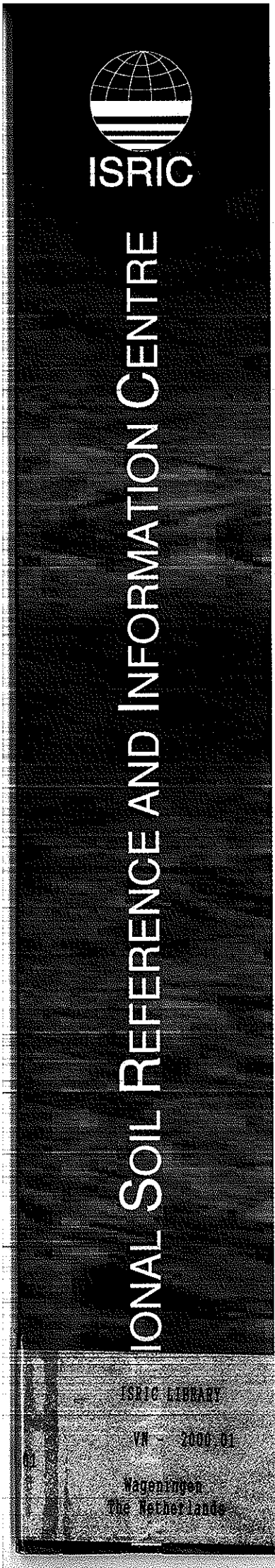

The Tropenbos Foundation

Vietnam

Reconnaissance of physical and biological resources

J.A. Dijkshoorn

Consultancy report

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TROPENBOS The Tropenbos Foundation

ISRIC International Soil Reference and Information Centre

Consultancy report

Part 1

Table of contents

Part 2

Annexes

1 Introduction

The aim of this study has been to collect, elaborate and evaluate the relevant information on the physical and biological resources of Vietnam. The study will serve as a background document for the Tropenbos Foundation, as to what variations in physical and biological resources are found in the country and have to contribute to the knowledge of locations in Vietnam, which might be selected as a Tropenbos site.

Use has been made of existing studies and documents on Vietnam, available in university libraries. Also resource persons have been consulted. Not all aspects could be covered, because information is scattered and not all is readily accessible. More relevant and probably recent information might be available at the various universities and research institutes in Vietnam. Time constraint has limited the search to easily accessible and available information, making use of both libraries and the World Wide Web.

2 Country background information

2.1 General

The Socialist Republic of Vietnam is situated along the eastern coast of the Indo-China Peninsula. It borders Cambodia and Laos to the west and China to the north. Vietnam stretches over 1600 km from latitude 8°33' to 23°22' N and longitude 102°8' to 109°35' E, covering a land area of 329.556 km² (1, 2)[1]. The South China Sea and the Gulf of Tonkin are the natural boundaries to the east, see Annex I, Figure 1.
The country is S-shaped with broad deltas of the Song Hong (Red river) in the north and the Mekong River in the south, linked by a narrow central section. At its narrowest point the country is only about 50 km wide. The Hai Van pass, in the hilly and mountainous area between the towns Da Nang and the old capital of Hue, marks a natural division between the northern and southern part of Vietnam. This natural division is also close to the 17° N demarcation line, which separated the Democratic Republic Vietnam in the north from the Republic of Vietnam in the south, during the Vietnamese-American war from 1964-973.

About three-quarters of the country is hilly and mountainous. The Hoang Lien Son mountains in the north-west of the country have the highest peaks of which the Fan Si Pan is the highest, rising to an elevation of 3143 m asl. These mountains form an extension of the Hengduan mountain range of China and are biologically related to south-west China. The mountains in the north-east of the Song Dong River are connected to the limestone ranges of China's Guangxi province and biologically related to southern China.
The Truong Son (formerly Annamite) mountains, a low mountain and steep hilly range, extend from the north-west mountains (approximately from Ca Song River) and reach into the Central Highlands up to 80 km north of Ho Chi Minh City in the Mekong delta area. It is a natural border to Laos and Cambodia and biological related to those countries. The narrow eastern coastal plains and foothills are a separate biological unit (2).
All these physiographic and geographic differences make that Vietnam is made up of equatorial lowlands, temperate plateaus and alpine peaks. Although Vietnam lies in the tropics, local conditions vary from frosty winters in the far northern hills to the year-round subequatorial

[1] The numbers between brackets refer to the corresponding number in the References (chapter 11).

warmth of the Mekong delta. At sea level, the mean annual temperature is about 27 °C in the south, falling to an average of 21 ºC in the north.
The two main delta areas of the country, the Song Dong river delta (15,000 km²) in the north and the Mekong Delta (60,000 km²) in the south are the most fertile and productive areas of the country and almost completely used for agriculture.

For a practical purpose, partly based on physical boundaries, the country is divided in 4 large units. These are separately described in this report. They are:

- Northern Vietnam, down to Nghe An province
- Central North Vietnam, from Nghe An to Thua Tien Hue province
- Central South Vietnam and the Central Highlands
- Mekong delta

2.2 Administrative division

After the reunion of both nations in 1975, the country consisted of 50 provinces and three autonomous areas, Hanoi, Haiphong and Ho Chi Minh City respectively. In November 1996 the provincial structure changed somewhat; the country now counts 58 provinces and three autonomous regions (4, 2). Annex I, Figure 2 shows the original provincial names and Annex II, Table 1 the changes of name at provincial level after 1996.

2.3 Population density and ethnic groups

The highest population density in the country is found in the delta areas of Mekong and Song Hong rivers, the lowest in the steep and mountainous areas of the central and northern provinces. The population density per province is shown in Annex I, Figure 3. Resettlement programmes of the 1980s, due to population pressure on land in both delta areas, and illegal residents in forest areas, have led to the destruction of thousands of hectares of forests by (illegal) logging and clearing for agriculture use (3). The higher population density now present in those areas, might have contributed to increased poaching and illegal wildlife trading. Forest fires are another cause of degradation, which may add to accelerated erosion of the forest edges in many parts of the country.

Officially there are 53 ethnic minority groups in Vietnam, see Annex I, Figure 4. The ethnic minority groups generally are confined to the mountainous areas of the Central Highlands and the mountains and hills on both sides of the Song Hong River. They are found to a lesser extent in the Truong Son Mountains of Central Vietnam. Most mountain people live in tribal communities and practise shifting cultivation (2, 30), see also Chapter 7.3.

3 Climate

The climate characterisation in this chapter follows the criteria of the study for Southeast Asia of the French Institute of Pondichéry, which classified the bio-climates of the Indo-China Peninsula (5). The characterisation is based on temperature, precipitation and the length of the dry season. For Vietnam, the study is based on 47 “primary” meteo-stations and 169 “secondary”. However, the length of the dry season is based on criteria presently no longer used, but the results might give a fair approximation of present approaches. In this study a dry month is defined as P (precipitation) < 2T (temperature), according to Bagnouls and Gaussen (5). The length of the dry season as shown in the recent National Atlas of Vietnam (6), gives a comparable result.

In general there is a distinct climate difference between northern and southern Vietnam. Firstly, there is a temperature gradient north-south, which is most pronounced in winter. Secondly, as in all mountainous areas, temperature depends largely on the elevation.

The total precipitation varies roughly between 1200 and 3000 mm/year. The lowest precipitation, of somewhat less than 1200 mm, is found in three areas; a small area north of the City of Vinh (Nghe An province), a coastal fringe bordering on the Central Highlands and in a strip north of the Mekong river. Highest precipitation, of more than 3000 mm, is found in the Truong Son mountain range and on some high plateau areas in the Southern Highlands, see Annex I, Figure 5. The length of the dry season varies between no dry months at all in parts of the Truong Son mountain range to 5 or 6 months in a part of the Mekong delta and along a coastal fringe in southern central Vietnam, see Annex I, Figure 6.

