The net utilizable merchantable volume per tree for each size class was based upon the utilization study made in the mills, log yards, and landings in SVN. Tree length logs and tree log multiples were measured and evaluated. Volumes calculated are for actual delivered logs. Individual log volumes were computed using the Hoppus log rule. Log volumes determined through the use of log rules differ from those derived from tree volumes computed for general forest inventory purposes essentially in that the former provide for a reduction in volume to account for those portions of the log that are lost in the conversion process and become mill residues.

In interpreting these inventory estimates it should be clearly understood that market value is based on the log scale and not on standing volume. The solid volume of wood standing in the forest is only a starting figure. The basis for sale is an estimate of actual volume of square sawn lumber that can be produced from the round logs. Log rules are used to make this estimate. The Hoppus rule, which was used to determine merchantable volumes in the utilization study, is commonly used in SVN and neighboring countries. In this study a total of 1154 logs from sixteen of the most commonly used species were evaluated. For each log taper, dbh and Hoppus volume were estimated. The following equations denote the method by which each was determined.

Calculation of dbh:

$$\text{Taper} = \frac{\text{large end diameter (cm) - small end diameter (cm)}}{\text{log length (m)}}$$

$$\text{dbh (cm)} = \text{large end diameter (cm)} - (0.5)(\text{Taper})$$

Calculation of volumes:

$$\text{Volume (Hoppus ft}^3) = \frac{1}{144}\left(\frac{C}{4}\right)^2 L \qquad \text{English system}^a$$

where

C = circumference at mid-length in inches

L = length in feet

The logs were assumed to be cut a stump height of 1.0 m (3.3 ft) and the dbh was taken to be at a height of 1.5 m (4.9 ft). Table IV B-3 summarizes the data on log scale by quality class from the utilization study. In SVN as in other areas of Southeast Asia, woods are marketed according to classes that reflect their value and utility. The classes used in this study and the species allocation to class are according to McKinley (1954) as follows.

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[a] The actual calculations were done using the metric equivalents.

Class A. Luxury Woods: Woods in popular demand because of the unusual contrast of color in venation, distinctive fiber arrangement, beautiful figuration, pleasing aroma, hardness, and adaptability to the arts, and above all the familiarity of the trade with the wood.

Class I: Woods characterized by great resistance to insects and borers (carpenter ants, termites, beetles) and to decay, by high density, strength, and toughness. Most of these woods are used for durable construction.

Class II: Woods utilized particularly in protected construction work because of their low decay resistance and for ordinary cabinet work; hard, medium heavy; cheaper than Class I and Luxury woods.

Class III: All woods called "white," soft and rather light. These woods are used in making packing cases, framing, and light temporary construction. Low resistance to insects and decay.

Table IV B-3 summarizes the results of the utilization study. The distribution of merchantable trees in the inland forests of SVN could not be determined in the field. For the purpose of inventory estimate it was assumed that the quality class distributon was similar to that in the forests of Cambodia east of the Mekong. The classification used by Rollet in the Cambodian inventory categorizes several important species one class higher than the classification reported by McKinley and used in the SVN market. For example, Lagerstroemia, one of the most common species in SVN, is listed as a Class I wood in Cambodia and as a Class II wood in SVN. Pahudia cochinchinensis is listed as a Luxury wood in Cambodia and a Class I wood in SVN. A number of other woods are listed in one higher class in Cambodia than in SVN. Accordingly, the use of Cambodian classifications for distribution purposes may result in a somewhat inflated merchantable inventory figure. Based upon the Cambodian inventory, it was assumed for the purposes of developing a SVN inventory that 69 percent of the small trees, 77 percent of the medium sized trees, and 66 percent of the large trees were of merchantable species.

Table IV B-4 gives the data from the photographic samples which formed the basis for the calculation of a pre-spray inventory of MR III. On the basis of these computations the estimated merchantable volume for the region was 16 million cubic meters. Table IV B-4 gives the inventory values for each micro-type. MR III includes 20 percent of the merchantable forest of SVN. Assuming that the forest structural composition for MR I and MR II is similar to that of MR III, an estimate of the merchantable forest inventory of the whole of SVN would be 82 million m^3. It should be noted that this merchantable volume inventory figure does not include the mangrove forests and the Melaleuca woodlands nor does it include the pine forests. These excluded forest types represent approximately four percent of the forest area of SVN.

Table IV B-3

Log Volume Data From Utilization Study

Class	No. of Logs	Percent of Total Logs	Average dbh (cm)	Average Vol. (m^3)	Percent of Total Volume
Luxury	154	13.3	48.7	0.77	5.9
I	253	21.9	71.6	2.06	25.8
II	707	61.3	65.2	1.83	64.0
III	40	3.5	79.1	2.21	4.3
Total	1154	100.0	(64.9)	(1.75)	100.0

Table IV B-4

Basic Data from Photographic Samples for Inventory Computations

Micro-Type	% of area in type	No. of merch. size trees per ha	No. of merch. size trees of merch. species per ha	Estimated merch. vol. m^3 Hoppus	Estimated vol. per ha m^3 Hoppus	Mean tree vol. in samples ha m^3 Hoppus
Closed Forest without substantial brush						
2	24.4	7.02	4.92	23,643,700	9.33	1.90
3	22.4	10.80	7.63	35,496,400	15,25	2.00
5	2.6	14.20	10.21	7,464,860	27.63	2.71
Open Forest						
4	0.7	6.80	4.72	600,311	8.25	1.75
Bamboo Forest and Forest with substantial brush						
1	5.2	1.20	0.83	782,685	1.45	1.75
2_1	10.2	3.89	2.70	4,958,020	4.68	1.73
3_1	10.3	4.05	2.81	5,259,380	4.91	1.75
4_1	0.8	3.47	2.42	365,426	4.40	1.82
4_2	2.3	2.99	2.10	959,984	4.02	1.91
Non-Forest						
6	10.9	1.58	1.09	2,063,010	1.82	1.67
7	6.9	0.07	.05	55,835	0.08	1.60
8	3.3	0.20	.14	77,590	0.23	1.64
Summary of Type Classes						
Closed Forest	49.4	9.11	6.43	66,604,960	12.98	1.99
Open Forest	0.7	6.80	4.72	600,311	8.25	1.75
Bamboo & Brush	28.8	3.38	2.35	12,325,495	4.12	1.76
Non-Forest	21.1	.87	.60	2,196,435	1.00	1.64
TOTAL ALL TYPE CLASSES	100.0	5.70	4.01	81,727,201	7.87	1.85

In interpreting this merchantable volume inventory estimate it may be useful to note what others have said about the useful volume of timber in this and comparable forest areas. In discussing the abundant lowland forests of SVN Rollet (1962a) suggests an exploitable volume of 8 to 13 m^3/ha "under actual exploitation practices and conditions." In the description of the inventory of Cambodia east of the Mekong, Rollet (1962b) says "it must be considered that a dense forest is very rich when it yields 15 meters cubed per hectare of currently commercial timber." Data from the inventory of the forests of Northeast Thailand give average merchantable volumes of about 17 m^3/ha.

This merchantable volume inventory estimate is greatly different from the average per hectare estimate of the merchantable volume of the inland forest affected by spraying that was used by Flamm (1970) and Westing (1971). It is appropriate to ask how one estimate of merchantable volume can be as high as 100 m^3/ha and others for the same and similiar forest areas can be in the range of 8 to 15. The answer to this question involves three main considerations: (1) the average composition of forest types in the region in question, (2) the mix of forest types in the region, and (3) the basis for determining appropriate standards of merchantability.

Concerning the first consideration, in the case of the inland forests of SVN, there are undoubtedly areas in which the total tree stem volume is 100 m^3 or larger, but the merchantability standards currently used in SVN reduce the merchantable volume even of these high volume areas to a very much lower figure.

As regards the second of the above three considerations, the inland forest area of SVN including the approximately 1,000,000 ha that were sprayed with herbicide contained little of this quality of forest and a very large proportion of forest remnants scattered widely within a mosaic of swidden agriculture clearings and young regrowth and brush. Even the dense secondary forests contain gaps, bamboo patches, and marshy areas. Figs. IV B-10 through B-14, representing the macro-types used in this analysis, provide an indication of this mixture of different forest quality. Hence, even though the most dense areas do in places carry high volumes per hectare, these high figures have to be averaged with very low figures from many other areas in obtaining the grand means to apply to extensive tracts. This important fact is by no means unique to the SVN forests but it is basic to all large-scale forest inventories. It does not, however, strike the eye of an observer in a helicopter who may see areas of heavy timber but may not mentally average these with the less dense and the vacant patches encompassed within the area designated on a map as forest.

The third consideration is the appropriate standard of merchantability. For example, if fuelwood were included in the merchantable wood category the inventory would be very much larger as will be shown in the discussion of the non-merchantable timber inventory. Since most of the biomass of the trees in a forest is potentially useful as fuel such inclusion could in principle increase the inventory on some specific areas by a factor of perhaps five to ten. This could come about in a number of ways. For example, when trees are cut for sawlogs and veneer logs, the logging residue (the remainder of the woody stem and crown) could presumably be cut up and used for fuel. Trees not useful for lumber or plywood because they are of unacceptable species or unacceptable quality could presumably be harvested and cut up for fuel. In point of fact this level of utilization is rarely achieved even in those parts of the world where wood for all uses is in very short supply. It is never even remotely approached in the forests of SVN where the supply of wood for all but the most highly specialized current uses is abundant while the supply for fuel, in the forest, far exceeds requirements.

