Vietnam has been under foreign domination for a long time. The Chinese occupied the country for ten centuries, and in 1862 Cochin-China became a French colony with the rest of Vietnam following in 1883. In 1943, with French permission, the Japanese came, to be followed again by the French in 1946 until 1954, at which time a partition of the country at 17°N was effected following a Geneva conference. American military advisers arrived in 1955, leading to a military build-up which climaxed between 1967 and 1969. These events, together with the strife before and after, mean that the country has been in a state of occupation or war for about 2000 years. Therefore it should come as no surprise that the Vietnamese army numbers amongst the four largest in the world and that a very strong sense of nationalism co-exists alongside economic chaos.

The reaction of many New Zealand foresters on learning that one of their kind has been working in Vietnam is to inquire about war damage to forests, in particular herbicide damage. The area where much of my time was spent largely escaped war damage. The Chinese incursions during the 1980 period did not reach that far south, while bombing during the American period did not extend that far north for fear of provoking an incident with the Chinese. However, I was fortunate enough to make several visits to the south and see some of the damaged areas and efforts to replace the forests. Quantitative data on the effects of war on the forests is difficult to find. Partly, this is because so little is known of the forest situation before 1960 and also because no full forest inventory has been carried out since.

In 1972, the University of Wageningen in The Netherlands commenced a study on the restoration of war-damaged forests in South Vietnam as a way of assisting recovery and rebuilding of Science and Technology in Vietnam. This study drew mostly from published work, much of it carried out by the National Academy of Sciences by direction of the American Congress. Much of the information in this article is drawn from the University of Wageningen report.

What I have attempted to do here is to describe some of the methods used to deny the Viet Cong the use of the forests, effects of these methods on the forests and recent attempts to replace the forests destroyed. Figures given in tables relate to South Vietnam as it existed before re-unification, i.e. south of 17°N.

Situation before the war
According to FAO, in 1955 about one-third of the country was covered by forests of economic importance which were classified into four types (Table 1).

<table>
<thead>
<tr>
<th>Type</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mangrove</td>
<td>280,000</td>
</tr>
<tr>
<td>Melaleuca</td>
<td>200,000</td>
</tr>
<tr>
<td>Dense forest and woodland</td>
<td>4,275,000</td>
</tr>
<tr>
<td>Pine forest</td>
<td>120,000</td>
</tr>
</tbody>
</table>

At this time, 44% was considered damaged or depleted and of the remaining 56%, half was inaccessible. Thus only 1,400,000 ha was both economically accessible and in a good state. Some plantation development on a small scale had been started by the French.

War actions
In the early sixties, with overt intervention by the Americans, war strategy changed from conventional war involving anti-personnel and anti-material weapons which had proven largely ineffective, to include techniques causing environmental destruction through the use of anti-plant weapons. By these means the Viet Cong were to be deprived of cover, sanctuary and food. Control of the population was facilitated by strategic hamlets and refugee camps. The most frequently used new weapons and techniques were:
- chemicals (toxic gases, defoliants and rain-inducing agents)
- high explosive munitions
- bulldozing
- incendiary weapons

During the war, South Vietnam was divided into four Military Regions, each having "War Zones" and "Free Fire Zones". Heaviest action occurred in war zones 1 and 111. Chemicals used included anti-personnel toxic gases, soil sterilants, herbicides and cloud-seeding agents. Since the major part of the programme involved the use of herbicides, most of the discussion here relates to these. Military application was aimed at defoliation to improve observation and, to a much smaller extent, crop destruction. Agent Orange was most often

One-year-old Eucalyptus camaldulensis on disced mounds, Da Nang.
used, representing about two-thirds of the total volume sprayed with applications of around 28 litres per hectare. Most of the applications (95%) were from low-flying C-123 aircraft. Military use started in 1962, continuing until 1971. From 1970, the use of herbicides was rapidly phased out because of the clear superiority of the land-clearing programme, worldwide criticism of the herbicide programme and general winding down of US involvement in the war. Data based on a study of herbicide expenditures researched by the Committee on the Effects of Herbicides in South Vietnam are shown in Table 2.

Between 1961 and 1973 a large number of high explosive munitions were thrown on Indochina from air and ground: roughly 50% by each means. From 1965 to 1973, 14,265 million kg were used and 10,176 million kg of this were used in South Vietnam. The major focus was the demilitarised zone, north of Saigon and the Ho Chi Minh trail.