Northern Vietnam
Because of absence of very high mountains to the north, cold air from the Polar-Siberian front systems intrude into northern Vietnam during winter, creating the winter (north-east) monsoon. These north and north-eastern winds are responsible for a rather quick fall in the temperature during the winter season. The cold air intrusion can reach up to the 17° N latitude. In the coolest month, the average temperature at low elevations is between 15 and 20 °C. There are also large temperature variations due to elevation differences, and locally very low absolute minimum temperatures are reached.
The precipitation in this northern area is between 1500 and 2000 mm/year, mainly in summer (south-west monsoon). The dry season lasts 3-4 months, from December to February/March. The climate in this area is also characterized by a hot summer and a moderate cool winter season, see Annex I, Figures 7 and 8.
More westwards and at higher elevations, generally between 500 and 1500 m asl., the temperature falls gradually to an average between 10 and 15 °C for the coolest months, with a dry period of 1 to 4 months. Precipitation varies around 2000 mm. This climate is characterized as cool, humid to very humid with a short dry season. It prevails in most of the northern upland and mountainous areas and dominates also in Laos and northern Thailand.
At the highest elevations, roughly above 1500 m asl, the average temperature for the coolest month ranges between 0 and 10 °C, with no or only a very short dry period. The total precipitation increases from 2000 up to 3000 mm/year. This climate is found more fragmented over the northern mountain areas, in particular in the northern provinces bordering on China and some high elevation areas south of the Song Hong river (Hoang Lien Son mountains).

Central north Vietnam
A climate similar, to that of the medium elevation areas of northern Vietnam, occurs in the Truong Son mountains; these mountains range from south of Vinh (Ha Tinh province) to the high elevation areas of the Central Highland (Kon Tum plateau). See Annex I, Figures 7 and 8. These mountains have cool climates, with a mean temperature between 5 -10 °C in the coolest month and large temperature fluctuations, ranging from 10 to 15 °C. They are also humid to very humid with no dry season and a rainfall of more than 3000 mm/year. See Annex I, Figure 5 and 6.
The coastal zone and Truong Son mountain footslope, between Vinh (about 19° N) and Quang Ngai (at 15° N) and some plateaus of the Central Highlands have a climate with comparable temperatures to the low elevation areas of the Song Hong delta, but with much less temperature

fluctuation. It is characterized by a hot climate with moderately cool winter seasons for the northern coastal zone (Vinh to Quang Tri). South of Quang Tri province, a hot climate without a marked cool season prevails for the southern coastal zone. Here the mean temperature of the coolest month lies above 20 °C. The mentioned coastal zones are very humid with a precipitation of more than 2000 mm/year, because both the south-west (summer) and north-east (winter) monsoon brings rain to these areas. The dry season is short and lasts only 1 to 2 months.

Central south Vietnam
Except for some high elevation areas in the Central Highlands, the mean temperature of the coolest month is above 20 °C. There is only a small to moderate variation in temperature. From the areas with a high elevation (plateaus) to a lower elevation, precipitation decreases from 3000 to less than 1500 mm/year. The lowest rainfall is recorded in a fringe along the southern coastal zone (only south-west monsoon).
The dry season last generally 3 to 4 months, but is longer in the coastal area. The climate is characterized as hot, without cool season, very humid to humid with small to moderate temperature variation. More to the west, moving into Cambodia and Thailand is drier. The precipitation is lower again and the dry period lasts 5 to 6 months. The climate of the Central Highlands might compare best with southern Burma and northern Malaysia. See Annex I, Figure 8 and 9.

Mekong delta
The climate of the Mekong delta is hot the whole year round; mean temperature is above 20 °C. Precipitation along the Mekong River, reaching into Cambodia, falls to less than 1500 mm/year, with a length of the dry season of 5 to 6 months.
South of the Mekong River the precipitation increases again to more than 2000 mm/year and this area has a shorter dry season of 3 to 4 months.

During hot weather, at the change of the monsoon season, destructive typhoons sometimes develop over the South China Sea. Occasionally they strike into Vietnam, generally in the central part of the country, bringing heavy rain and flooding.

4 Geology
A geological map at scale 1:2 million (8), was used as a source for the description.

Northern Vietnam
The Song Hong River still marks the Mesozoic fold belt, which separates the Eurasian plate from the Indo-Australian. This fold belt extends from the eastern border of Tibet and Yunnan province in China, in a north-west to south-east line across Vietnam, into the Gulf of Tonkin. It marks the late Mesozoic collision between the Southeast Asian subcontinent and the main Eurasian continent (9). The Song Hong river valley is partly filled up by Tertiary sediments, and eastwards the river delta is made up of sediments from Quaternary age.

North of the Song Hong River, rocks are dominantly of sedimentary origin, dating from lower and middle Jura with rock composition varying from schistose series of clayey/silty marls and sandstones. These rock types are mostly found at lower elevations. From Hanoi, bending in a

north-west arc along the northern and north-western border with China, up to the town of Ha Giang, older Paleozoic sedimentary rocks, mainly Carboniferous and Permian limestone occur in quit extensive areas. One of these limestone areas occurs north-west of Hanoi and west of the line Hanoi-Lang Son at the Chinese border. In this belt pockets of igneous intermediate rock, such as rhyolite and dacite occur (8 and 9).

Also south of the Song Hong river Mesozoic folding marks the geology and landscape. Most formations run in north-west to south-east direction and extend far into the Truong Son Mountains. At the border with China, south of where the Song Hong river enters Vietnam, extensive ortho-gneiss (with Fan Si Pan peak), granite, dacite and rhyolite folded formations occur, alternated with Paleozoic and lower Mesozoic sedimentary rocks, which are made up of schist, sandstone and limestone from Devonian to Triassic age. Especially this belt of limestone from Devonian age gives much variation in the landscape. See Annex I, Figure 11 for limestone areas.

In the far southwest corner in Lai Chau and Son La provinces, bordering to Laos, extensive formations of crystalline schist and granites are found. This rock is intercalated with younger sedimentary rocks, mostly claystone, marls and sandstone of middle Jurassic age. This formation extends far into Laos and northern Thailand.

Central north Vietnam
Most of the mentioned formations are found back in the Truong Son mountains of the central northern part of Vietnam, ranging from Nghe An province to Quang Nam province (Da Nang). These formations are of a similar age and composition as mentioned for northern Vietnam. Dominating in the northern part of the Truong Son chain are sedimentary rocks, such as schist, sandstone and limestone, varying from Devonian to upper Jurassic age. Smaller areas of granites, gneiss and crystalline schist formations also occur. A rather large area of limestone occurs in Quang Binh province at the border with Laos.

Central south Vietnam
The dominance of a large granite formation, just north of the town of Da Nang, marks the geological difference between northern and southern Vietnam. An extensive area of gneiss, mica-schist and granite occur between the towns Da Nang (Quang Nam province) and Play Cu (Kon Tum province). South of Play Cu, characterizing the northern part of the Central Highlands, a large basaltic lava plateau of Neogene (Pliocene) and late Quaternary age occur in Gai Lai province. More to the south, other smaller basaltic plateaus occur, of which those in Dac Lac and Lam Dong province are the most extensive. The basaltic lava plateau of south Dac Lac province extends further to the west into Cambodia. Dominating are tholeitic basalts, which are silica-over-saturated and characterized by low-calcium pyroxenes. Small areas occur of olivine basalts, mainly along faults. On the basalt plateaus bauxite is found, sometimes in coherent layers. Some of these are promising for exploitation e.g., near Dac Nong and Boa Lac in Lam Dong and Dac Lac province (10).
Along the east flank of the Central Highlands granitic rocks dominate, alternating with dacite, rhyolite, and with some clastic rocks, such as sandstone and other siliceous rock, most of Devonian age. Recent sedimentary deposits occur in the narrow coastal zone and in the many small valleys penetrating the uplands.

At the west side of the Central Highlands, in between the basaltic plateaus of the provinces Dac Lac and Gai Lai, sedimentary rocks of Jurassic age are found. They comprise clay, marl, and sandstone or schistose-sandstone of ancient lagoon, continental and sub-continental formations.