It should be noted, too, that the merchantable inventory for a specific forest area can be immediately increased if merchantability standards are changed to permit use of currently non-merchantable species, smaller trees, larger portions of the presently merchantable trees, and more defective specimens of presently merchantable species. Thus, the existence of pulp mills, fiberboard or particle board plants might change utilization standards dramatically. This is, of course, a situation that prevails in many tropical countries. A meaningful merchantable inventory, however, can be based only upon wood utilization facilities that are actually available.

Kinds of Impact and Effects

Like extensive forests in any part of the world, those in SVN are composed of many stands of different age, size, structure, and species composition. The kind and amount of damage caused by any disturbance depends on these stand characteristics as well as the kind and amount of the disturbance. As explained at the outset of this chapter, effects of forest disturbance can be considered in the categories of loss of merchantable volume, loss of growth, and loss of growing stock (plus loss of seed source), and our principal, quantitative effort was directed at determining the first category.

Merchantable volume is the amount of timber of such species and size as is saleable in the current market. Precise specifications and measurement standards are described later. This volume is in the bole[a] of the larger trees which due to their greater height often form a canopy over smaller trees. When dense native stands are cleared for agriculture or selectively harvested for timber, the remaining

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[a] The bole is that portion of the tree stem that lies between the top of the stump and the first branch.

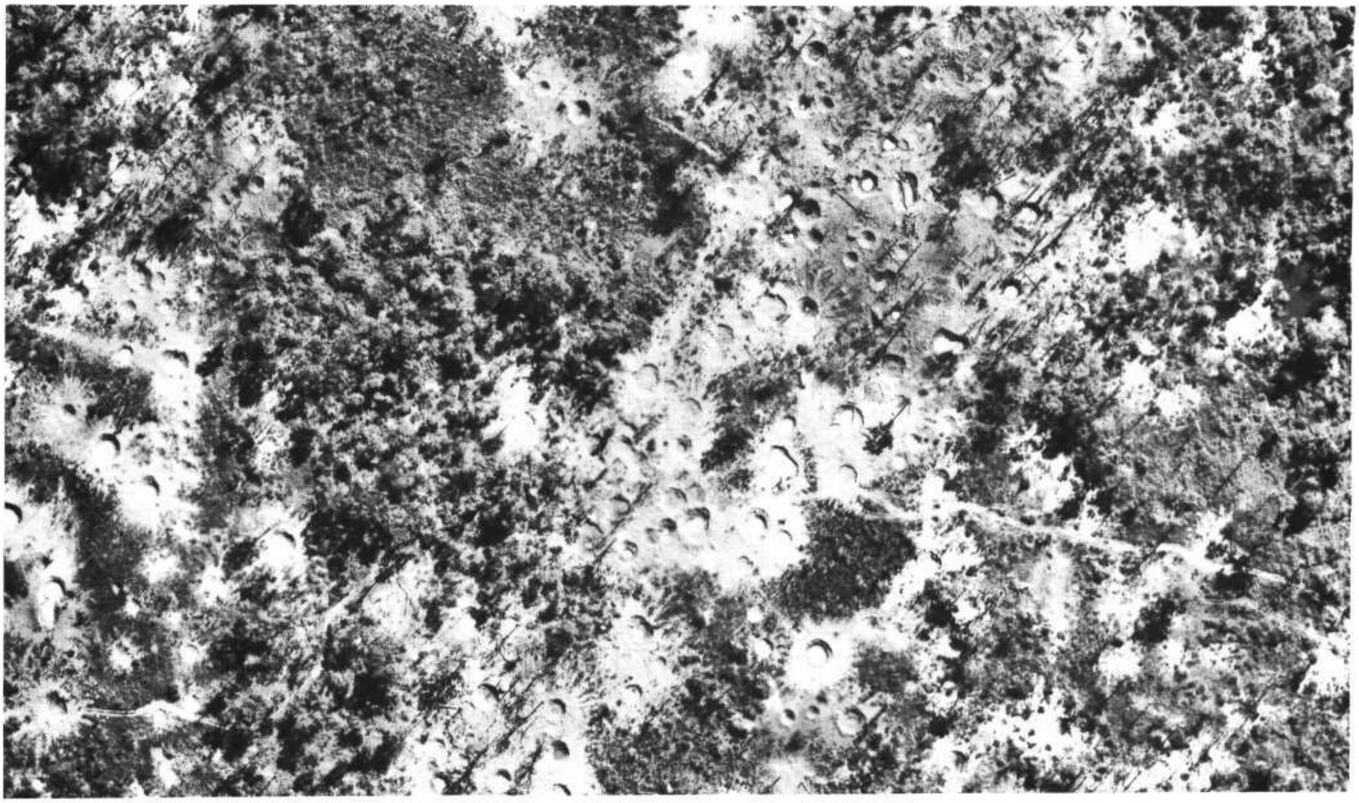

Fig. IV B-18. An example of heavy bomb strikes. Photo taken in 1972 at a scale of 1:2,000.

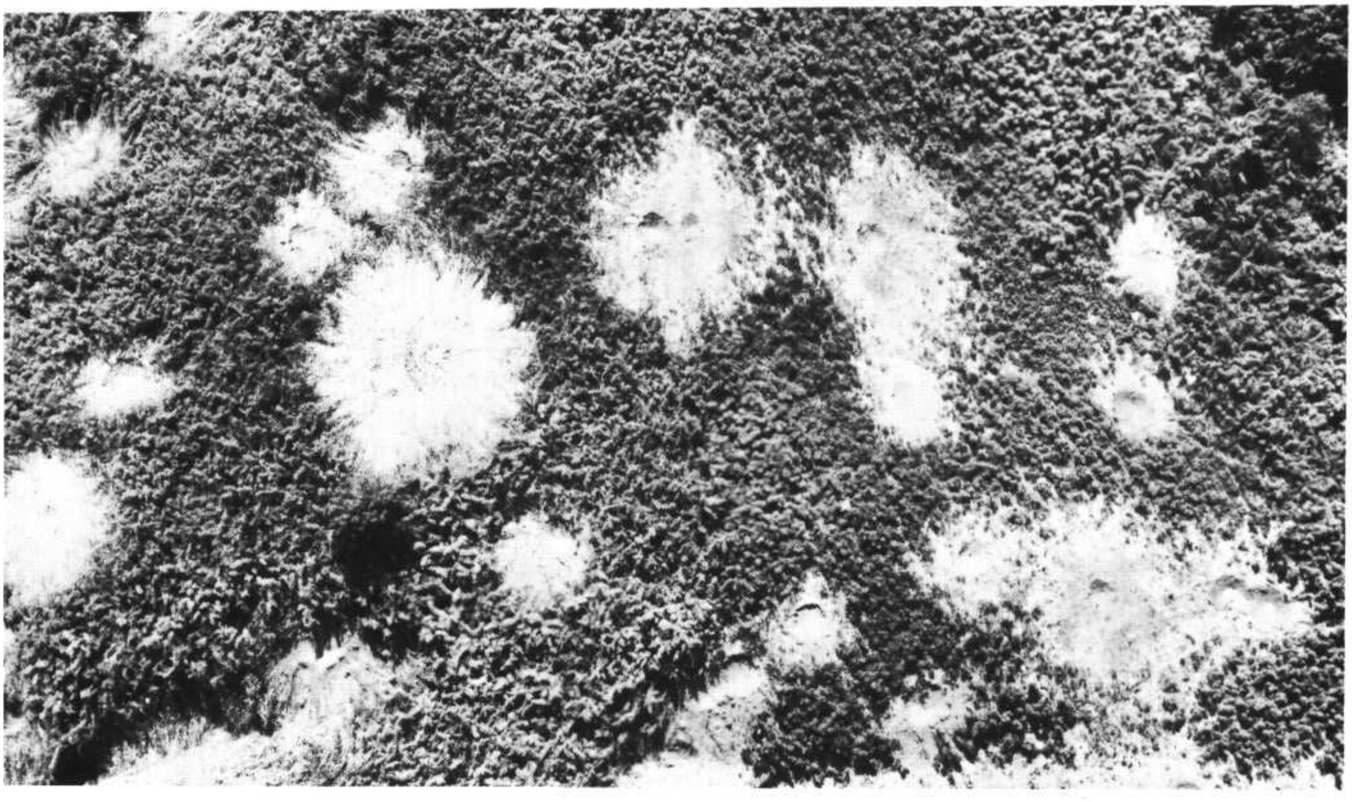

Fig. IV B-19. Recent bombing of secondary forest showing areas cleared of all forest vegetation. Photo taken in 1972 at a scale of 1:2,000.

