliths based on necessary technology innovation in taking and gluing soil monoliths". After that Miklaszewski wrote about collection of soil monoliths in agricultural museum in Varsaw, Poland with the conclusion that soil monoliths are taken in the wooden boxes with the shape of length 100 - 200 cm for easily taking, transporting and displaying.

In 1929, Polynov and its counterparts in the Institute Dokuchaev compiled the book "Introduction of methodology of monoliths and soil samples for research in laboratory".

In the first half of this century, in the methodologies of collection of soil monoliths in spite of no dealing with the maintenance technology, but there are several tests for stabilizing soil by some materials. The method of using saturated sugar was applied in the former Soviet Union (Ponomareva, 1974).

The maintenance of soil monoliths was introduced in 1928; Schlacht mentioned to utilization of thick coarse paper spread glue and press on surface of profile, after drying the soil stick on paper. This method, according to Jager and Van der Voort (1966), is suitable only for sandy soil or soil with medium texture, one thin layer of soil profile is glued on the coarse paper resulting to "a thin sample" (Lacquer Peel). The technology of collection of soil monoliths into the metal or wooden boxes is used as the methodology of the first method done by Russia. In the last two decades, the suitable equipments were used, creating long cylinder shape soil sample with natural surface (Matelski, 1949).

Some chemicals are used for absorbing soil materials (Maarse and Terwindt, 1964; Bouma, 1969), mainly the adhesive materials create from *Nitrocellulose* (Voigt, 1936 and Gracanic, Janecovic, 1940) and glue *Vinylite* (Berger and Muckenheim, 1978). Some people used the materials from glue of *Polieste* (Maarse and Terwindt, 1964), while Hammond (1974) absorbed organic matter by immersing soil into Polyetylen Glycol. Bouma (1966) used different materials. Van der Voort (1970) compiled one directory on collection and maintenance of soil monoliths and the thin samples. From 1966, International Soil Museum (ISM) used the adhesive materials from *Nitrocellulose* and *Polymethyl Methacrylate* to maintain soil monoliths in the "Procedure of collection soil units for International Soil Museum" (Published in 1972, and republished in 1974, 1975 and 1977).

International Soil Museum was established in 1952, but until the 7th International Soil Science Congress (ISSC, 1960) and 8th ISSC (1964) was introduced and recognized. In 1966, ISM officially established in Wageningen, The Netherlands.

In January 1984, the ISM was named International Soil Reference and Information Center (ISRIC) funded by UNESCO, FAO and ISSS.

At present, ISRIC has collected and displayed more than 800 monoliths with modern technique with soil database and information of more than 60 countries in the world. ISRIC is the place to exchange experiences, study, education, workshops on soil in the World.

3.2. Process of establishment of Vietnam Soil Reference and Information Center:

At the beginning of decade 60 of last century, together with soil survey and classification for soil map at scale 1/500,000 and 1/1,000,000 in the whole country after unification of country 1975, many soil monoliths of main soil units have been collected. These monoliths are keeping naturally in the wooden boxes 100 x 20 x 8 cm. Soil analysis database and information are limited. In the war, these monoliths were moved in many places, and it was keeping in the poor conditions, therefore almost all could not be used.

At the beginning of 1980, through the international relation the soil information and soil museum step by step developed. With the idea of establishment of National Soil Museum in Vietnam, the National Institute for Soils and Fertilizers (under the Ministry of Agriculture and Rural Development) sent staffs to ISRIC to study the new international standard's methodology of collecting basic documents, collection and processing soil monoliths and after 10 years it has condition of application.

In 1992, the Department of Soil Genesis of NISF in collaboration with chemistry experts of macromolecular compound manufactured the glues with high quality as the glues to be used in ISRIC, suitable with the humid tropical in Vietnam. This result help us the prospect to establish the Soil Museum in Vietnam with international standard. In 3 years, with the limited fund, the researchers successfully found and applied the home make glues with lower price in processing of monoliths that can keep the soil colour and basic properties.

In 1995, with the national fund approved by the Ministry of Agriculture and Rural Development, Ministry of Planning and Investment, Ministry of Finance, the project "*Surveying and Evaluating Soil Quality to Establish Soil Reference, Database and Information in Vietnam*" was implemented in two phases: Phase 1- from 1995 to 1997, and phase 2 - from 1998 to 2000.

The results of the project created premise for establishing the National Soil Reference and Information Center.