Mekong Basin
Scattered and smaller plateau remnants of basaltic rocks extend from the Central Highlands into the Quaternary lacustrine sediments of the Mekong basin.
This most southern region including the Mekong river area consists almost completely of recent Quaternary sediments. Peat formation occurs in Minh Hai province, close to the coastal belt of the Gulf of Thailand.

5 Soils and landforms

Consulted have been the soil maps of North Vietnam (11), scale 1: 0.5 million and of South Vietnam (12), scale 1:1 million. A tentative correlation of the Vietnamese classification with the FAO/Unesco legend is given by Ref. (14). This soil correlation, based on the soil information of the southern Central Highlands, is used to correlate tentatively the legend of the soil map of North Vietnam to the FAO Soil Groups and sometimes at subgroup level. As the Vietnamese classification use different criteria (based on the Russian system), it is almost impossible to correlate directly to the FAO Soil Groups. The units of the Vietnamese legend often contain two or more Soil Groups of the FAO legend. Despite this problem a very provisional correlation is presented in the Annex II, Table 2.

Northern Vietnam
The pattern on the soil map of northern Vietnam is very complicated. Therefore a general description of the occurring soils is given for 3 sub-areas. Although not described in this section, information can be obtained also from the general maps on relief and natural landscape (7), see Annex I, Figure 10 and 11.
North of the Song Hong River: The north-eastern uplands are strongly dissected. The dominant elevation is about 600 m and the highest peaks reach over 1000 m. The dominant soils are shallow (less than 50 cm deep), pale yellowish (Fq in the legend) and derived from sandstone/ claystone. Tentatively these soils, particular the deeper ones, correlate with Acrisols and the sandy ones probably with Arenosols (13). Close to the Chinese border, also yellowish red soils on claystone and metamorphic rock (Fs) with a medium soil depth occur. These soils correlate probably with the Acrisols and Lixisols.
Northwest of Hanoi, the dominant elevation is generally between 800 and 1200 m asl., with peaks reaching 1500 m in the east to more than 2000 m in the west. The landscape is strongly dissected. Yellowish red soils (Fs) derived from metamorphic rock and claystone dominate. Scattered are large karst units with steep hilly and mountainous areas and shallow soils (Leptosols, with probably Rendzic and Lithic subgroups), on Carboniferous and Permian limestone. Red soils on limestone (Fv) are sometimes indicated within less dissected karst areas. A large area of these red soils occurs in eastern Bac Thai province. These soils correlate probably with (Chromic) Luvisols and might be calcareous. Also small units of reddish brown soils (Fk) on neutral and basic (volcanic) rocks occur. Correlation is difficult, but probably they are "richer" soils, with a high base saturation of more than 50% and correlate with Lixisols, or even Luvisols. Yellowish red soils (Fa) occur on the acid igneous rock in western Bac Thai province

and in southern Ha Giang province at the north-west border with China. These soils are generally deep to very deep and correlate probably to Ferralsols.
In the mountainous areas the soils have thick, humus rich topsoils (FHa in the legend), indicating umbric/mollic horizons. (The Russian classification considers humic subgroups at higher elevation, above 1000 m asl). These soils correlate to humic Ferralsols at subgroup level, or with Umbric or Dystric subgroups levels of other Soil Groups. The steep and high mountain ranges have dominantly shallow soils and rock outcrop (Leptosols)

South of the Song Hong River, the landscape is a strongly dissected, characterized by parallel running geological formations. The Hoang Lien Son mountain range reaches elevations of more than 2500 m asl (highest Fan Si Pan peak 3143 m.). The parallel running Song Da river marks a dissected, hilly to mountainous landscape at somewhat lower elevations, generally around 1500 m. Higher elevations up to 2000 m asl are encountered again in the south-west corner of Lai Chau and Son La provinces at the border to Laos. The soils follow this geomorphologic pattern; shallow and moderately deep, yellowish red soils (Fs) occur in the lower valleys, where claystone and metamorphic rock surface. The soils of the Hoang Lien Son mountains are characterized, due to its parent material of acid igneous rock, by shallow to medium, yellowish red soils (Fa) at lower elevations, changing into humic yellowish red soils (FHa) at medium elevations and humic yellowish grey soils with podzolic properties (HA in the legend; has leached horizon, but difficult to correlate to FAO Soil Groups) and rock outcrops at the highest elevations (around 3000 m). South of this range and generally up to the Song Da River, the landscape is less dissected. Here, yellowish red soils (Fs) on claystone and metamorphic rocks and light yellowish soils (Fq) on sandstone dominate.

South of Song Da River, a dissected belt of (ultra-) basic intrusive rock (gabbro and dolerite) alternates with limestone rocks. The shallow red soils on limestone (Fv) and medium deep, reddish brown soils on basic volcanic rocks (Fk), both with almost bare outcrops, are typical soils for this narrow belt, which reaches eastwards as far as the coastal lowland. Small units of humus-rich, red soils on limestone (FHv) also occur at higher elevations.
Along the south-western border with Laos, yellowish red soils (Fs) on metamorphic rocks and light yellowish soils (Fq) on sandstone, both with variable depth, are found in the valleys and lower valley slopes. Summit areas and upper valley slopes generally have soils with distinctly higher organic matter content (FHs and FHq, humic subgroups). These units occur especially in the border area with Laos, in Lai Chau province, while humic yellowish grey soils with podzolic horizons (HA) are common in Son La province (15).

Central north Vietnam
The north-western range of mountains and hills continue in the lower, but generally strongly dissected, Truong Son mountain range. Dominant soils are, depending on the parent materials, yellowish red soils on acid igneous rock (Fa), yellowish red soils on metamorphic rock and claystone (Fs) and light yellowisch soils on sandstone (Fq). For correlation to FAO/Unesco Soil Group, see Annex I, Table 2.
Soils have generally a shallow to medium depth. In the steep mountainous areas, most of them along the border with Laos, the yellowish red and light yellowish soils have high organic matter contents (FHs, FHa and FHq), while humic grey soils with a podzolic horizon (HA) occur at the highest and wettest mountain tops.

In Quang Binh province, a dominant part of the Truong Son mountains shows karst phenomena with rock outcrops and very shallow soils. This karst area continues into Laos; soils are related to those described for the northern limestone areas. South of this karst area, in Quang Tri province, most soils are indicated on the soil map as very shallow. They include light yellowish soils on sandstone (Fq) and yellowish red soils on claystone and metamorphic rock (Fs). Other sources (21) mention that extensive areas occur of strongly eroded, skeletic soils. One of the reasons of degradation in this area is the intensive defoliation and war acts (bombing) during the Vietnam-American war, see Annex I**,** Figure 22 and 23.

Central south Vietnam:
The legend of the general soil map of South Vietnam, at scale 1:1 million, is different from that of North Vietnam (12). The legend for South Vietnam is composed, in view of the agriculture potential of the soils. The description of soils in the legend includes parent material as well as topography. Strongly dissected, mountainous areas are indicated as a very large complex unit, while very small areas of alluvial soils and areas with a plane to rolling relief are indicated on the map separately.

The southern range of the Truong Son mountains and the eastern part of the Central Highlands are indicated as a complex of mountainous soils. This complex comprises mostly red and yellow podzolic soils and lithosolic soils, which correlate to Acrisols and possibly Lixisols, respectively Leptosols and probably Regosols.
The large basalt plateaus, occurring in the Central Highlands, are indicated as having earthy red latosols (correlate probably with (geric) Ferralsols), red and yellow latosols, correlating with Ferralsols (rhodic and xanthic subgroups) and reddish brown and red latosol (rhodic Ferralsols). This is confirmed by a recent study, which classified most of these soils as Ferralsols, because of its ferralic diagnostic horizon, although soils also show a distinct clay increase with depth and argic diagnostic properties (13).
Other sources (16) confirm small areas of Nitosols on the basalt plateau in Gia Lai province, which are probably related to the olivine basalt, appearing along fault zones on the plateau (10). This source also indicates that most Acrisols (on acid and metamorphic parent materials) are shallow (lithic) or have a high content of oxidic concretions or hardened plinthite within 50 cm of the surface (skeletic soils).
The most southern part of the Central Highlands (southwest of Dac Lac and Lam Dong provinces) has dominantly Ferralsols (xanthic and rhodic subgroups) on the basalt plateaus. According to a recent study (13) these basalt plateaus represent old relatively stable landscapes. This explains why most soils on the plateaus have a "petroplinthic layer", in the form of gravel or stones within 100 cm depth, particularly on the side slopes of the interfluves, which also might be related to the reported bauxite layers (10). Subdominant soils of the area are Acrisols, developed on metamorphic sedimentary rocks, with a skeletic phase (16).