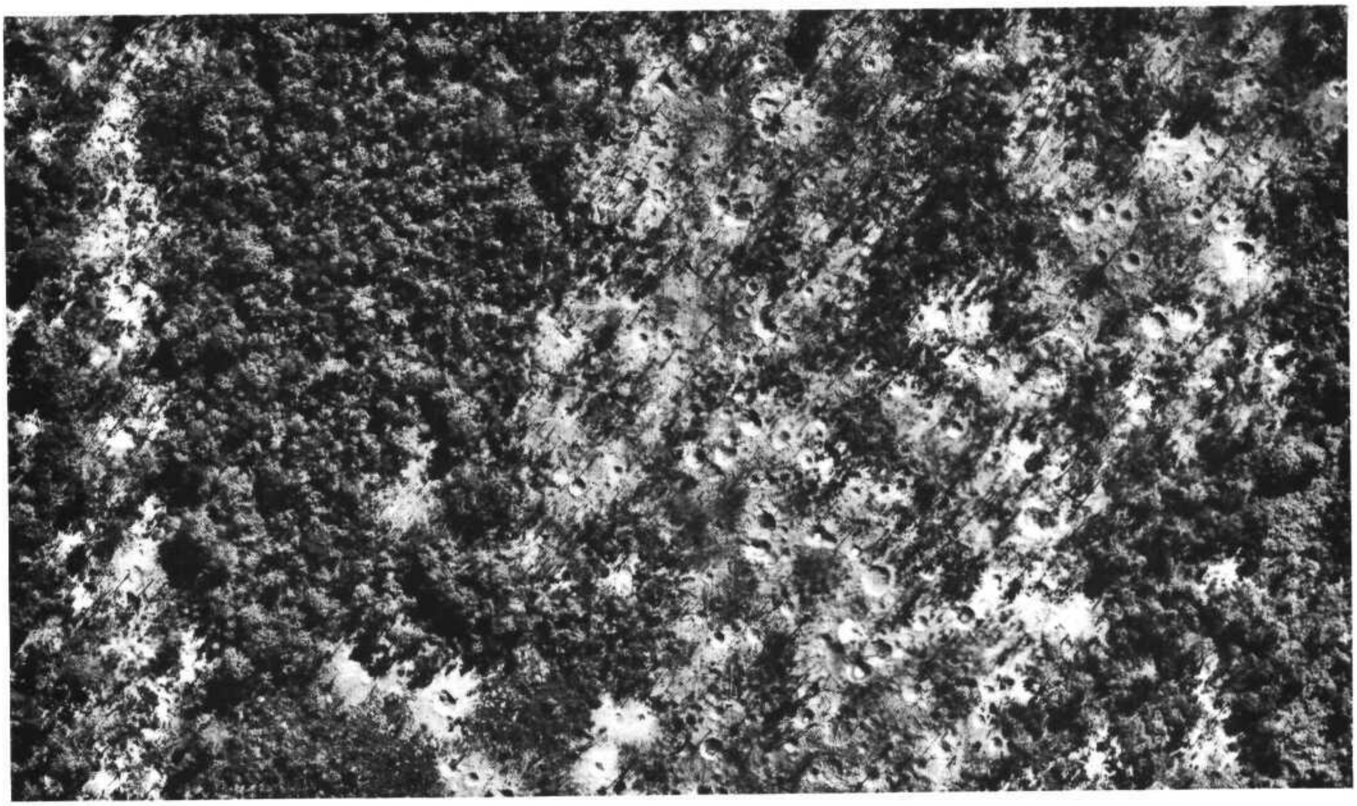

Fig. IV B-20. Bomb damage to forests showing strips cleared by sticks of bombs.

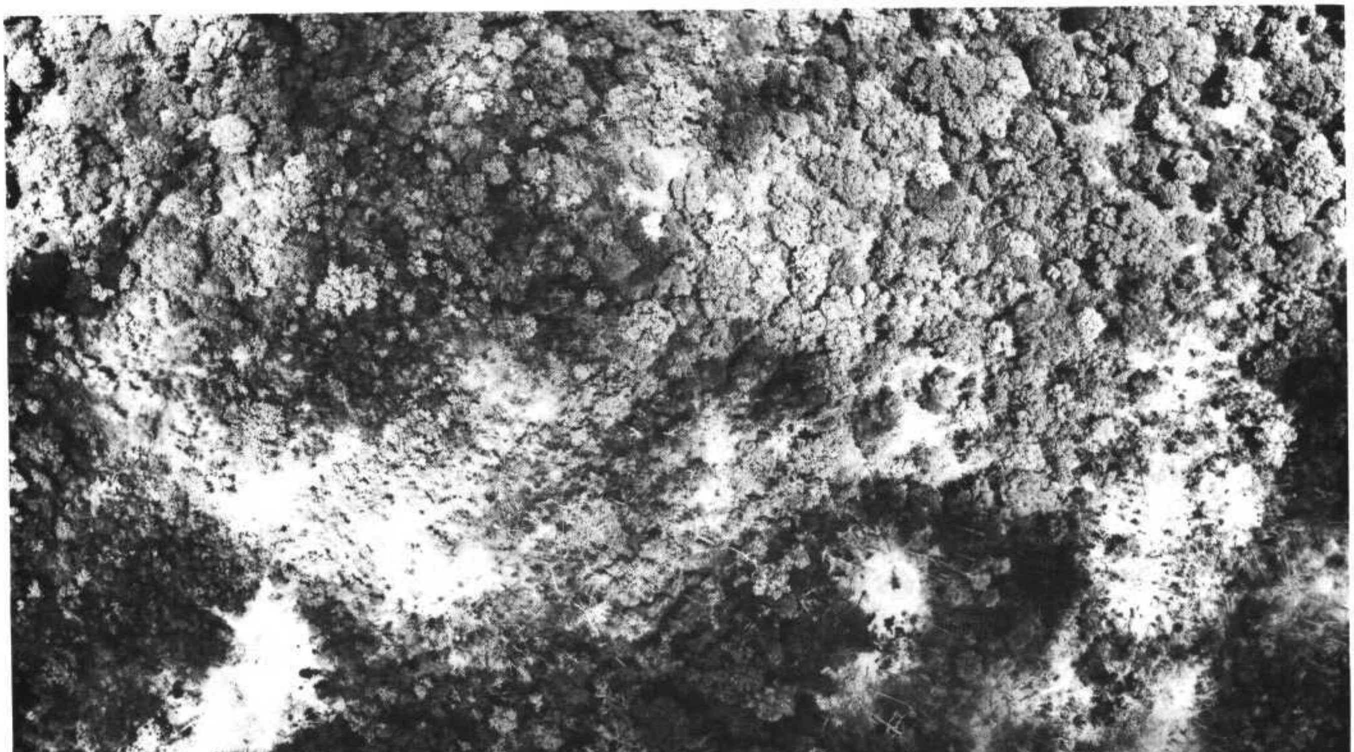

Fig. IV B-21. Older bomb damage showing lack of definition as forest recovers. Such damage appears as white streaks on large scale photographs.

The third form of military disturbance, herbicide application, caused defoliation and kill of susceptible species. Some trees were killed by one dose and the kill increased markedly with repeated application, the spacing in time of multiple applications being undoubtedly an important factor in this respect (Fig. IV B-22). Within the inland forest sprayed by defoliation and crop destruction missions the distribution of herbicide was as follows:

No. of herbicide exposures (impacts)	Hectares Sprayed	Percent
1	694,386	64.29
2	251,439	23.28
3	90,540	8.38
4	31,410	2.91
5 +	12,262	1.14
Total	1,080,037	100.00

Using 1:5,000 aerial photographs areas sprayed once, twice, three times and four or more times were compared for evidence of damage to merchantable size trees. It was clear from this analysis that areas sprayed once rarely suffered any significant damage. Damage was usually light on areas sprayed twice. Those areas sprayed three or more times showed heavy damage with the level of damage increasing markedly with increased spray frequency. Figs. IV B-24 through B-27 show areas sprayed once, twice, three and four times. Not only merchantable size trees were killed but also smaller ones; hence both merchantable volume and growing stock were killed. The loss in seedlings and small trees cannot be assessed from aerial photographs of the scale available. Other trees lost their foliage and often part of the crown was also lost but the tree survived: in these cases the loss would be the reduced growth during and, if part of the crown was killed, following the defoliated period. Yet other trees were unaffected. A major task of the Committee was to assess the kill in the various tree categories. An indication of the extent of spraying is given in Fig. IV B-7d where the shaded portions indicate all areas covered by defoliation missions; the blackened portions represent areas sprayed four times or more.

Civilian impact on the forest was in the form of urban development, agricultural clearing, and harvesting for fuelwood and timber. Several of the major towns expanded considerably between 1958 and 1969. Often the surrounding forest was cleared to provide agricultural land.

Conspicuous near towns and along roads is a progressive removal of stands of small trees, presumably for fuelwood and/or light construction. At first a few foot paths become visible but over the years a maze of trails develop and the stand of trees is reduced to scattered remnants and brush. Since spraying was widespread, fuel cutting often happened in areas already sprayed. Where new roads were constructed there is evidence of timber cutting; when this was near a town which also exhibits expansion, it is reasonable to suspect the cut trees contributed lumber for the construction of houses.