3.3. Vietnam Soil Reference and Information Center (ViSRIC):

At present, 60 soil monoliths of 13 soil groups, 31 main soil units according to the Vietnamese soil classification in 1976 (legend of soil map at scale 1/1,000,000) are displayed in the ViSRIC. The soil monoliths are processed, and displayed by international standard, high stabilization suitable for hot and humid weather in Vietnam.

The soil database and information are printed in Vietnamese and English keeping in the boxes with every monolith and in computer, including:

- + The displayed labels according to soil monoliths:
 - Sign and place of soil profile taken.
 - Photo of landscape.
 - Information concerning soil monoliths.
 - Location of monolith on the map.
 - Land and soil evaluation.
- + Basic information of soil profiles:
 - Description of soil profiles.
 - Basic soil physical and chemical properties.
 - Weather data and related data.
- + Soil maps of the country, ecological regions and related documents.
- + Maps related to soil:
 - Map of agricultural weather resource.
 - Geological map.
 - Map of forest changing in Vietnam.
 - Map of soil slope, etc...
- + The samples of parent rocks.
- + Introduction systems.

It is considered that the Vietnam Soil Reference and Information Center is the national valuable property not only in contribution of the development of soil science, but also the place to study, exchange knowledge, education, etc...

3.4. The exploiting capability of the Center:

For promoting the quality in soil research, many seminars of scientific experience exchange were organized, such as soil classification, soil analysis methods, etc...between researchers in the institute and other institutions, the soil association, the universities, the agriculture and related experts.

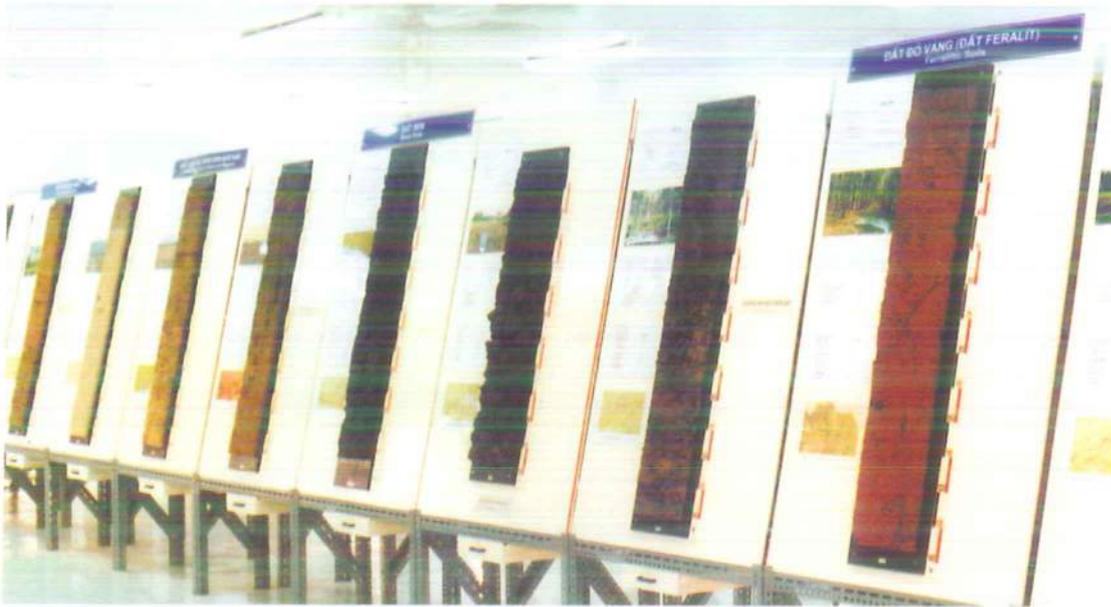
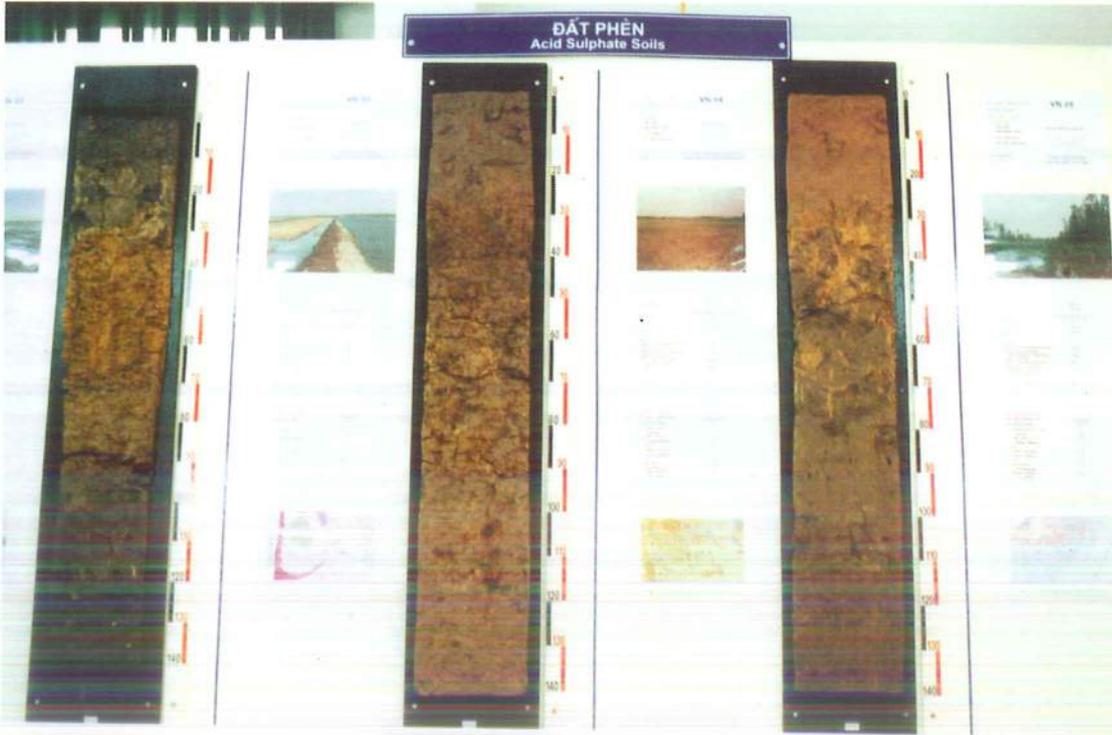
The Center accepted the visits of many international guests/delegates from France, England, Belgium, Holland, Germany, Denmark, Sweden, Swiss, Norway, Canada, United State, Australia, China, Japan, Indonesia, Thailand, Laos, Philippines, Republic of Korea, Iraq, etc... At the same time, provided the necessary information for international cooperation in agricultural activities.