Mekong basin
Between the recent alluvial deposits of the Mekong River and the southern fringe of the Central Highlands a belt of old alluvium with a flat to undulating topography occurs. Soils are classified as grey podzolic soils (12). Similar soils in the Dak Lak province are classified as Luvisols and Lixisols (13). This study also describes related soils, derived from old alluvium with an abrupt textural change, such as Planosols.

Along the main river channels of the Mekong (and Song Hong) undifferentiated alluvial soils dominate (eutric and dystric Gleysols). The acid sulphate soils (thionic subgroups of Fluvisols and Gleysols) and potential acid sulphate soils dominate west of Ho Chi Minh City up to the border with Cambodia. The acid sulphate soils make up about 40% of the Mekong delta (17). Other (potential) acid sulphate soils, often in combination with salinity, occur in the most southern corner of the country (a.o. Minh Hai province). In this southern part, west of the city of Ca Mau, also areas with peat occur, which correlate to Histosols.

6 Ecological zones

Only one source was found, giving a preliminary division of Vietnam in ecological regions and zones. A map showing these ecological zones is given in Annex I, Figure 12. The legend of this map (zones indication) is found in Annex II, Table 3.
The map is compiled on basis of a combination of natural resources, natural environment and ecosystems of Vietnam (18). Distinguished are 10 ecoregions divided into 38 ecozones. No further elaboration is given on differences between regions and zones, as to understand certain divisions on the map. Because of this lack of background information and the small scale of the map, it was considered less suitable for further use and description. Nevertheless it gives a number of zones, which do not show up in divisions on other maps and might be of help to understand the ecological differences in Vietnam.

7 Vegetation and land use

There are varies sources giving information on vegetation (and land use). Some give only information on forest and others in combination with biodiversity e.g., IUCN (20) and WCMC (1). It appears that different criteria are applied for classification and characterization of forest type/vegetation cover as shown in the legend. Others give actual status, decline of forest cover over the last 50 years or additional information on the type of vegetation (salinity or acidity). It is therefore difficult to compare maps and legends, although all add to the understanding of differences in forest cover. The approaches depend for a large part on the different interests of the composers and the purpose of the vegetation maps.

In this chapter mainly the actual vegetation map of Vietnam (23) is used to describe the vegetation, because it gives the most complete information, see Annex I, Figure 13. Use has also been made of a more schematic vegetation map of Indochina (22) and of a small scale vegetation map of Vietnam (25), see Annex I, Figure 15 and Figure 10. The map of Annex I, Figure 15 is included to give an impression of the regional distribution of the main types of vegetation over the Indochina peninsula.
The actual vegetation map, Annex I, Figure 13, has 28 vegetation classes divided over 9 vegetation groups, including two herbaceous vegetation groups. The classes described in the legend also mention dominant or characteristic species. A short description of the dominant classes in the different regions is given, including details of their distribution. The unit number between brackets in the text refers to the vegetation unit in the legend.

Northern Vietnam

The pattern of the vegetation cover of northern Vietnam is rather complex. Responding to strongly varying physical conditions, the vegetation can be related to their area of origin; Yunnan-Himalaya, southern China and India-Malaysia (15). In this description only general classes are given and because of its complexity, northern Vietnam is for this description subdivided into 3 smaller regions.
North and just south of Song Hong river exist extensive areas, that which are dominated by tropical medium tall grassland (*Imperata cylindrica*, often mixed with *Combopogon spp., Sorghum propinguu v.v.*) and tall grassland (*Saccharum spp., Miscanthus spp., Themada giganta v.v.*) with scrub species (*Aporosa microcalya, Phyllanthus emblica, Wendlandia spp., Careya sphacrica v.v.*) and scattered trees species (*Dillenia spp., Bauhinia spp., Cratoxylon spp, v.v.*) mainly lowland and submontane (unit 23). Subdominant in this area is a similar vegetation as unit 23, but without shrubs and trees and mainly submontane and montane (unit 24).
Although herbaceous and shrub vegetation dominate, patches of evergreen closed forest are also found very scattered over the area. They are characterized as tropical evergreen moist seasonal submontane broad-leaved forests (dominated by species of the families *Fagaceae, Lauraceae, Magnoliaceae and Theaceae*) sometimes mixed with needle-leaved species (*Dacrydium pierrei, Podocarpus imbricatus, Keteleeria spp.*) (unit 3). A number of these units occur on or around limestone formations. The national parks Ba Be, as well as Cuc Phuong south of Song Hong river, are found in such areas, see also Annex I, Figure 18 and Annex III, Appendix 4.
However, most limestone formations have shallow soils and an evergreen and semi-deciduous shrub vegetation (units 17, 18 and 19; only the latter unit has karst). Dominant is vegetation unit 17, tropical mainly lowland and submontane shrub *Rhodomyrtus tomentosa, Melastoma spp., Memecyclon edule, Breynia fruticosa, Myricaes culenta, v.v.* with scattered tree species (*Trema orientalis, Mallotus paniculatuc, Litsea spp., Microcos paniculata, v.v.*). Vegetation unit 18 is similar to unit 17, but without trees, while unit 19 has tropical lowland and submontane broad-leaved scrubs (*Taxotrophis ilicifolius, Dimerocarpus brenieri, Teonongia tonkinensis, v.v*) on limestone with karst.

South of the Song Da River down to the border of Laos, a herbaceous vegetation (unit 24) dominates.
In a study on land use in the Song Da watershed (15) a more detailed list of plant species in the provinces Son La and Lai Chau is given. The study states that at present the main vegetation type is secondary forest and it is hard to find any completely undisturbed natural vegetation. Tropical rainforest is located at the lower altitudes, open savanna type of forest in the drier areas, semi-decideous forest at higher altitudes with temperate trees like oak and chestnut and mountainous forest at the highest elevations. Grasses (such as *Imperata cylindrica*), shrubs, secondary forest and bamboo vegetation occur where human influences (mainly shifting cultivation and to minor extent logging) have caused removal of the primary vegetation.
In the southeast of this area, on the transition from the northern mountains and hills to the lowlands, a relatively extensive limestone area occurs (unit 9), of which Cuc Phuong national park forms a part. The vegetation here is classed as tropical evergreen moist seasonal submontane broad-leaved forest on limestone (*Burretiodendron brilletii, Platycarya spp., Croton pseudo-verticillata, v.v.*) sometimes mixed in places with needle-leaved species (*Fokienia hodginsii, Pinus kwangtungensis, v.v.*)

Central north Vietnam

Central north Vietnam has two main zones: the coastal zone and the zone of the mountainous and hilly Truong Son range.
The mountainous and hilly Truong Son range, starting in northern Nghe An province down to Quang Binh province, has rather closed (not fragmented) areas of tropical evergreen moist seasonal submontane broad-leaved forest (unit 3) along the border with Laos. Adjacent to this evergreen submontane forest belt are scattered areas of tropical evergreen moist seasonal lowland broad-leaved forests (unit 2), which are dominated by some species of the genera *Aglaia, Dracontomelum, Canarium* and *Nephelium*, and sometimes by one or more others, like *Erythrophleum fordii, Madhuca pasquieri, Vatica fleuryana v.v*. This vegetation unit is alternated with patches of tropical lowland bamboo and submontane forest (unit 6) with pure stands of species of the genera *Neohouzeuoa, Dendrocalamus, Schizostachyum, Bambosa xytenanthera*.