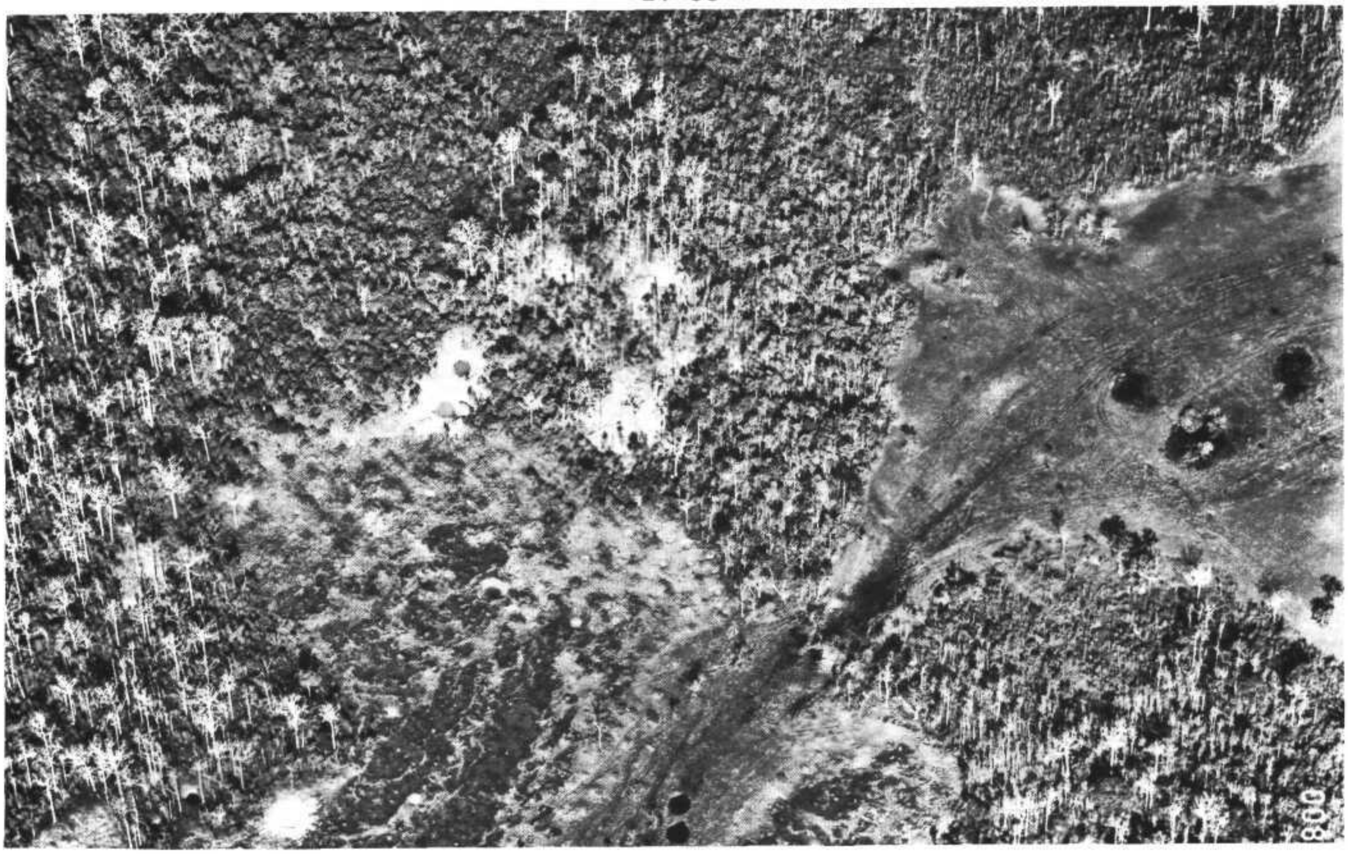

Fig. IV B-22. Area in north XT quadrangle sprayed from 4 to 7 times showing heavy large tree mortality from herbicide treatment.

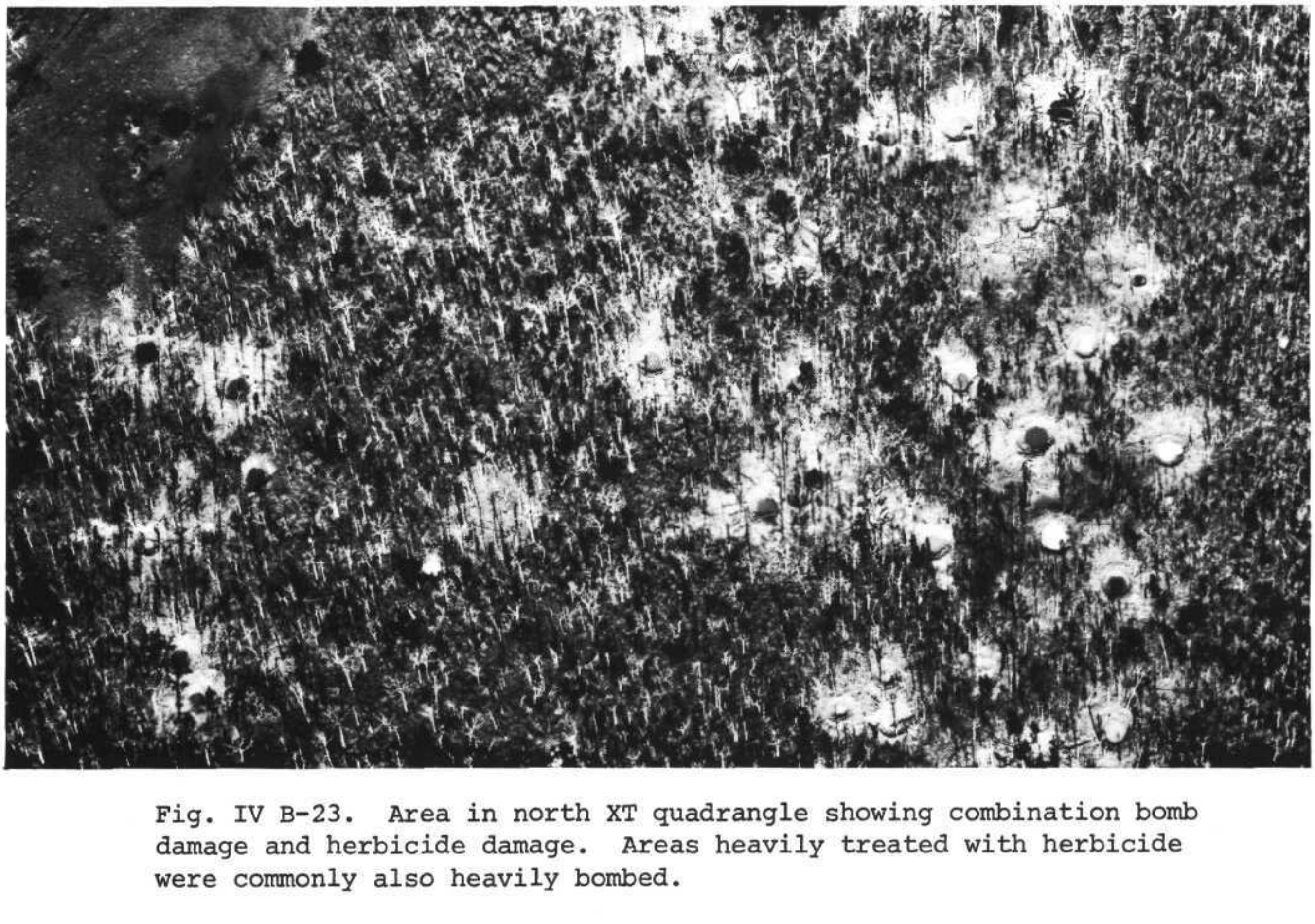

Fig. IV B-23. Area in north XT quadrangle showing combination bomb damage and herbicide damage. Areas heavily treated with herbicide were commonly also heavily bombed.

Fig. IV B-24. Area sprayed once with herbicide. Note brush and small trees in inactive swidden clearings.

Fig. IV B-25. Area sprayed twice with herbicide.