Up to now, there were hundred times of students, researchers from the Universities of Mining and Geology, Agro-Forest University of Thai Nguyen, Hanoi University of Agriculture Number 1, University of Agro-Forestry of Hue, Hanoi University, etc...visited and studied and exploited the data and information in the Center.

In fact, the soil monoliths and information and database of the Center are valuable documents for research, education to serve in agricultural development.

SOME PICTURES OF
SOIL REFERENCE AND INFORMATION CENTER





CHINA

SOIL PROFILE LOCATION NETWORK



LEGEND

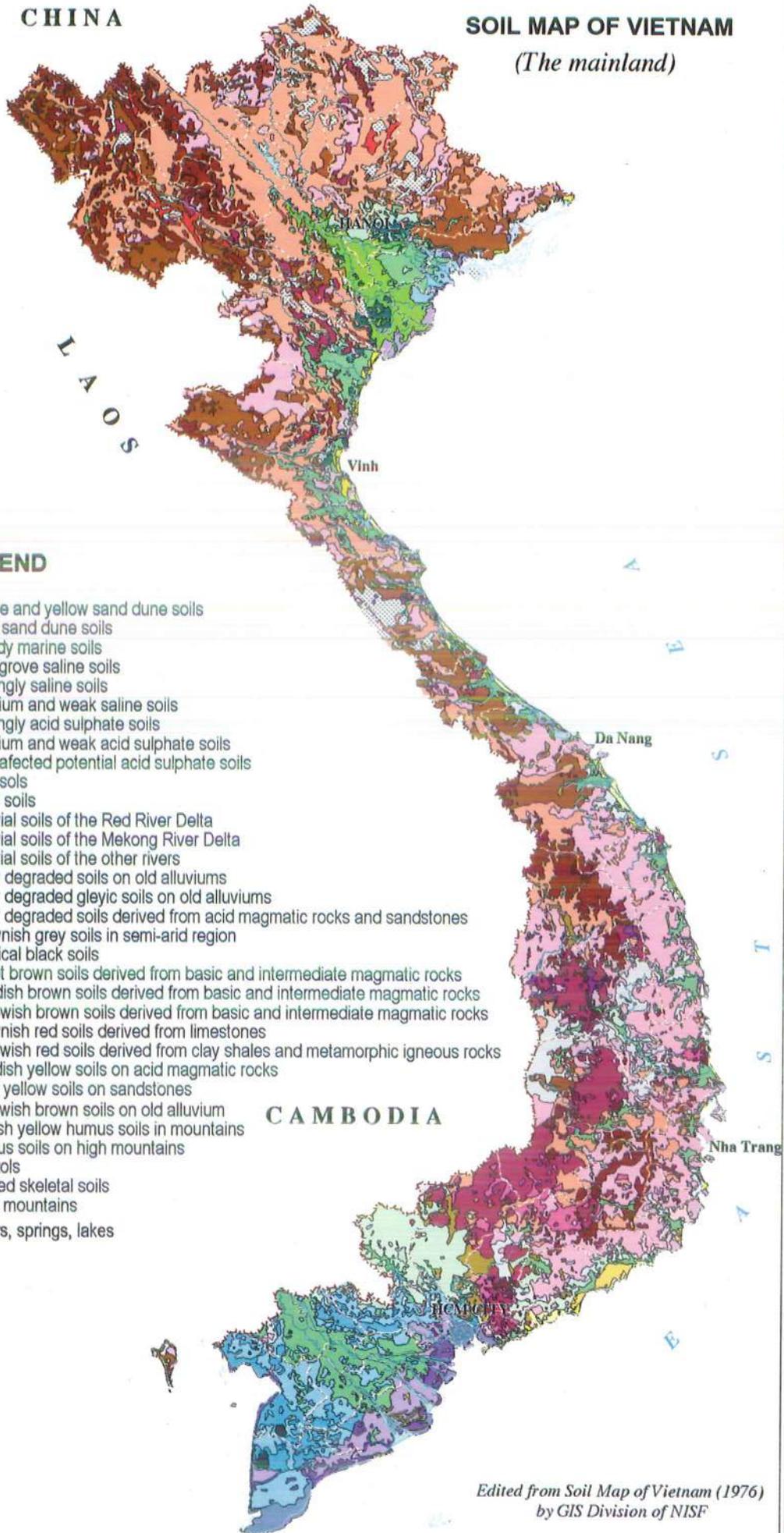
-  Location of soil profile
-  Number sign of soil profile
-  National boundary
-  Province boundary
-  Rivers, springs

Conformation based on Topographical map of Vietnam (1976) at scale 1:1,000,000

CHINA

SOIL MAP OF VIETNAM

(The mainland)