The coastal zone is dominantly used for agriculture, although interesting coastal wetlands and lagoons occur (32). In the coastal lowlands, but also in the lower mountain range, a herbaceous vegetation (unit 23), scrubs (unit 17) and areas in permanent use for agricultural (unit 28) are found, including areas with shifting cultivation, regenerated shrubs and herbaceous xerophytic vegetation (unit 27).
In these provinces only few areas with karst and limestone vegetation (unit 19) are found. A large area with karst phenomena and evergreen and semi-deciduous broad-leaved scrub vegetation on limestone (unit 19) occurs in the central part of Quang Binh province.

Central south Vietnam
Several vegetation types are found scattered over the Central Highlands. However, a rather large area of closed tropical evergreen moist seasonal submontane broad-leaved forest (unit 3) occurs around the city of Play Ku (mainly on the north-east side) in Gia Lai province. Typically, most of this forest is not found on the basalt plateau, but in areas where acid metamorphic parent material dominates. A similar situation exists around Da Lat, Lam Dong province, where the same type of forest is found on comparable parent material and soils (Acrisols).
An exception is found west of Da Lat in Dac Lac province (between Dak Nong and the border with Cambodia), where evergreen forest (unit 3) is indicated on soils (Ferralsols) derived from basaltic parent material (13).
The area, situated between these two mentioned forest concentrations, covering southern Gai Lai and northern Dac Lac provinces has dominant herbaceous vegetation (unit 23). Subdominant are tropical deciduous lowland and submontane broad-leaved woodland (unit 16), dominated by *Dipterocarpus obtusifolius, D. tuberculatus, Shorea obtusa, S. siamensis*, and woodland and tropical drought deciduous lowland and submontane broad-leaved forest (unit 14) dominated by the same genera as for vegetation unit 16.
In the Central Highlands extensive areas on the basalt plateaus are used for agriculture (unit 28). Main commercial crops are coffee, rubber, and where the climate is suitable (drier): cashew. The occurrence of regenerated shrubs and herbaceous xerophytic vegetation (unit 27) in Kon Tum and Gia Lai provinces is probably related to the shifting cultivation still practised in the area, see Annex I, Figure 14. In the southern part of the Central Highlands (Lam Dong province) extensive areas of tropical pine lowland and submontane forest (unit 7) occur on degraded soils (Pinus merkusiana, P. khaya). Also patches of tropical bamboo lowland and submontane forest (unit 6) with sometimes pure stands of the genera *Neohouzeuoa, Dendrocalamus, Schizostachyum* and *Bambosa xytenanthera* are found in this area.

From the Central Highlands to the eastern lowlands various vegetation types occur. Tropical bamboo lowland and submontane forest (unit 6) is common, as well as patches of evergreen moist seasonal lowland broad-leaved forest (unit 2). Along the western border with Cambodia, a xerophytic herbaceous vegetation is most common (unit 23).

The Mekong delta

The Mekong delta is almost completely used for agriculture. Only small areas of original forest are left untouched. These are mangrove forests (unit 11), along the tidal coast and dominant in the most southern tip of the country (south-west of Ca Mau) with species of the genera *Avicennia, Rhizophora, Bruguiera, Sonneratia v.v.*, and *Melaleuca leucodendra* lowland forest (unit 10) occurring on very acid peat soils (west of Ca Mau).

During the war most of the mangrove forests have been heavily damaged by spraying with defoliants, especially those near the southern capital of Ho Chi Minh City. A replanting programme, which was launched shortly after the war, has been successful in re-establishing mangrove forest in many places along the main river branches.

Much damage to the mangrove forest has recently been caused by the many fish (shrimp) ponds, constructed in the period around 1990, by digging up the acid producing pyrite layers. This has resulted in acidification of the water of the fishpond, affecting not only the shrimp production very negatively, but also the mangrove vegetation (26). As production was no longer feasible, many fishpond areas have been abandoned. The Vietnamese government has started a restoration programme of this coastal belt, supported by a donor agency (27).

Also the original *Melaleuca* forest is disappearing rapidly and only small areas are left untouched. One of the reasons is that the peat soils disappear slowly, because of improved water management (drainage) of surrounding agriculture lands, and causing degradation of the forest. The government has launched reforestation programmes, mainly of *Eucalyptus*, but also of *Melaleuca leucodendra*; the latter is endemic to the peat areas and is successfully grown on acid sulphate soils in the delta (26). As 40% of the Mekong delta is classified as having (potential) acid sulphate soils and more than 10% is regarded as highly acid, a reforestation with *Melaleuca* is possibly and perhaps the only sustainable land use option for these highly acid soils.

7.1 Forests cover

The “Conservation Atlas of Tropical Forests Asia and the Pacific” (20) gives an estimate of actual forest resources and a map, showing the historical and actual forest areas of the country. It also gives information on biodiversity, national parks and nature reserves. When comparing different publications, figures on forest cover are not always consistent. Probably different interpretations (satellite imagery) and forest definitions are used. Moreover the terms forests and forest land are sometimes interchanged. The latter includes denuded hillsides and barren lands (which will eventually be reforested), resulting in a doubling of the area. This is exemplified in Table 1 (below), it gives figures on forests and forestland taken from the Asian-Pacific Forestry Sector Outlook Study (28).

Table 1. Forest and forest land (in millions of hectares). Source: (28)

	Total	Forested	Non-forested
Special use forest	1.2	0.9	0.3
Protection forest	8.0	3.5	4.5
Production forest	9.9	4.9	5.0

Forest land (total)	**19.1**	**9.3**	**9.7**

The table indicates even a larger area of barren lands and denuded hills (non-forested) forest land than land actually covered by forest. A different set of data (Table 2) is given by the IUCN (20). Although these figures are based on 1990 interpretations, they are considered by IUCN as fair estimates in the light of the high FAO figures of 1995 (28). The IUCN study (Table 2) divides the forest in five ecological forest classes, see also Annex I, Figure 16.

Table 2. Estimates of forest extent in Vietnam. Source: (20)

	Area (km²)	% of land area
Rain forest		
Lowland	28,040	8.6
Montane	7,520	2.3
Mangrove	1,610	0.5
Sub totals	*37,170*	*11.4*
Monsoon forest		
Lowland	18,010	5.5
Montane	1,500	0.5
Sub totals	*19,510*	*6.0*
Totals	**56,580**	**17.4**

Comparing the figures of Tables 1 and 2, there appears a rather large discrepancy between both approaches. The first table (in millions of hectares) indicates roughly 58% of Vietnam's territory as forest land and 28% as forests. According to IUCN (20), these figures seem to be unduly optimistic and, therefore, Table 2 is more realistic.
In Annex I, Figure 16 is shown the distribution of forest areas over the country, together with the locations of national parks and nature reserves. Comparing this forest map to the vegetation map (Annex I, Figure 13), it confirms that most forest is concentrated in the Central Highlands and on the Truong Son mountain range. This map also shows that different forest types (depending on management and elevation) are found at relatively short distances for both areas.

7.2 Non-wood forest products

Non-wood forest products are important trading products for the people living in or close to the forest areas. In Vietnam the forest products are called "dac san" or "special forest products" (28).
Main forest products are:

- Cinnamon, bark and oil are sold at high prices.
- Anise, produced mainly for export.
- Pine resin, tapped from "resinous pine" (*Pinus merkusii*) and three-needle pine (*Pinus khaya*).
- Bamboo and rattan, bamboo occurs everywhere in Vietnam. It is an important construction material and also used in the paper industry (Northern Vietnam).
- Medicinal forest plants, over 1800 plant and grass species are giving high-valued pharmaceutical products.

- Essential oils, e.g. cajeput oil (*Maleleuca*), eucalyptus oil, citronella oil and Litsea oderata oil.

Additional information on prices, export market and where the products generally are produced is given by FAO (29).

7.3 Shifting cultivation

In Vietnam the total population, practising shifting cultivation is almost 3 million, (1991 estimates). About 70% of the "ethnic minority" population still use some form of shifting cultivation, particularly the Hmong, Dao, Bana, Ede and Giarai (30). It is practised in mountainous regions throughout the country, particularly in the north-western region (Song Da and Song Hong watersheds) and in the Central Highlands, see Annex I, Figure 14.