Systematic land-clearing using D-7E Caterpillar tractors, armoured and equipped with shear blades or Rome ploughs, was introduced in 1965. Initially these were used to clear strips 100 to 200m wide each side of important communication lines. By mid 1968, organisation of machines into companies of about 30 machines for extensive forest clearing started. It became apparent that this means of area denial to the guerillas was in some ways superior to herbicide spraying. It has been estimated some 325,000 ha of forest (2% of South Vietnam) were cleared. The iron triangle north and north-west of Saigon in Military Region 111 was the heaviest concentration of this work. Attempts were also made in some areas to burn the defoliated forest but most attempts failed because of the high humidity.

### Effects on forests

Most strongly hit were the moist evergreen forests in the northern part of South Vietnam, the most semi-deciduous forests and the dry deciduous forests north and north-west of Saigon. About 1.1 million ha of inland forest were sprayed once or more. Of this, about 60% was located in Military Region 111. Spraying effects were dependent on vegetation type, number of sprayings, interval between sprayings, agent used, weather conditions and season.

The moist evergreen forests, moist semi-deciduous forests and montane forest are multi-storeyed, uneven-aged and often very rich in species – on average 100 to 150 different species/ha. After one spraying, all species drop their leaves within two to three weeks.

Resistant and partly attacked species will sprout again at the start of the wet season. Sensitive non-protected species in the canopy and upper stratum are killed. Generally, application of herbicides has resulted in relatively large gaps in the canopy and stimulation of growth in non-attacked and resistant species. The most sensitive species in the canopy and upper stratum are: Anisoptera spp., Lagerstroemia spp., Panussia cochinensis, Parinium sp. and Pterocarpus pedatus. Less sensitive are: Dipterocarpus alatus, Hopea odorata and Shorea cohinchinensis. Among the most resistant are Cassia siamea and Sandoricum indicum. The improved light conditions after spraying and the higher degree of resistance of monocotyledons to the commonly used herbicides Agents Orange and White favoured the release and dispersal of bamboo. Table 3 taken from the University of Wageningen study shows the estimated mortality of trees after one or more sprayings in dense forest.

#### TABLE 2: Herbicide spraying in South Vietnam from 1961 to 1971. All areas in ha x 10^3

<table>
<thead>
<tr>
<th></th>
<th>South Vietnam</th>
<th>Inland Forests</th>
<th>Mangrove</th>
<th>Cultivated Land</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Surface area (ha.)</td>
<td>17,429</td>
<td>10,400</td>
<td>288</td>
<td>3,120</td>
<td>3,626</td>
</tr>
<tr>
<td>B. Total sprayed area</td>
<td>1,446</td>
<td>1,078</td>
<td>105</td>
<td>106</td>
<td>157</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of sprayings</th>
<th>Area %</th>
<th>Area %</th>
<th>Area %</th>
<th>Area %</th>
<th>Area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>955</td>
<td>66</td>
<td>693</td>
<td>64</td>
<td>58</td>
</tr>
<tr>
<td>2</td>
<td>324</td>
<td>22</td>
<td>251</td>
<td>24</td>
<td>27</td>
</tr>
<tr>
<td>3</td>
<td>115</td>
<td>8</td>
<td>90</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>4 or more</td>
<td>50</td>
<td>4</td>
<td>44</td>
<td>4</td>
<td>8</td>
</tr>
</tbody>
</table>

#### TABLE 3: Spray effects on dense forest

<table>
<thead>
<tr>
<th>No. of sprayings</th>
<th>% of total sprayed area</th>
<th>% of trees killed outright</th>
</tr>
</thead>
<tbody>
<tr>
<td>one</td>
<td>66</td>
<td>10</td>
</tr>
<tr>
<td>two</td>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td>three</td>
<td>8</td>
<td>50</td>
</tr>
<tr>
<td>four or more</td>
<td>4</td>
<td>85-100</td>
</tr>
</tbody>
</table>

It was assumed by the Committee on the Effects of Herbicides that these closed forest types, after spraying once or twice, would restore themselves if sufficient regeneration was present. Three, four, or more sprayings favoured the extension of bamboo and Gramineae. The hallier and thicket forest types consist of fast-growing, short-lived species which proved highly sensitive to herbicide spraying. Spraying of bamboo forest, while causing dieback of above-ground parts, had a very short-term effect because of sprouting. In these types, herbicide spraying probably lead to an extension of the bamboo area.

The dry deciduous forests and open forest formations have a simple open structure with one or two tree storeys and after herbicide attack large gaps are formed which permit light to reach the forest floor more easily than in the more complex, multi-storeyed forests.