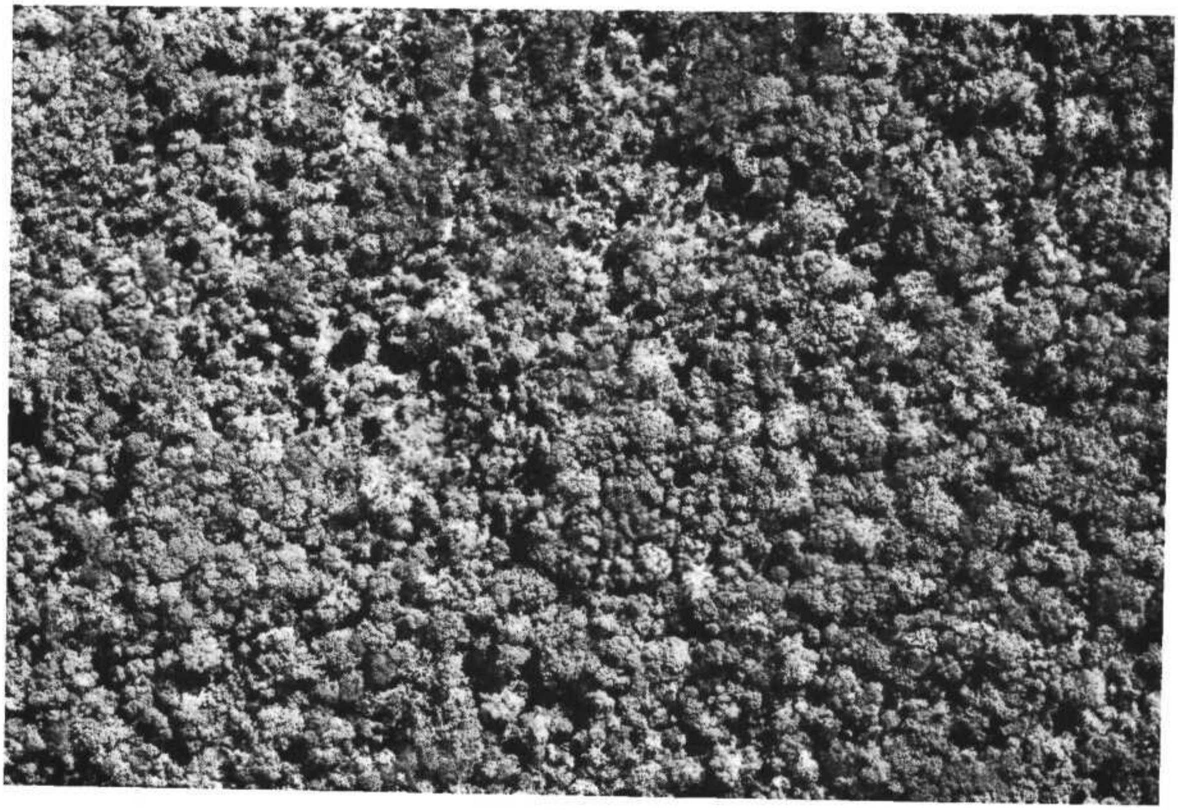

Fig. IV B-26. Area sprayed three times with herbicide.

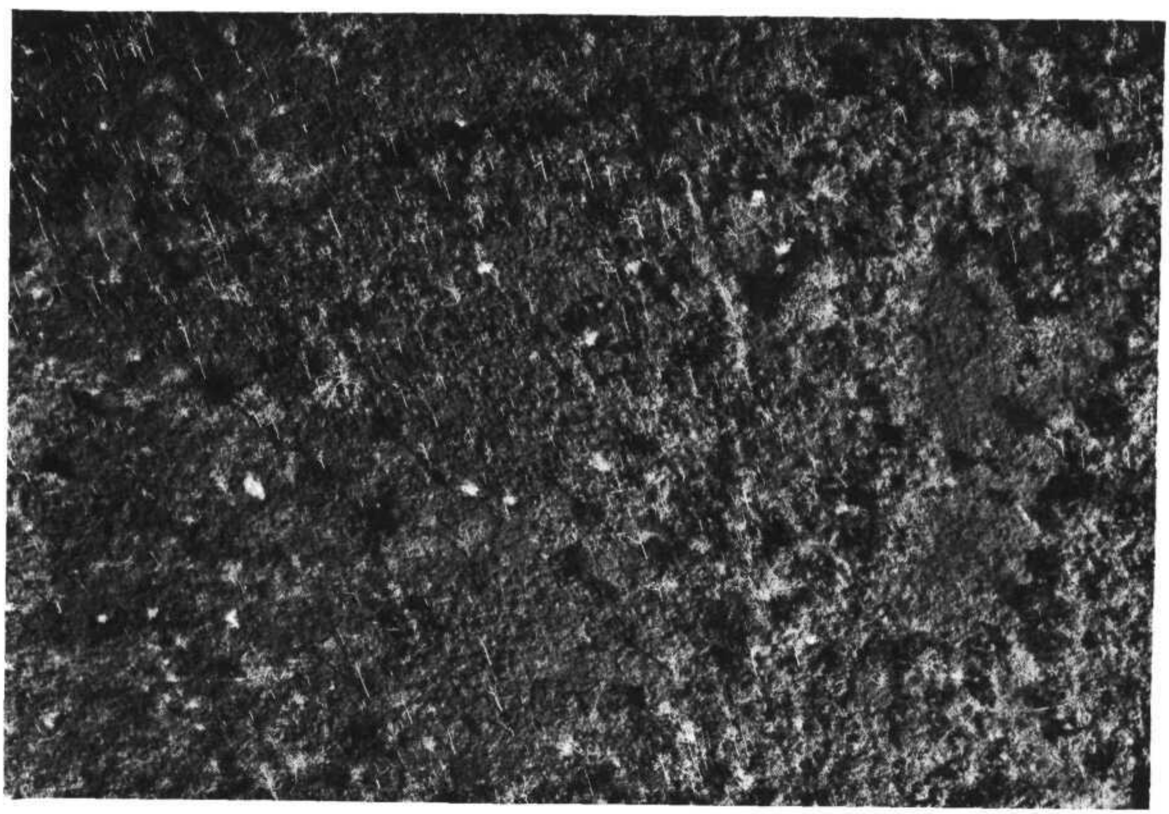

Fig. IV B-27. Area sprayed four times with herbicide.

It should be quite clear from the maps in Fig. IV B-7a through 7-d that the military and civilian impacts were often intermingled, and that heavy bombing occurred widely over the same areas where herbicide was sprayed (Fig. IV B-23).

Assessment of Merchantable Timber

The assessment of merchantable timber damage is based upon an estimate of dead trees in the forests of SVN.

The estimate of dead tree numbers was made from 1:5,000 scale photographs by counting the visible dead trees of merchantable size. The sampling procedure is illustrated in Fig. IV B-28.

Every third low-level photograph was sampled in order to avoid photo-overlap. Each frame was subdivided into 162 (9 by 18) quadrats of equal size, each quadrat corresponding to 1.5625 ha (about 3.7 acres). The total sample area covered by all films used was approximately 196,000 ha. In each third photograph, a count was made of the number of squares that fell under one of the 12 forest types considered (Table IV B-5). This count provided an estimate of the proportion of area in that photograph covered by each type present in the frame. The total area sampled was approximately 143,000 ha.

A rectangular area in the center of each photographic frame was used as the sub-sample area in which dead trees were counted. This sub-sample area was of 12 quadrats by 5 quadrats and equivalent to 93.75 ha (about 235 acres) on the ground. Dead tree counts were limited to this center area in order to minimize edge effects and overlap errors. The total area of dead tree counting was 33,830 quadrats (52,859 ha or 130,500 acres).

In each quadrat, dead merchantable trees were counted and recorded according to the forest type within the quadrat. Many quadrats had no dead trees of merchantable size. The number of quadrats in which dead merchantable size trees were observed converted into total hectares is termed the "Observed Merchantable Mortality Area" (OMMA).

OMMA is not necessary for the purposes of computation. However, it is a useful concept in interpreting the results of this study in the context of tree mortality on areas where the mortality actually occurred. The casual observer is conscious of the sprayed areas that exhibit dead trees and of the number of dead trees on those areas. He is not so conscious of the areas sprayed that show no dead trees. Mortality in terms of OMMA reflects the impression that an observer obtains when he views the inland forests of SVN from an aircraft over-flight. Many areas that were sprayed during the herbicide missions now show no visible merchantable trees. Hence a value for the ratio of dead trees to total sprayed area even though it is correct will seem to be very low when it