There are different types of shifting cultivation each with a different impact on the natural environment (15). Two main types are practised in Vietnam: migratory and sedentary shifting cultivation.

Migratory (pioneer) shifting cultivation is practised only by a few ethnic minority groups. The most important type, sedentary (rotational) shifting cultivation, can be divided into two subtypes, at least for the north-western regions.

a) Upland based shifting cultivation, practised in highland areas above 1000 m with 2 or 3 years cropping and 5 to 10 years of fallow, and
b) Supplementary shifting cultivation on often steep valley slopes. The latter practice has a very strong impact on its environment and results in severe erosion and rapid decline in crop yields. This type of shifting cultivation is mainly due to scarcity of land in the area, forcing people to use steep slopes for agriculture, while not adapting to more sustainable cultivation practices required for these steep slopes (15).

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7.4 Forest fragmentation

Very little information on forest fragmentation in Vietnam has been found. The University of Hanoi, in co-operation with the University of Honolulu, Hawaii, has been studying forest fragmentation effects on watershed functions of a side in Hoa Binh province (northern Vietnam). The research was aimed to study hydrologic processes, which included measurement of meteorological, soil, and eco-physiological variables of a forest plot (31).

The results of this study indicate that shifting cultivation, as it has been practised for centuries in northern Vietnam and probably elsewhere in the country, has led to a landscape dominated by forest fragments of secondary vegetation and a mosaic of agriculture fields, pastures and forest fragments. The total area of forest did not change over a period of 40 years, but significant changes have occurred in the spatial distribution of the forest. The study revealed that the number of closed canopy forest fragments has increased from 3 to more than 700, while the size decreased from 1000 to only 2 hectares. Perhaps the biggest effects of tropical deforestation can be ascribed to the change from relatively homogeneous forest to a highly heterogeneous post forest cover. The report concluded also that further study is necessary on the fragmentation of forest and the indicated influences on the ecology of the whole ecosystem and the hydrology of the watershed.

8 Biodiversity

The country has a great wealth of biological diversity in its forests, waterways, and marine areas. This richness is shown in the absolute numbers of species and also in the proportion of species endemic to Vietnam. Much of this diversity is the result of local isolation, producing a patchwork of endemic species (32).

An estimated 33% of the flora of northern Vietnam is endemic, whilst it is estimated that for the entire flora the figure is as high as 50% (1). Endemism is not spread evenly over the country. The main mountain blocks such as the Da Lat plateau in the Central Highlands and the Hoang Lien Son Mountains in north Vietnam carry the highest levels of endemism.

According to a WCMC assessment in 1992, Vietnam was rated as 16th most biologically diverse country of the world. Annex II, Table 4, gives the number of species of the different taxa already known compared to the estimated world total. In some cases, especially regarding higher plant species, this is underestimated, as 7000 species have been identified now, while it is estimated that Vietnam has about 12000 species of higher plants (1).

Similarly, the number of endemic vertebrate species is given in Annex II, Table 4 and a list in Annex III, appendix 1. Vertebrate species of some of Asia's rarest animals occur in Vietnam, such as the kouprey, banteng, Javan rhinoceros, Asian elephant, tiger, Eld's deer, crested argus, green peacock, and still other forest animals not mentioned. Annex II, Table 4 gives the number of species considered by IUCN to be threatened in Vietnam, including the categories rare, endangered and vulnerable, while Annex III, Appendix 2, lists the globally threatened animal species in Vietnam.

One of the most threatened species is the Javan rhino. In the past this animal occurred in the northern provinces bordering Laos and in the Central Highlands. Nowadays the only place, where it still occurs in its natural environment, is in the Cat Tien National Park, Song Be province. Elsewhere in Vietnam the animal is probably extinct (33). More of such examples and information e.g., on primates, can be found in the various documents and publications dealing with the fauna of Vietnam.

Although Vietnam's wildlife is rich, it is in precipitous decline because of the destruction of habitats and illegal hunting. Less than 20% of the country remains forested, while also this is under threat from slash-and-burn agriculture and excessive logging (1). In an attempt to safeguard this wealth of biodiversity, the Government of Vietnam has established a number of important sites as national parks, protected areas and nature reserves.

Vietnam has seven national parks and more than 50 nature reserves (1,18, 20), see Annex 1, Figures 18 and 19, and the list in Annex III, Appendix 3. Together, these national parks cover about 200,000 ha and the nature reserves 670,000 ha. Even more nature reserves are proposed for buffer areas of the existing parks (18).

Annex III, Appendix 4, gives a description of five national parks viz., Cat Ba, Ba Be and Cuc Phuong National Parks in the north, Bach Ma National Park in the centre, and Nam Cat Tien National Park in the south.

A special biodiversity is found in karst areas. In most cases these areas differ in many aspects from the regionally known ecosytems. Karst areas form a very typical landscape, which sometimes are just "islands" with their own flora and fauna, and with a much larger and different surrounding landscape. Because of the special properties of limestone parent rock, karst areas in the tropics often have substantial areas of almost bare rock and shallow soils. Chemically, these

soils are dominated by the presence of a high content of calcium and magnesium. These two elements, often present in excess, restrict the availability of other nutrients to plants. This already is in contrast to most tropical soils, which are strongly weathered, low in bases and generally dominated by aluminium and iron oxides.
The climate is an important factor in karst formation. In southeast Asia, the climate has been broadly the same over millions of years (34). High precipitation leads to spectacular and complex karst shapes above ground and large caves underground. These karst shapes, large and small, often create an extreme inhospitable landscape, which are so inaccessible that often they stand as remnants of a natural environment in otherwise different or intensively cultivated agricultural land.
The above-ground edaphic conditions for the flora and fauna on limestone are often harsh and fluctuate substantially. Because of the dominantly underground drainage of karst areas, organisms living on limestone may be subject to periodic or prolonged droughts. The thin and often patchy vegetation cover provides little shade. This is in contrast with the moist and damp conditions in the underground caves. Here, far underground, no sunlight enters and temperature and humidity are almost constant. A complete different ecosystem can exist with exceptional organisms, such as cavefish, giant insects, and others. Endemism for flora and fauna is high in limestone areas, often restricted to only a few sites and entirely to limestone (island endemism). In Vietnam, only two limestone areas are studied and floristic surveys have been carried out (34).

8.1 Flora

In the colonial time the French compiled “Le Flore Générale de l'Indo-Chine (35). Also there exist an illustrated Flora of Vietnam, with a short description in Vietnamese and one summary line in English, both studies are very useful, but not complete (36).
The project Plant Resources of southeast Asia (PROSEA), which includes Vietnam, has almost completed the taxonomic study on about 5000 useful plant species of the region. The study has resulted in a series of more than 20 handbooks, published between 1989 and present (37).
Another study on the “Flora de Cambodia, Laos, et Vietnam “ is presently made by a French Institute (36). This new Flora covers the whole existing flora of the peninsula and is complementary to the PROSEA study and will replace the old publication of “Le Flore Générale de l’Indo-Chine”. It is estimated that the “Flora de Cambodia, Laos et Vietnam” is completed now for about half (36).

Furthermore there exist several studies on parts of the Vietnamese flora. Recently a guide on orchids was published (38) and also a book on “Vietnam Forest Trees” (39) is available. The latter publication gives a short description of the morphology, distribution, ecology, and the use of tree species.
The study and inventarisation of medical plants in Vietnam have attracted much attention and a number of books on this topic have been published.

8.2 Fauna

Like the flora, also Vietnam’s fauna has attracted quite some attention in recent years. Partly, because of the rather extensive list of rare and endangered animals existing in Vietnam, but also because of the gap in knowledge of the southeast Asian tropical forest fauna. The new attention has resulted in e.g. the discovery of two new species of mammals in Vu Quang forest reserve (Ha Tinh province) (40).