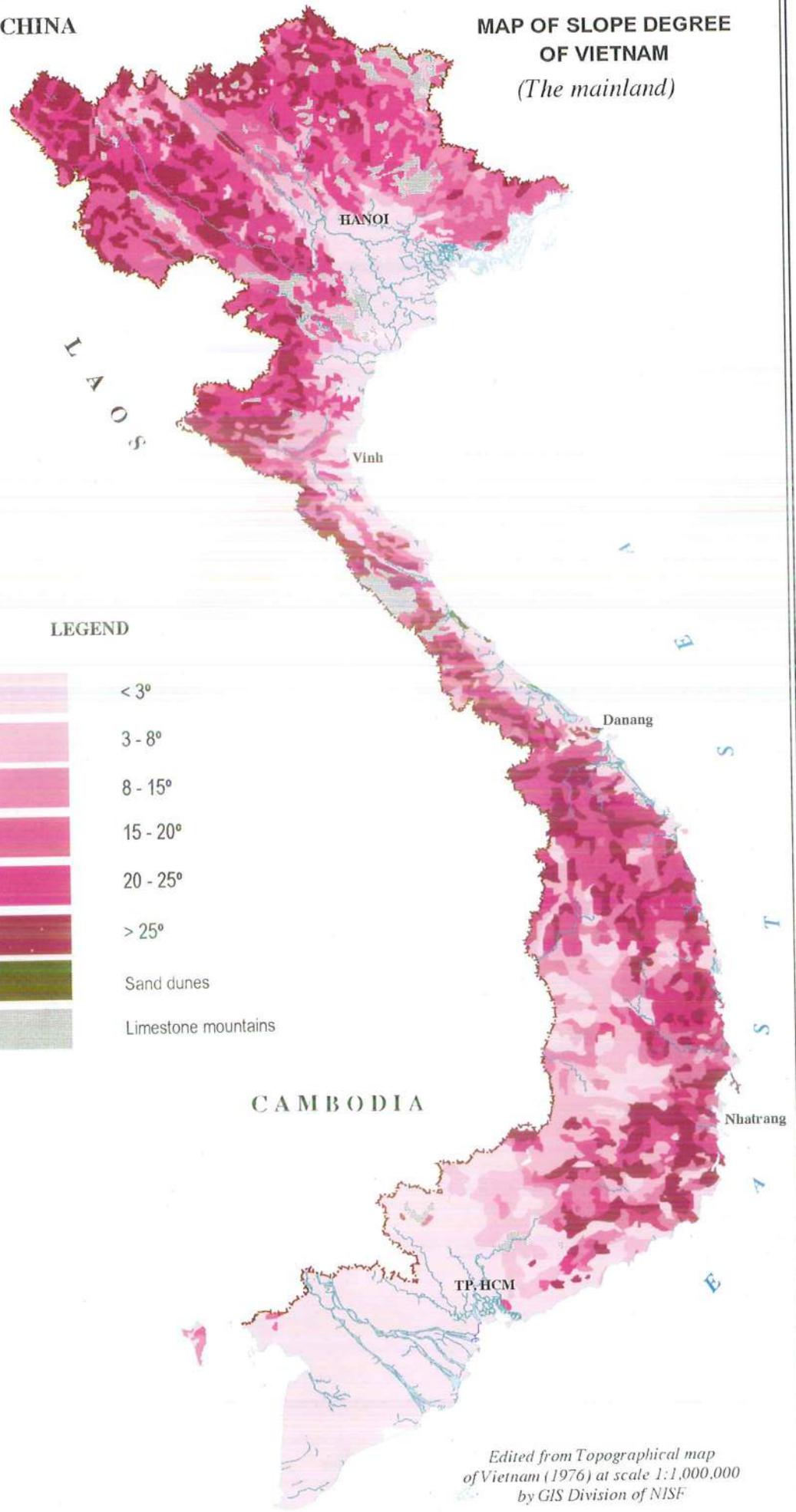
LEGEND

- White and yellow sand dune soils
- Red sand dune soils
- Sandy marine soils
- Mangrove saline soils
- Strongly saline soils
- Medium and weak saline soils
- Strongly acid sulphate soils
- Medium and weak acid sulphate soils
- Salt affected potential acid sulphate soils
- Gleysols
- Peat soils
- Alluvial soils of the Red River Delta
- Alluvial soils of the Mekong River Delta
- Alluvial soils of the other rivers
- Grey degraded soils on old alluviums
- Grey degraded gleyic soils on old alluviums
- Grey degraded soils derived from acid magmatic rocks and sandstones
- Brownish grey soils in semi-arid region
- Tropical black soils
- Violet brown soils derived from basic and intermediate magmatic rocks
- Reddish brown soils derived from basic and intermediate magmatic rocks
- Yellowish brown soils derived from basic and intermediate magmatic rocks
- Brownish red soils derived from limestones
- Yellowish red soils derived from clay shales and metamorphic igneous rocks
- Reddish yellow soils on acid magmatic rocks
- Light yellow soils on sandstones
- Yellowish brown soils on old alluvium
- Redish yellow humus soils in mountains
- Humus soils on high mountains
- Podzols
- Eroded skeletal soils
- Rock mountains
- Rivers, springs, lakes

Edited from Soil Map of Vietnam (1976)
by GIS Division of NISF

CHINA

**MAP OF SLOPE DEGREE
OF VIETNAM**
(The mainland)



LEGEND

-  < 3°
-  3 - 8°
-  8 - 15°
-  15 - 20°
-  20 - 25°
-  > 25°
-  Sand dunes
-  Limestone mountains

*Edited from Topographical map
of Vietnam (1976) at scale 1:1,000,000
by GIS Division of NISF*

CHINA

CLIMATIC REGIONS
OF VIETNAM
(The mainland)

LEGEND



Total annual radiation
Total annual sunny hour
Rainy season
Biggest rainfall period

BI

≤ 140 Kcal/sq.cm
 ≤ 2000 hours
From April to September
From June to August



Total annual radiation
Total annual sunny hour
Rainy season
Biggest rainfall period

BII

≤ 140 Kcal/sq.cm
 ≤ 2000 hours
From April to October
From June to August



Total annual radiation
Total annual sunny hour
Rainy season
Biggest rainfall period

BIII

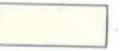
≤ 140 Kcal/sq.cm
 ≤ 2000 hours
From May to October
From July to September



Total annual radiation
Total annual sunny hour
Rainy season
Biggest rainfall period

BIV

≤ 140 Kcal/sq.cm
 ≤ 2000 hours
From July to December
From August to December



Total annual radiation
Total annual sunny hour
Rainy season
Biggest rainfall period