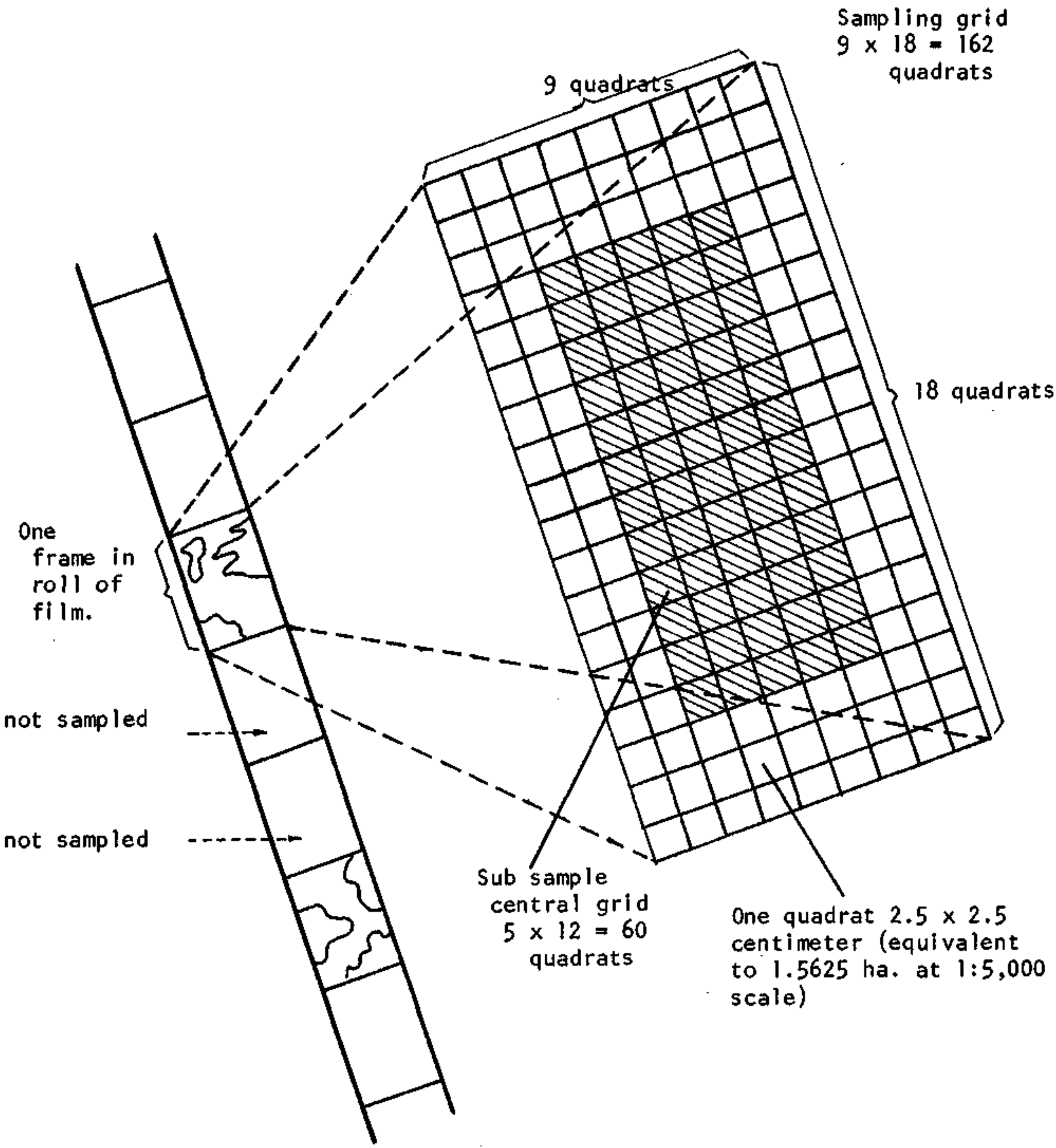

Fig. IV B-28. Sampling technique used in tree counting. Each third frame of the film (left) is placed over a grid with 9 x 18 = 162 quadrats. The relative area of different forest types is based on count of quadrats per type throughout the whole (162 quadrat) grid. Dead merchantable trees were counted in all quadrats within the central (5 x 12 quadrat) sub-sample area. Live and dead merchantable trees, in three size classes, were counted in one quadrat per forest type in each third photo frame.

Table IV B-5

Summary of Merchantable Dead Tree Sample Data

Forest Type Code	Total No. of Sampled Hectares	Ratio of Type Area to Total Area	Mean No. of Live and Dead Trees/ha	Total OMMA (ha)	Ratio of OMMA to Total Area by Type	Total No. of Dead Trees Counted	No. of Mean Dead Trees/Total Area (ha)	No. of Dead Trees/ OMMA (ha)
2	12880	0.244	7.02	2496	0.194	2967	0.230	1.19
3	11851	0.224	10.86	2208	0.186	2582	0.218	1.17
5	1383	0.026	14.26	209	0.151	181	0.131	0.87
4	349	0.007	6.81	109	0.313	194	0.556	1.77
1	2766	0.052	1.20	223	0.081	264	0.095	1.18
2_1	5382	0.102	3.89	856	0.159	1051	0.195	1.23
3_1	5500	0.104	4.05	1022	0.186	1223	0.222	1.20
4_1	412	0.008	3.47	139	0.338	156	0.379	1.12
4_2	1207	0.023	2.99	344	0.285	527	0.437	1.53
6	5747	0.109	1.58	497	0.086	593	0.103	1.19
7	3640	0.069	0.07	30	0.008	63	0.017	2.11
8	1743	0.033	0.20	34	0.020	43	0.025	1.25
	52860	1.000	5.72	8167	.154	9844	0.186	1.21

is considered by an observer who has been examining locations where damage is very great and dead merchantable tree frequency is high. Dead merchantable trees per OMMA ha was used in discussion to make the data more meaningful to an observer with such an experience.

In Table IV B-6 are listed the number of quadrats having 0, 1, 2, etc. dead merchantable trees for 25,680 quadrats. In Table IV B-5 is a summary of the dead tree statistics. It should be noted that dead tree counting proceeded over the entire sample area; it was not limited to areas recorded as having been sprayed. Hence no calculation is given, at this point, for dead trees relative to area sprayed.

Computation of Damage to Merchantable Timber

The first computation procedure bases the damage estimate on the dead tree count within each type of forest over the entire sample area. The following are the essential steps in calculation:

(1) Est. total dead merch. trees in all sprayed SVN inland forests

$$= \text{Total dead trees in sample} \times \frac{\text{Sprayed area of SVN forests}}{\text{Sprayed area within sample}}$$

$$= 9{,}844 \times \frac{1.08 \text{ million ha}}{11{,}195 \text{ ha}}$$

= 950,000 trees (all species)

(2) Est. total dead merch. trees in forest type in all SVN (e.g., #1)

$$= \text{Total SVN dead trees} \times \frac{\text{Number of dead trees in forest type in sample}}{\text{Number of dead trees in all forest types in sample}}$$

$$= 950{,}000 \times \frac{264}{9{,}844}$$

= 25,500 trees (all species) in forest type #1

Process repeated for all forest types.

(3) Est. total dead volume of merch. trees of merch. species in a forest type in SVN = Sum, for each of 3 tree size classes, of est. dead merch. trees in forest type

x [fraction of trees in tree size class

x fraction of trees of merch. species in the size class

x average merch. volume per tree in the size class].

Process repeated for all forest types.

Table IV B-6

Number of Quadrats Having Given Number of Dead Trees

# Dead Trees Per Quadrat	Code Number of Forest Type												
	2	3	5	4	1	2_1	3_1	4_1	4_2	6	7	8	All Types
0	4897	4558	559	107	1225	2150	2115	124	339	2519	1751	827	21231
1	802	714	81	20	78	246	310	35	75	157	5	10	2533
2	289	254	25	11	16	114	123	28	48	55	4	4	971
3	124	107	4	10	13	47	65	8	25	21	1	2	427
4	56	45	2	7	6	23	22	4	13	18	2	1	199
5	37	26	1	6	2	17	14	0	15	8	0	2	128
6	12	19	1	3	2	8	9	0	3	5	1		63
7	10	15		1	2	2	5	0	4	2	1		42
8	4	10		0	1	8	2	1	0	1	0		27
9	3	7		2	1	1	4		1	3	1		23
10	5	3			1	0	1		3	1	0		14
11	6	1				0	2		0		1		10
12	0	0				0	1		0				1
13	2	1				1			1				5
14	1												1
15	2												2
16	0												0
17	1												1
18	0												0
19	0												0
20	0												0
21	0												0
22	0												0
23	0												0
24	0												0
25	1												1
26	0												0
27	0												0
28	0												0
29	1												1
Total Quads	6523	5760	673	167	1347	2617	2673	200	587	2790	1767	846	25680 = 40,125 ha

The sum of the total merchantable volumes for all forest types is the estimated total damage. The computations were conducted for the area of MR III alone and for the whole of SVN. The results were:

MR III	All of SVN
725,000 m^3	1,245,000 m^3

Considering the variation inherent in the sampling and in the counts and measurements it is the judgment of the Committee that the damage to merchantable timber is within a range of 0.5 million and 2 million cubic meters. A discussion of the sources of variation as they are related to the damage estimate follows.

Discussion of the Estimated Merchantable Volume Damage

Calculations to this point have been based upon the assumption that all of the dead volume of merchantable trees was due to herbicide treatment. Clearly this is not reasonable. Normal mortality is a common phenomenon in multi-aged forests. The structure of the forest evolves from a continuing mortality in each age class resulting in the familiar J-shaped curve which emerges from the plotting of tree frequency as a function of tree diameter. This mortality rate varies depending upon the forest type. A generalized forest structure curve for the forests of Southeast Asia of the sort represented in this study shows that the tree numbers in a particular size class of trees is reduced by a factor of about three as these types move over an average diameter increase of 20 cm.

That is to say, the number in the 40 cm diameter class is about one-third the number in the 20 cm diameter class. Thus for every 30 trees that have a 20 cm diameter at any given time only 10 will survive to become 40 cm in diameter. This process goes on throughout the range of diameter classes represented in a stand. Thus normal mortality results in dead trees. Those of small size decompose rapidly and disappear. Those of large size decompose much more slowly and remain as visible snags for a number of years. Clearly the dead tree count would include some of those trees. Other trees were killed by bombing, shelling, burning and logging and these too would have the effect of inflating the expectation of herbicide kill. It was not possible to remove all of this non-herbicide related mortality. Given the pattern of herbicide application it was attempted to make a judgment concerning the contribution of normal mortality to the dead tree count. An estimate not described here was based upon a study of forest areas in SVN included in the sample areas studied but remote from any area recorded as sprayed. These areas show the pattern of isolated dead trees typical of normal mortality and are quite different in their appearance from forests known to have been sprayed and showing heavy mortality (Fig. IV B-29).