The knowledge of the Vietnamese fauna is still incomplete; it can be summarised as follows (41):

Levels group	Geographical spreading	Ecology	Important species	Special subjects
Vertebrates	++	+	+	+
Invertebrates	+/-	-	-	+/-
Insects	+	-	+/-	+/-

With: ++ high level of knowledge, - low level of knowledge.

Most knowledge exists about the larger terrestrial animals and their geographical distribution. Also a bird guide of Vietnam (41) and several taxonomic publications of mammals and other subgroups are available. No guide on mammals of Vietnam seems to exist.
It is known that several forest bird surveys have been made in different parts of the country. Results of some surveys have been published in journals on nature conservation (42). Birds are important in the tropical forest ecology, amongst others in regulating insect population and also in seed distribution.
The Mekong delta is an important habitat for water birds of which several are endemic. This area and other wetlands (e.g., coastal fringe of central north Vietnam) are important areas for migratory birds from the north. A few bird sanctuaries (amongst others for cranes) are located in the Mekong delta (42).

9 Effects of war actions

There are several sources giving account of the destructive methods used during the late Vietnam war and the effects on the vegetation (43, 44, 21). A special report of the Committee of the American Congress on the herbicide use in south Vietnam (44) gives much information on the use of defoliating agents and the effects on the environment. In some publications the war has been called a “forest war”, because most war acts, especially those in final years were directed to destroy the forest vegetation. A comprehensive record is given in the literature study of a group of forestry students of the Wageningen Agricultural University (21). This study is used as main information source.

Because traditional weapons had little effect on the Vietcong guerrillas (anti-person and anti-material weapons), the Americans shifted in the course of the conflict to new methods, often referred to as “ecological warfare”.
The new methods had to destroy the forest resources, which gave the Vietcong cover, and also to destroy the crops on the small farmers’ fields, which were used as food supply. To end this Americans divided the country in different war zones. Annex I, Figures 20 and 21 show the areas where warfare was most intensive.

The ecological methods the Americans have been using are:
- Chemical spraying (toxic gasses, defoliating agents, rain inducing agents)
- Heavy explosive ammunition (grenades and carpet bombs)
- Bulldozers for forest clearing
- Fire inducing weapons

From this list, the use of chemical spraying, especially the defoliating agent “Orange”, is the most known and criticised. Most spraying has been applied in the period 1960 - 1970. The peak in the spraying has been between the years 1967 and 1969. From 1970 on spraying activities decreased rapidly and land clearing by bulldozer increased strongly. It appeared that clearing of forest areas by bulldozer were much more effective than spraying. In a number of cases combinations of methods were applied and sometimes methods followed each other, resulting in completely destroying the vegetation and exposure of bare soil.
Of the locations of spraying, the famous Ho Chi Minh route has been one of the most important targets. This supply route of the Vietcong had its main track north-south on the territories of Laos and Cambodia along the border with Vietnam. There is evidence that spraying and bombing was concentrated along those borders (Annex I, Figures 22 and 23).
Heavy spraying has been applied also in the mangrove forest areas, and at large in areas north of Ho Chi Minh City up to the southern Central Highlands. Figures about the total acreage sprayed are not consistent and vary between 15 and 30% of the total area of south Vietnam; this includes areas sprayed more than once. The quantities of defoliating agents (phytocides) used are more consistent and amount as much as 75 million litres.

Heavy bombing, resulting in craterization, has been done in the northern 5 provinces of south Vietnam, the border areas with Laos and Cambodia (Ho Chi Minh route) and the area north of Ho Chi Minh City, Annex I, figure 22. Seven million tonnes of heavy explosives (about 11 million bombs and 217 million grenades) have resulted in intense craterization of those areas (44). Accounts of heavy bombing with “Daisy Cutters” (15.000 lbs. bombs) report that one such a bomb clears an area as large as a football field and kills nearly all animal live in a radius of 1 km. (45). It is estimated that all this bombing has resulted in an area of about 150.000 ha of craters (an average crater has a diameter of 8 m and a depth of 4 m).

Originally, forest clearing activities were restricted to 100-200 m on both sides of the main north-south roads. From 1968, heavy bulldozers were organised in units of 30 machines and could clear large areas of forest, which were important hiding places of the Vietcong. It is estimated that in the rather short period about 325.000 ha forest has been cleared, excluding those areas of agricultural lands (rubber and other tree crops), which also were destroyed.
The effects of this ecological warfare on man and environment have been far reaching and are extensively dealt with in the mentioned study (21). Especially the effects on the forest vegetation are very difficult to qualify, because of difference of exposure (different vegetation layers), its natural variation, and the very few data of forest inventories from before the war. Also there is a large difference in sensibility of plant species for the various methods and agents used e.g., it was mentioned that *Melaleuca* forest dies already after one herbicide spraying.
The spraying, bombing, and land clearing must have affected the fauna of South Vietnam. A direct effect has been the disturbance and the partial destruction of habitat and ecosystems.
It is also evident, although very difficult to quantify, that spraying must have had an indirect effect on the health and condition of the forest animals.

10 Evaluation

Vietnam has a rich and large variation in physical and biological resources as shown in the many publications. Therefore an evaluation and choice of a most suitable location for a Tropenbos site

is rather difficult, because so many aspects have to be considered. Furthermore, what criteria would be the most decisive in the selection? This evaluation focuses on three factors as the most important; 1) where are the regions with dominant tropical forest; 2) which areas have rich soils or parent material, and; 3) which areas have a high biodiversity.

Forest reserves have been decreasing rapidly in the past decennia (1) and large forested areas have only secondary forest or herbaceous and shrub vegetations, even barren lands and denuded hills are common in Vietnam (28). However, as indicated in Chapter 7, relatively large areas of forest still occur at several locations in the Central Highlands and in the Truong Son mountain range bordering to Laos (Annex I, Figure 16). Both areas are classed as having tropical evergreen seasonal submontane forest, but differences in composition of forest species can be expected, as the latter area has a clear seasonal influence and much lower temperatures in the winter period. This might have contributed to the occurrence of needle-leaved species and others, which do not occur in the forests of the Central Highlands. In the forest areas of the Central Highlands, in particular those at lower elevations, because of its dry season, species of the genera *Dipterocarpus* are found, which do not occur in the northern Vietnam. (Annex I, Figure 15). Moreover in the Central Highlands, a high proportion of forest, of different forest types, occur at relatively short distances. This makes the area more attractive as a study site e.g., an upstream part of a watershed area.
As shown in Annex I, Figure 13, forest areas in northern Vietnam, although still extensive in total extent, are scattered over the region and distributed in small forest patches. Moreover, the composition of the forest species has changed, compared to the central Highlands, to more temperate species, because of the distinctly lower winter temperatures. However, some forest areas at lower elevations might still be of interest e.g., the forest area south of Hanoi of which the national park of Cuc Phuong and reserve are part. This area has forest but also karst areas, and is located in a transition zone between the northern lowlands and the Truong Son mountain range, with moderate winter temperatures; see Annex III, Appendix 4. (N.B. Sources are not consistent on this area; compare Annex I, Fig.13 and Fig.16).

Interpretation and comparison on soils appear difficult, because of lack of information on soil correlation to internationally accepted systems. The Vietnamese legend describes soils in terms of colour, parent material and depth, and not on basis of soil horizons and properties, as is internationally accepted. Only one source (14) contributed to a better understanding of the inherent properties of a number of Vietnamese soils. This report correlated soils, occurring in the Central Highlands and classified according to the Vietnamese legend, to the FAO/Unesco legend. Although the legend of the soil map of northern Vietnam is related to the present Vietnamese legend, several units were not found in this correlation table (14) and one can only guess to what it correlates in the FAO/Unesco legend. Sufficiently detailed soil information to correlate to FAO/Unesco standards is probably lacking for most of northern Vietnam.

A tentative comparison of the soils of the Central Highlands and those of the Truong Son range is made. Both locations have generally very weathered soils and probably no major forest vegetation differences are expected to be attributed to differences in soils as found from the studied maps, see also Annex II, Table 5. This is confirmed by Vidal (22), who states that the most dominant factor for the occurrence of moist, evergreen tropical forest is climate, and to a lesser extent soil.