NI

> 140 Kcal/sq.cm
 > 2000 hours
From August to December
From September to November



Total annual radiation
Total annual sunny hour
Rainy season
Biggest rainfall period

NII

> 140 Kcal/sq.cm
 > 2000 hours
From May to October
From July to December



Total annual radiation
Total annual sunny hour
Rainy season
Biggest rainfall period

NIII

> 140 Kcal/sq.cm
 > 2000 hours
From May to October
From August to December

TOTAL ANNUAL RAINFALL



(mm/year)

800
1.200
1.600
2.000
2.400
2.800
3.200
3.600
4.000
4.400
4.800

Da Lat

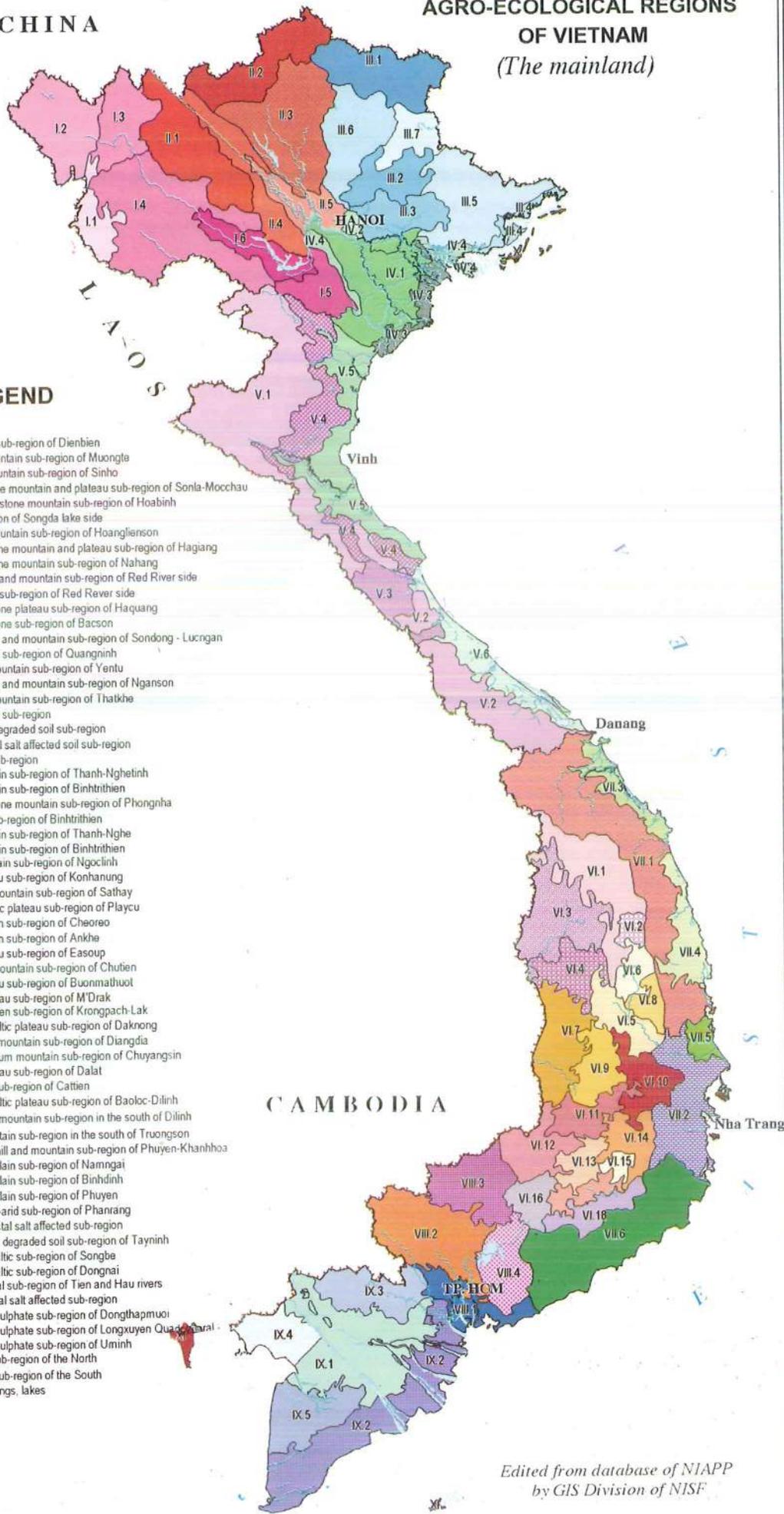
Meteorological station



Edited from database of
General Department of Hydrometeorology
by GIS Division of NISF