Damage from munitions exploding...
includes direct destruction from the blast
and from shrapnel directly severing the
tree, or indirectly by causing wounds
allowing fungi entry. Dipterocarpus
spp., Anisoptera spp. and Hevea brasili-
tensis are particularly susceptible to the
latter form of destruction while Hopea
spp. and Lagerstroemia spp. are more
resistant. Many estimates of numbers of
trees destroyed by bombing and shelling
have been made. They vary so widely
that it makes little sense to present them
all here. For interest's sake, one table
prepared by Odum (1974) and included
in the Wageningen report is shown
below and estimates the area cleared by
bombs on the assumption that one 500lb
bomb clears an area of 730m².

<table>
<thead>
<tr>
<th>Landuse Land surface in %</th>
<th>0.0%</th>
<th>17.23%</th>
<th>58.80%</th>
<th>1.60%</th>
<th>22.31%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>Total bombs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965</td>
<td>0.96 x 10⁶</td>
<td>0.5</td>
<td>120</td>
<td>400</td>
<td>10</td>
</tr>
<tr>
<td>1966</td>
<td>1.5 x 10⁶</td>
<td>1.0</td>
<td>190</td>
<td>670</td>
<td>20</td>
</tr>
<tr>
<td>1967</td>
<td>2.8 x 10⁶</td>
<td>1.3</td>
<td>360</td>
<td>1,610</td>
<td>30</td>
</tr>
<tr>
<td>1968</td>
<td>4.3 x 10⁶</td>
<td>1.9</td>
<td>540</td>
<td>1,860</td>
<td>50</td>
</tr>
<tr>
<td>1969</td>
<td>4.2 x 10⁶</td>
<td>1.8</td>
<td>530</td>
<td>1,780</td>
<td>50</td>
</tr>
<tr>
<td>1970</td>
<td>2.9 x 10⁶</td>
<td>1.3</td>
<td>370</td>
<td>1,250</td>
<td>30</td>
</tr>
<tr>
<td>Totals</td>
<td>1965-70</td>
<td>16.9 x 10⁶</td>
<td>7.8</td>
<td>2110</td>
<td>7170</td>
</tr>
</tbody>
</table>

Estimates of economic loss by herbi-
cide spraying also vary widely and in
many cases the distinction between mer-
chantable and non-merchantable is
unclear. The average estimate appears
to be about 15 million m², including both
merchantable and non-merchantable
classes. No figures for timber loss due to
land clearing could be found. No doubt
there exists a large element of double
counting in some of these figures as
many areas have been bombed, shelled,
sprayed and land cleared.

Restoration

Because the number of sites visited was
limited and facts are hard to find, some
examples only of the plantation pro-
grammes are included here. With a
bountiful supply of labour and a great
deal of commitment, much has been
accomplished. With the advent of the
opening of a eucalypt chipwood export
market to Japan, interest in establishing
plantations is high, particularly in the
south.

1. Mangrove forests

Duyen Hai District lies adjacent to and
south of Ho Chi Minh city. Being so
close to the then Port of Saigon and lying
across the shipping routes, it was a
favoured sanctuary for the Viet Cong

and was aerially sprayed until the man-
grove forests were totally destroyed.
Between 1978 and 1981 the entire 22,000
ha area was replanted in Rhizophora
apiculata using seed collected from the
Minh Hai mangrove area further south.
This was direct seeded into the mudflats
at an intensity of 10,000 seeds to the ha.
Form pruning and thinning are carried out
to produce charcoal wood. 15 to 20
year rotations are anticipated with yields
of construction wood as well as charcoal.
Form and growth rates appear reason-
able and the overall result very
impressive. These areas are now being
transferred over to Agricultural Enter-
prises for developing into combined
shrimp farming and forest ventures.

TABLE 4: Vegetation cleared off by bombs (in 100ha), year by year for different
land use categories (after Odum, 1974)

<table>
<thead>
<tr>
<th>Landuse</th>
<th>City land</th>
<th>Agricultural land</th>
<th>Forest land</th>
<th>Mangrove</th>
<th>Rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
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<td>7.8</td>
<td>2110</td>
<td>7170</td>
</tr>
</tbody>
</table>

North west of Ho Chi Minh city can be
found the sulphated acid soils in Hoc Mon
and Binh Chamh Districts. These are
perpetually wet organic soils supporting
a mass of Junceus spp. on some sites and
Melaleuca forest on others. Many of
these areas form part of the new eco-

2. Grey sand soils

Much of the area immediately north of
Ho Chi Minh city consists of plain topo-
ography of alluvial grey sands. The top
soil is very compacted, but further down
the profile clay content increases and the
soil is more friable. Some of the most
intense fighting of the war occurred in
these areas and in places it is rather remi-