On the other hand, differences of parent material are observed in the legends describing the soils of the Truong Son range and the Central Highlands. This might contribute to differences in soils not investigated and not expressed in the legend. It is generally expected that differences in parent material have influence on the vegetation e.g., fertility aspects, micro-nutrients, physical soil properties, etc. These factors are expected to be more favourable on the basalt plateaus of the Central Highlands. These soils, derived from basalt and correlated to Ferralsols, are strongly weathered and have sometimes skeletic (very gravelly) or petroplinthic (hard sesquioxide) layers. They are generally preferred for agriculture to those of the strongly weathered soils on sedimentary and (acid) metamorphic rock (Acrisols). For the same reason forest sites on basalt plateaus probably have to be preferred to those on the sedimentary rocks of the Truong Son range.

Special soils and soil conditions are found on the basic parent materials of the karst and limestone areas. Similarly, special conditions occur in very acid soils e.g., peat and acid sulphate soils or saline coastal areas. Such areas have specific forest types as elaborated in Chapters 7 and 8. Also the biodiversity found in these areas has adapted or is tolerant to these specific conditions. Examples are the mangrove forest in the delta areas and the Maleleuca forest on the peat soils (Mekong delta). Both forest types have strongly declined in the last decennia, but are expending again because of successful replanting programmes.
Limestone areas are rather extensive in northern Vietnam as a part of the various mountain ranges. Limestone does not occur in the southern part of the country. This parent material creates specific soil conditions, such as excessive surface drainage, underground rivulets and generally shallow soils with excessive calcium, inducing deficiencies of other nutrients. They support a specific biodiversity with a high endemism, often of species that occur only in few of these karst areas (island endemism). Vegetation is mostly herbaceous with shrub or poor forest vegetation. But exceptions also occur, such as the karst area of Cuc Phuong National Park.
Another aspect of karst areas is that most are difficultly accessible.

Vietnam has a rich biodiversity and the number of endemic species of Vietnam's flora is high. Endemism is not evenly distributed over the country. Generally, a high biodiversity and endemism occur in the mountainous areas of northern Vietnam, the Truong Son range, and in the Central Highlands e.g., Da Lat plateau of southern Vietnam.
Centres of plant diversity are more concentrated in the Central Highlands than in northern Vietnam (1). This study of World Conservation Monitoring Centre (WCMC) mentions the Cuc Phuong National Park as the most northern centre and none is located in the Truong Son mountain range.

A negative aspect of southern Vietnam, including the Central Highlands, is that the many war acts have been concentrated in this region, particularly the area north of Ho Chi Minh City, (Annex I, Figure 20). It is not clear is to what extent flora, fauna, and biodiversity have been affected, as damage can be very site-specific.
Table 3 gives a relative assessment of factors evaluated and summarizes those for 4 main regions.

Table 3 Assessment of different features for a potential Tropenbos site in Vietnam.

Location	Northern	Central	Central South	Mekong

Features		North	& Highlands	Delta
Primary forest	-	+	+	-
Secondary forest	+	++	++	+
Forest fragmentation	++	+	+(+)	+
Logging	+	+	++	+
Shifting cultivation	++	+	++	-
Rich parent material	±	-	+	±
Karst /Calcareous soils	++	+	-	-
Indigenous people	++	±	++	-
Endemic species	++	+	++	+
Endangered species	++	+	++	+
War actions/relicts	-	±	+(+)	+(+)
Final evaluation				

Relative assessment: ++ very high; - low level or absence of feature

11 Summary of possible Tropenbos sites

Northern Vietnam:

1. Cuc Phuong National Park:
    - One of the karst areas of North Vietnam.
    - (Shallow), mostly calcareous soils
    - High proportion lowland forest in the park area (Annex III, Appendix 4).
    - Centre of plant diversity and endemism
    - Short distance (some 100 km) from Hanoi and good access
    - Ethnic minority people live in or close to the park, practising shifting cultivation
    - No war relicts
    - Probably one of the better known and studied parks
    - International involvement of WWF and GEF
    - Area probably representative for lowland karst, but less so for the surrounding non-karst areas.
    - Social forestry development project (GTZ-funded) in neighbouring provinces (Song Da watershed).

Central north Vietnam:

2. Truong Son mountain range e.g., Vu Quang nature reserve:
    - Extensive, lowland and montane rainforest (partly primary)
    - Representative for a large part of the Truong Son mountain range
    - Occurrence of needle-leaved species
    - Very humid climate, cool in winter (mean 5-10 ºC coolest month)
    - Shallow soils with high organic matter content on acid metamorphic and sedimentary rock.
    - Occurrence of endangered animal species
    - Accessibility probably difficult, mountainous, few roads in the area
    - No war relicts
    - The SNV-Foundation is (or was) involved in the maintenance of the Vu Quang nature reserve.

Central south Vietnam: Central Highlands

3. Nam Bai Cat Tien National Park
    - Extensive lowland monsoon forest (dominantly secondary)
    - Occurrence of areas with lowland rainforest in the surroundings (watershed Dong Nai river)
    - Representative for the southern part of the Central Highlands
    - Tropical monsoon climate, dry season from November to April
    - Basaltic and granite parent material (eroded basalt plateau).
    - Strongly weathered Ferralsols and Acrisols, with sesquioxide layers.
    - Centre of plant diversity and endemism
    - Occurrence of endangered animal and plant species

- Good accessibility (some 120 km from Ho Chi Minh City)
- Ethnic minority people living in the park, shifting cultivation and cashew nut planting (33)
- Very heavily defoliant spraying during the war
- Technical and financial support WWF (Netherlands government and other donor agencies).

4. Yok Don nature reserve:
    - Open forest vegetation with grass undergrowth (savannah) influenced by fire
    - Closed forest along the rivers
    - Tropical monsoon climate with distinct dry season between October and April
    - Parent material mainly Jurassic sandstone and claystone
    - Soils dominantly Lixisols/Luvisols and soils with abrupt textural change (Planosols)
    - Centre of plant and animal diversity
    - Ethnic minority groups in the part, shifting cultivation and resin collection.
    - Probably war act, particularly bombing
    - Technical support of WWF
    - Good access to reserve, (still?) poor access in reserve

Mekong delta

5. Ca Mau Peninsula:
    - Mangrove and *Melaleuca* forest
    - Brackish tidal areas and small area of very acid peat formation with *Melaleuca*
    - Vegetation strongly damaged during the war (defoliation) and subsequently dying of large forest areas
    - Replanting programmes for mangrove and *Melaleuca* forests successful
    - Dynamic landscape with coastal erosion and sedimentation
    - Specific biodiversity coastal area
    - Supported by IUCN and other donor agencies (Netherlands government)
    - Reasonable access

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(11) Soils map of North Vietnam, 1979, Hanoi; scale 1:500.000. Legend according to Vietnamese soil classification, non-officially translated from Vietnamese. Mixed geo-pedogenetic soil legend, based on Russian classification system. Correlation to FAO/Unesco legend of the Soil Map of the World is very difficult, because of its quantitative description and lack of criteria. Tentatively a correlation is given at Soil Group level. (Annex II, Table 2). The letter code between brackets, given in the text, refers to the unit in the Vietnamese legend. In Vietnam there exist a national soils map at scale 1:1.000.000, (1998?), with a correlation to FAO/Unesco soil legend (pers. comm., email message). Unfortunately it was not possible to dispose of this map (it is obtainable in Hanoi). Therefore, use has been made of the mentioned older studies.

(12) General soil map of South Vietnam, scale 1:1 million, (Moormann, 1961). Legend still based on geomorphology of soils, old (American) classification system

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(24) Land use map and vegetation maps available at ISRIC (1982, scale 1:1 million) gives also background information. Due to the rapidly changing circumstances, this information is not up to date any more. Deforestation in the last 25 years has advanced at a high rate and the map shows a too high cover of forest land, as compared to Figure 16.
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