CHINA

AGRO-ECOLOGICAL REGIONS OF VIETNAM (The mainland)



LEGEND

- I.1. Sunken sub-region of Dienbien
- I.2. Low mountain sub-region of Muongla
- I.3. High mountain sub-region of Sinho
- I.4. Limestone mountain and plateau sub-region of Sonla-Mocchau
- I.5. Low limestone mountain sub-region of Hoabinh
- I.6. Sub-region of Songda lake side
- II.1. High mountain sub-region of Hoanglienon
- II.2. Limestone mountain and plateau sub-region of Hagiang
- II.3. Limestone mountain sub-region of Nahang
- II.4. Low hill and mountain sub-region of Red River side
- II.5. Sunken sub-region of Red River side
- III.1. Limestone plateau sub-region of Haquang
- III.2. Limestone sub-region of Bacson
- III.3. Low hill and mountain sub-region of Sondong - Lucngan
- III.4. Coastal sub-region of Quangninh
- III.5. Low mountain sub-region of Yentu
- III.6. Low hill and mountain sub-region of Nganson
- III.7. Low mountain sub-region of Thatkhe
- IV.1. Alluvial sub-region
- IV.2. Grey degraded soil sub-region
- IV.3. Coastal salt affected soil sub-region
- IV.4. Hilly sub-region
- V.1. Mountain sub-region of Thanh-Nghetinh
- V.2. Mountain sub-region of Binhrithien
- V.3. Limestone mountain sub-region of Phongnha
- V.4. Hilly sub-region of Binhrithien
- V.5. Flat plain sub-region of Thanh-Nghe
- V.6. Flat plain sub-region of Binhrithien
- VI.1. Mountain sub-region of Ngoclinh
- VI.2. Plateau sub-region of Konhanung
- VI.3. Low mountain sub-region of Sathay
- VI.4. Basaltic plateau sub-region of Playcu
- VI.5. Sunken sub-region of Cheoreo
- VI.6. Sunken sub-region of Anke
- VI.7. Plateau sub-region of Easoup
- VI.8. Low mountain sub-region of Chutien
- VI.9. Plateau sub-region of Buonmathuot
- VI.10. Plateau sub-region of M'Drak
- VI.11. Sunken sub-region of Krongpach-Lak
- VI.12. Basaltic plateau sub-region of Daknong
- VI.13. Low mountain sub-region of Diangdia
- VI.14. Medium mountain sub-region of Chuyangsin
- VI.15. Plateau sub-region of Dalat
- VI.16. Hill sub-region of Cattien
- VI.17. Basaltic plateau sub-region of Baoloc-Dilinh
- VI.18. Low mountain sub-region in the south of Dilinh
- VII.1. Mountain sub-region in the south of Truongson
- VII.2. Low hill and mountain sub-region of Phuyen-Khanhhoa
- VII.3. Flat plain sub-region of Namngai
- VII.4. Flat plain sub-region of Binhdin
- VII.5. Flat plain sub-region of Phuyen
- VII.6. Semi-arid sub-region of Phanrang
- VIII.1. Coastal salt affected sub-region
- VIII.2. Grey degraded soil sub-region of Tayninh
- VIII.3. Basaltic sub-region of Songbe
- VIII.4. Basaltic sub-region of Dongnai
- IX.1. Alluvial sub-region of Tien and Hau rivers
- IX.2. Coastal salt affected sub-region
- IX.3. Acid sulphate sub-region of Dongthapmuoi
- IX.4. Acid sulphate sub-region of Longxuyen Quach
- IX.5. Acid sulphate sub-region of Uminh
- X. Island sub-region of the North
- XI. Island sub-region of the South
- Rivers, springs, lakes

Edited from database of NIAPP by GIS Division of NISF

CHINA

**MAP OF FOREST CHANGES
IN PERIOD OF 1943 - 1995**
(The mainland)



LEGEND

-  1943 forested - 1995 unforested
-  1943 unforested - 1995 forested
-  1943 - 1995 forested
-  1943 - 1995 unforested