3. Sulphate acid soils

North west of Ho Chi Minh city can be
found the sulphated acid soils in Hoc Mon
and Binh Chamh Districts. These are
perpetually wet organic soils supporting
a mass of Junceus spp. on some sites and
Melaleuca forest on others. Many of
these areas form part of the new eco-

4. Dipterocarp plantations

Ma Da Enterprise is located north-east of
the Ben Toa airbase and still retains
most of its area under dipterocarp forest.
Logging is a major activity, utilising old American equipment. Tectona grandis, E. camaldulensis, A. mangium and A. auriculaeformis are grown. The fast-growing introduced hardwoods are looked upon as a means of providing short-term cash flow via the fuelwood and pulpwod markets. Most enthusiasm is reserved for Dip terocarpus alatus and Hopea odorata which they are attempting to re-establish following clear cutting by interplanting nursery-raised stock into a cover crop of A. auriculaeformis which is progressively removed. The oldest such plantation seen dated back to 1982 with the dip terocarp varying between 2 and 6m in height beneath a scattered canopy of Acacia 15m high. A leguminous crop of Indigofera teysmannii is also being tried in association with the above species. 60-year rotations for the dip terocarp sawlings are envisaged.

At the adjacent Hieu Liem Enterprise, capitalist experimentation with various types of joint ventures between the workers and the Enterprise management is being successfully tried. The annual planting rate is about 800ha. Individual workers retain ownership of the trees they have planted, with some returns paid back to the Enterprise in proportion to the inputs the Enterprise has supplied. Mixtures have been freely experimented with, as there is a high degree of consciousness of the need for long-term soil improvement. A mixture of 10 rows of eucalypt for pulpwod to one row of acacia was said to be best. Because of the shortage of State funds with which to finance forest investment, the joint ventures are being watched with a great deal of interest for possible application elsewhere. Also of interest is the pond full of crocodiles at the headquarters - a gift from Fidel Castro. The progeny of these must have found their way to Ho Chi Minh city, as the swim ming pool at the Forest Research Institute was also occupied by these beasts. The significance of such gifts goes cause to wonder.

5. Pine forests

In the highlights above 700m a s.l. Pinus kesiya is managed as natural stands and as plantations. In the Da Lat area, 110,000ha of this species can be found. Protected from fire and shifting cultivation are the main problems reducing the success of re-establishment. Natural regeneration is good in most places and some very successful plantations were seen. On the low-lying country close to the coast from Da Nang in the south up to Ninh Binh in the north, Pinus merkusi is commonly grown. On an area basis, this species, together with E. camaldulensis, would seem to be the most commonly planted species at present in Vietnam. The P. merkusi is much troubled by fire, insects (notably defoliators and shoot borers) and weeds. The overall impression is that the success rate with this species is very low and from a timber-growing point of view one wonders why they simply don't give up and try something else less plagued with troubles. However, the timber aspect is very much secondary in their minds, as most of the value with this crop lies in the resin for which a valuable export market exists. After age 15 years bleeding can commence. Other species of interest in this area are Casuarina equisetifolia used for dune fixation and extensive early plantations of E. exserta widely planted before imported seed became more readily available.

International assistance in forestry

One cannot help but be impressed by the huge labour input applied to the plantation programmes. Much of this work is carried out by single women who keenly feel the war legacy of shortages of husband material, so necessary in this poor society where the family unit is the cornerstone to economic security. While much has been and is being achieved, other impressions are that a much greater degree of success would be possible if protection problems were overcome and planting programmes were based on better technical and economic bases. There is a great need for improved seed, more work into species and provenance selection and indeed establishment generally. The good work started by the French fell to a low level on their departure, due to a lack of finance and capable substitutes.

After reunification, support was given by the Swedes in the north to a plantation project associated with a paper mill. Russia and some east-European countries have assisted with local and overseas training and indirectly through material assistance. A series of U.N.D.P. projects, often of a short-term nature, are a continuing feature. These usually rely on local Chief Technical Advisers who oversee a number of projects and are supported by a steady stream of short-term specialist consultants. Food support through the U.N.D.P. has also been invaluable in recent years to parts of central and northern Vietnam to alleviate famine and provide the quid pro quo for enlarged planting programmes which the State finds difficult to finance.

More recent arrivals to the forestry scene are the Australians, working through non-governmental organisations until the Kampuchea problem is resolved. They are located north-east of Ho Chi Minh city in the District where their army contingent was once based. The French are returning again, probably to Da Lat, and the Japanese are said to be investing in eucalypt plantations in the south.

References

"Restoration of war-damaged forests in South Vietnam" (1978). Published by the University of Wageningen, Netherlands. Volumes 1 and 11.