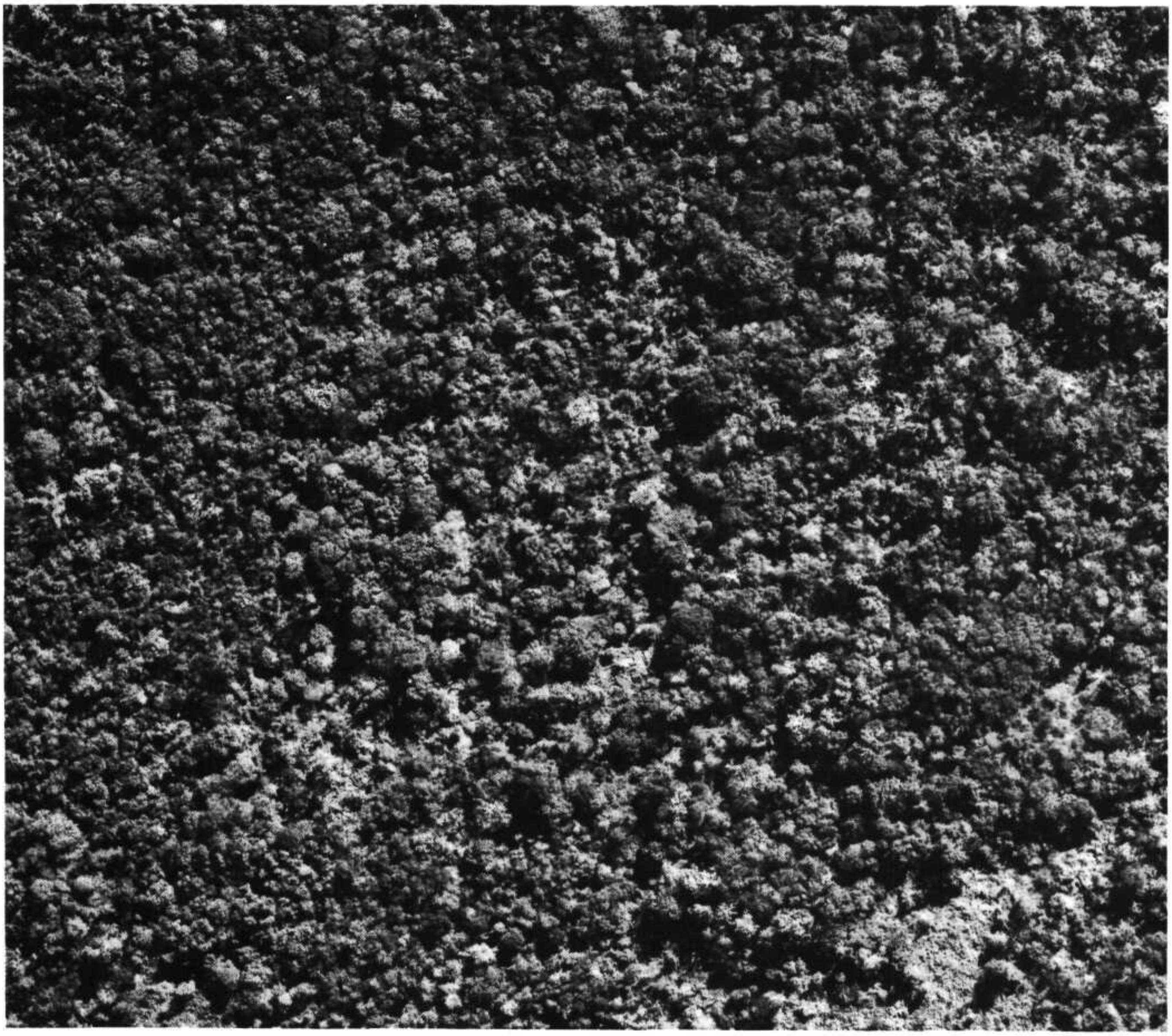

Fig. IV B-29. Area of forest not treated with herbicide. Some dead trees are visible. This background mortality is due either to natural mortality or to human activities.

Logging on an economic basis, a very common practice in SVN, leads to the occurrence of a disproportionate number of large non-merchantable trees in the upper canopy of the forest. They are either trees of non-merchantable species or specimens of merchantable species that are non-merchantable because of major defects. These trees can grow to large sizes because they are regularly disregarded in normal timber harvesting operations because they are not useful for lumber and plywood. They are also passed over by farmers searching for fuel since because of their size they are difficult to fell for individuals equipped only with axes. As a result these trees grow to very large sizes before dying a natural death and because of their size they commonly remain visible as standing hulks for a long time. In his study of the Cambodian inventory, Rollet (1962b) eliminated all trees over 130 cm in diameter on the basis that they were large trees of this non-merchantable kind. In addition to the substantial contribution which the large non-merchantable trees make to the background of normal mortality they also contribute to overestimating the merchantable loss in sprayed areas since, as large emergent trees they occupy a very vulnerable position in the upper canopy of sprayed stands.

A second important cause of dead trees in SVN was bombing and shelling. Areas photographed soon after bombing show much tree mortality outside of the immediate hit zone. Examination of photographic sequences over a number of years indicates that rapid revegetation tends to quickly convert the area to a broken forest without visible evidence of the individual bomb strikes but with swaths and pock marks covered with small trees and shrubs. The areas surrounding these openings often contain dead trees that were severely damaged but not totally destroyed (Figs. IV B-18 through B-21).

Apart from tree mortality not caused by herbicides, a number of other factors can affect the accuracy of the various elements in estimates of merchantable timber losses. The computations discussed above depend for their accuracy on the accuracy of the individual separate figures used to obtain the final answer. In Table IV B-7 is a list of possible factors which may have affected the estimates. This list is not complete but includes the important factors.

One of the major elements in the computation is the count of dead merchantable trees. As the table indicates this count can be affected by a number of factors, some causing an overestimate, some an underestimate; where the same factor could lead to one or the other it is listed in both columns of the table. For example, errors of measurement or of judgment of size of trees could lead to either over or underestimation. Before discussing this question further it is appropriate to note some relevant facts about the determination of the minimum merchantable size of trees. For standing trees, the most generally used measure of size is diameter at 1.5 m above ground (or at the top of buttress in trees having that characteristic) referred to as dbh. The most direct evidence of what minimum diameter is accepted on the market is data from factory log yards.

Table IV B-7

Possible Factors that may have Affected the Estimates of Damage

Parameter	Effect of Factors on Estimates of Herbicide Damage to Merchantable Timber: Overestimate	Effect of Factors on Estimates of Herbicide Damage to Merchantable Timber: Underestimate
A. Count of dead merchantable trees killed by herbicide	1) Trees dead; trees seen by observer	
	- size misjudged - diameter limit too low (dead trees at low end of distribution) - film scale fluctuation - stem covered in vines - death not due to herbicide - dead tree not merch. species - dead tree not merch. quality - dead tree part rotted before spraying	- size misjudged - diameter limit too high (dead trees at high end of distribution) - film scale fluctuation - stems covered with vines - crown decayed to smaller diameter
		2) Trees dead, present, but not seen by observer
	3) Trees seen, not actually dead	
		4) Trees dead but absent (cut or rotted) - trees cut and salvaged are not considered a loss - trees rotted are loss if of merch. species, otherwise not
	5) Sampling	
	- sample areas overrepresent heavy damage	- sample areas overrepresent light damage
	6) Natural mortality	
	- no correction made	- not applicable

Table IV B-7 (cont'd)
Page 2

Parameter	Effect of Factors on Estimates of Herbicide Damage to Merchantable Timber: Overestimate	Underestimate
B. Total number of hectares of forest sprayed	1) Mission records	
		- areas sprayed but records missing - faulty records omitted from analysis
	- compensation for mission records assumes no overlap - actual spraying in different location than recorded	- actual spraying in different location than recorded
	2) Spray swath width	
	- actual width less than nominal 80 m	- actual width greater than nominal 80 m
C. Number of hectares of each type of forest within sprayed area of whole country	1) Sampling	
	- sample area over-represents non forest and low merch. volume forests	- sample area over-represents high merch. volume forests
D. Total number of hectares sprayed within area sampled	1) Location of spraying	
	- actual spraying in different location than recorded	- actual spraying in different location than recorded

Another important element in accuracy of dead tree counts is the measurement and judgment of tree size. As previously described, dead trees were counted from a sampling area subdivided into quadrats (2.5 by 2.5 cm) each equivalent to 1.5625 ha of land area at film scale 1:5,000. It is important to realize the magnitude of the tree count sampling. A total of 33,830 sample quadrats was inspected; on these a total of 9,844 dead merchantable-size trees were observed. A summary is presented in Table IV B-6 of the number of quadrats found to have 0, 1, 2, 3, etc. trees within the subsample of 25,680 quadrats; these frequencies are listed both by forest micro-type and for all forest types together. It is obvious that, while counts of 10 or more dead merchantable-size trees were recorded, the majority of the counts were lower. In fact, the average count per quadrat having at least one dead tree is 1.883 (equivalent to 1.205 trees per ha within areas having at least one dead tree). This dead tree count was made on photographic film of scale stated as 1:5,000. Reference trees of 45 cm. dbh and others of crown diameter 10 m were located by precise micrometer measurement on reference photographs used by the observers to judge, on other frames, whether dead trees were larger or smaller than those representing the minimum merchantable size. Initially the observers used the stereoscope frequently, but once they were well practiced, the stereoscope was used only intermittently for quality control purposes and to check in doubtful situations. This practice was followed for two reasons; first, the magnitude of the sampling job precluded use of stereo throughout; second, at 1:5,000 scale a 45 cm tree appears as a line of just less than 0.1 mm width which is quite readily visible except when the tree is covered by vines or hidden in the shade of other vegetation. In general this can happen only if the tree crown has rotted or broken off and only a crownless stump or "snag" is left standing. The higher the probability of such rot or breakage, the less is the likelihood that the tree was of a merchantable species since durability and merchantability are closely related. (On the other hand, if a dead tree is covered with vines and clearly visible its size may be overestimated. Thus, covered trees appear in Table IV B-7 as a potential factor for both over- and underestimate.)