CAMBODIA

*Edited from database of FIP1
by GIS Division of NISF*

THE METHODS OF SOIL ANALYSIS

- *Particle size*: Removal of organic matter by H_2O_2 (30-35%). Dispersion by Natri Hexametaphosphat/Natri Carbon, shaking over night. Sand is separated from clay and silt with a 0.05 mm sieve. The sand is fractionated by dry sieving, the clay and silt fractions are determined by the pipette method.
- *Bulk density*: Use metal tin with 100 cub. cm volume, straight into determined soil horizon to give soil in natural, dry in temperature of $105^{\circ}C$ and weight until invariable weight.
- *Particle density*: Picnomet method.
- *Soil moisture*: Calculation of the results of soil analysis is done on basis of "oven-dry" soil.
- *Porosity*: Calculating from bulk density and particle density.
- *pH*: The pH of the soil is potentiometrically measured in the supernatant suspension of a 1: 2.5 soil : liquid mixture. The liquid is either water (pH H_2O) or a 1M KCl solution (pH KCl).
- *Exchangeable acidity and aluminium*: The sample is percolated with a potassium chloride solution. The acidity brought into solution from various sources in the soil is measured by titration.
- *Potential acidity*: The acidity extracted by a $BaCl_2$ - TEA buffer solution pH = 8,2 (TEA = trietanolamin). After centrifugation an aliquot of supernatant solution is titrated with acid to measure the residual base.
- *Organic carbon (OC)*: The Walkey - Black method is followed. This involves a wet combustion of the organic matter with a mixture of potassium dichromate and sulphuric acid. After reaction the residual dichromate is titrated against ferrous sulphate with barium Diphenylamine Sulphonate.
- *Nitrogen*: The Kjeldahl procedure is followed. The sample is digested in sulphuric acid and organic nitrogen is converted to ammonium sulphate. The solution is then made alkaline and NH_3 distilled. The evolved ammonia is trapped in boric acid and titrated with standard acid.
- *Total of phosphorus total*: Used perchloric and sulphuric acid combustion and dissolved compound phosphorus in soil. Phosphorus is determined by spectrophotometer method.
- *Available phosphorus*: The phosphorus is fractionated by HCl 0,1 N and NH_4F 0,03M of a 1: 7 soil:liquid mixture. Phosphorus in the extract is determined colorimetrically with ascorbic acid as reducing agent.
- *Total of potassium*: The sample is combusted and dissolved by HF and $HClO_4$ mixture according to M.Jackson, potassium in the extract is determined by Flamephotometer.
- *Available potassium*: Used ammonium acetate to extract 1M (pH = 7) to extract of a 1:10 soil: liquid mixture. Available potassium in the extract is determined by flamephotometer.

- *Exchangeable bases*: The sample is digested NH_4OAc 1M (pH =7). Ca, Mg, K, Na, cations in the extract are measured by Atomic Absorption Spectrophotometer (AAS - 3300 Pekin Elmer).

- *Cation exchange capacity*: The sample is subsequently percolated with sodium acetate, the excess salt is then removed and the adsorbed sodium exchanged by percolation with ammonium acetate. The sodium in this percolate is a measure for the CEC.

- *Base saturation*:

$$\text{Base saturation (in \%)} = \frac{\text{Exch. Ca + Mg + K + Na} \cdot 100\%}{\text{CEC}}$$

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CONTENT

FORWARD	1
INTRODUCTION	2
Chapter 1	
OVERVIEW ON NATURAL CONDITIONS, THE MAIN PROCESSES OF SOIL FORMATION AND SOIL CLASSIFICATION IN VIETNAM	3
1.1. Natural condition	3
1.2. The main soil forming processes in Vietnam	10
1.3. Soil Genesis and Classification Research in Vietnam	21
Chapter 2	
THE BASIC INFORMATION OF THE MAIN SOIL UNITS OF VIETNAM	25
2.1. The Sandy soils	25
2.2. The Saline soils	35
2.3. The Acid Sulphate soils	44
2.4. The Swampy soils and Peat soils	51
2.5. The Alluvial soils	56
2.6. The Grey Degraded soils	76
2.7. The Brownish Grey soils in semi-arid region	84
2.8. The Tropical Black soils	87
2.9. The Ferralitic soils	92
2.10. The Reddish yellow humus soil in mountains	132
2.11. The Humus soils on high mountains	135
2.12. The Podzols	138
2.13. The Eroded skeletal soils	141
Chapter 3	
INTRODUCTION OF VIETNAM SOIL REFERENCE AND INFORMATION CENTER (ViSRIC)	144
3.1. Establishment of Soil Reference and Information Center	144
3.2. Process of establishment of Vietnam Soil Reference and Information Center	145
3.3. Vietnam Soil Reference and Information Center (ViSRIC)	146
3.4. The exploiting capability of the Center	146
SOME PICTURES OF ViSRIC	147
THE METHODS OF SOIL ANALYSIS	155
REFERENCES	157