It should be noted that differences in tree counts between observers would not be reflected in proportional differences in tree volumes. Below is an example of a stand table for an all-aged multi-species forest in Southeast Asia (Rollet, 1962b) to which has been added crown sizes, tree volumes (i.e. merchantable volume) and stand volumes based upon criteria used in this study:

Dia. Class Breast Hgt., cm	120+	110	100	90	80	70	60	50	40	30	20	Total
Crown dia. m^3	30.0	27.2	24.5	21.5	18.9	16.2	13.5	11.0	8.7	6.4	4.0	
No. of trees/ha	1	1	1	2	3	3	7	10	16	36	75	155
Vol./tree m^3	4.2	3.9	3.6	3.1	2.6	2.0	1.4	1.0	0.7	0.4	0.2	
Stand vol. m^3	4.2	3.9	3.6	6.2	7.8	6.0	9.8	10.0	11.2	14.4	15.0	92.1

When the trees killed by herbicide are large, it is unlikely that the decision of whether or not to tally it would be the subject of debate among observers, its crown, dead or alive, would dominate the overstory. As large trees they would not disintegrate in a few years nor would they be completely covered by vines or be otherwise obscured.

The larger, upper canopy trees are represented in the stand table above by the upper portion of the diameter range. The important point concerning proportionality can be grasped by noting the following: the largest tree (120+ cm) represents 0.6 percent of the number of trees above 20 cm dbh, but 4.6 percent of the stand (total volume), the 3 largest trees together make up 1.9 percent of the number but 12.7 percent of the volume. Thus, the smaller the trees, the greater their number but the less the percent of total volume added per additional tree.

Arguments over the admissability of dead trees will occur at the margin of minimum size where tree numbers are large but tree volumes are small. The following tabulation indicates the relation between tree numbers and tree volumes assuming that a 40 cm dbh tree is the minimum tree size standard and assuming observers differ by 50 or 100 percent in either direction from the standard in counting numbers of trees.

Effects of Tree Counting Errors on Volume Estimation

	Values at 40 cm Standard	Counting Trees Smaller than Standard (Overcount)		Missing Trees Larger than Standard (Undercount)	
		50%	100%	50%	100%
Number Trees counted	44	66	88	29	22
Est. stand volume[a]	63 m^3	73 m^3	80 m^3	53 m^3	46 m^3
Volume % error from standard	--	16	27	16	29

These figures indicate that a difference between observers even as great as 100 percent at the tree size margin would have an impact on volume of less than 30 percent and that smaller counting differences would cause even lesser differences in the estimated volume.

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[a] Obtained by interpolation from graph of cumulative stand numbers and volume.

It should not be inferred from this example that equally qualified observers using the same criteria for counting would differ by factors as great as 50 or 100 percent. Differences in tree counts among observers used by the Committee were in fact very much less than this.

The importance of this example is that it illustrates that while misjudgment of tree size can be regarded as a random error (i.e., observers can default in either direction), the effect of overestimating the number of dead trees implies counting trees of smaller than average merchantable volume. Higher tree counts for this reason do not lead to proportionally higher merchantable volume. Since the minimum merchantable diameter is already assigned the smallest reasonable value, rather than an average figure, it is considered that the tree counts are, if anything, on the high side.

As indicated by the equations used in computing the damage estimates, the volume of dead merchantable trees is computed by first subdividing them according to size class, and then multiplying the average volume per tree in the size classes by the number of dead trees in the respective size classes. Average volume per tree differs considerably, hence it is important that the subdividing of total number of dead trees into size class subtotals be done correctly.

Murray and Vaughan (1969) studied aerial herbicide applications in hardwood forests in Thailand and evaluated them for maximum effect and minimum drift. As a result of these experiments they concluded that "only a very small percentage of the total spray will actually penetrate the canopies and that only the top and peripheral areas of the vegetation will be contacted by the herbicide." Since spraying first affects the upper canopy trees, it is to be expected that where only a few trees are killed these would be upper canopy trees. The question then becomes, "What sizes of trees are present in the upper canopy?" A special study was conducted to analyze the size distribution of dead trees, and how it related to size distribution of all trees. The results established clearly that over the whole size range of merchantable trees, the dead tree distribution is indistinguishable from that of all merchantable size trees. This implies that the death of trees is random with respect to size and, therefore, is evidently a function of species, health, etc. Hence, the fractions used in the equations, which were derived from total merchantable tree size distribution, are correct for the purpose of estimating dead merchantable volume.

The scale of aerial photographs is determined by the focal length of the camera, a factor which is fixed, and the height of the aircraft above the ground being photographed, which varies both because of the topography of the ground and variations (rise or fall) in height of the aircraft. The intended scale of the films used in dead tree counting was 1:5,000. Each film was sampled for scale at several points over its length. The average scale for all films was 1:4,975; this is very close to the nominal value, and variation around this mean scale generally did not exceed ± 4 percent. The effects of scale being smaller than 1:5,000 (e.g., 1:5,200) are: (1) the actual land area equivalent to the 2.5 by 2.5 cm sampling quadrat is greater than the 1.5625 ha assumed in the analysis, and (2) tree sizes based on an assumed scale of 1:5,000 are less than they are in reality. The first effect leads to the estimated number of dead trees per ha being greater than they are in fact; the second effect leads to undercounting the merchantable dead trees. Effects of the scale being smaller (e.g., 1:4,800) than assumed are opposite. Since the scale fluctuations were generally small and in both directions, their combined effect was considered negligible and no adjustment was made in the tree count figures.

Mission Records

The quality of these records is discussed in Section III C(1). Two points are of major concern, namely mislocation of missions and missing records.

Where the area sprayed differed in location from the one given in mission records, the "area sprayed within sample" would be affected if the mislocation moved the spraying out of or into the path of the sample area photographed. However, there is no basis for assuming a greater tendency in the one or the other direction and the error can be considered to be random.

An estimate of missing records is given in Table III C-1. The consequence of records being missing is that the area sprayed would be greater than assumed. However, since the sampling pattern is random with respect to spraying it is reasonable to assume that both the "total area sprayed in SVN" and the "area sprayed within sample" would increase in approximately the same proportion if the area for which records are missing were added to the data bank. Since these two figures are used in a ratio, an equal proportional change in both would leave the ratio unchanged; hence, no attempt was made to adjust for missing records. The key figure in the computation is the total number of dead merchantable trees; since these were counted wherever they occurred, and not only where the records indicated spraying, it is considered that missing records have not invalidated the estimate to any serious extent.

Because of wind and turbulence caused by the aircraft itself the spray may spread more or less widely than in calm air, or may in extreme cases be displaced wholly from the area vertically below the aircraft. While it is possible that for these and other reasons the spray swath may be wider (or narrower) than the nominal 80 m, the general pattern of spraying must be noted (Section II B).

Most of the herbicide was applied in missions placed in parallel arrays. Increase or decrease of swath width in areas so treated would simply tend to miss or fill along the adjacent borders of these missions. Clearly these fluctuations could lead to overlap of treatments but only at the expense of dilution in the intended spray target area.

Frequency of actual as compared with recorded application could be affected by fluctuation in spray swath width so that some areas thought to have been sprayed 2 times, for example, might in fact have been sprayed 3 times, or only once. These errors would tend to be random and would balance out. Thus, they do not influence the assessment of damage.

Adequacy of Sampling

The Committee decided early in its deliberations that it was essential to use low elevation, up-to-date aerial photographs as samples for damage assessment purposes. Originally, thirty-five areas were selected to be photographed as samples. This selection was made on the basis of the only information and material available to the Committee at that time, namely printouts of the herbicide operations from the HERBS tape, and the Rollet vegetation map. The selection was made so that the sample areas would be representative both of impact (spray) frequency and of the Rollet forest types. Another consideration was to have them easily identifiable by some prominent landmarks. However, upon presenting the list of these samples to MACV we were advised that photo coverage of this number of small spots was too hazardous. Accordingly a new system of aerial photographic sampling was devised involving the use of long strip samples. These were selected to permit coverage comparable to that sought in the original sampling scheme. The strip sampling method gave a much larger sample than would have been obtained using the small area samples originally planned but was somewhat more restrictive in terms of the number of independent locations provided. The strips were flown twice, in the wet and the dry season (October 1972 and January-February 1973, respectively) but the overlap was far from accurate so that the actual sample area was almost doubled. On many of the flights back-up black and white photographs were also taken. This extensive coverage and duplication permitted the rejection of photographs whose quality made assessment difficult without jeopardizing the size or representativeness of the sample. A map of the photographic strips used in sampling is given in Fig. IV B-30. The figure shows how the 16 rolls of film coverage are located in relation to the sprayed areas in MR III. These modifications substantially increased the size of the sample but somewhat changed the original sampling plan, 23 of the originally selected 31 sample areas (26 percent) being excluded from the new sample flight lines.

The representativeness desired in such a sample is that it provides an adequate, proportional sample of the various types of forest

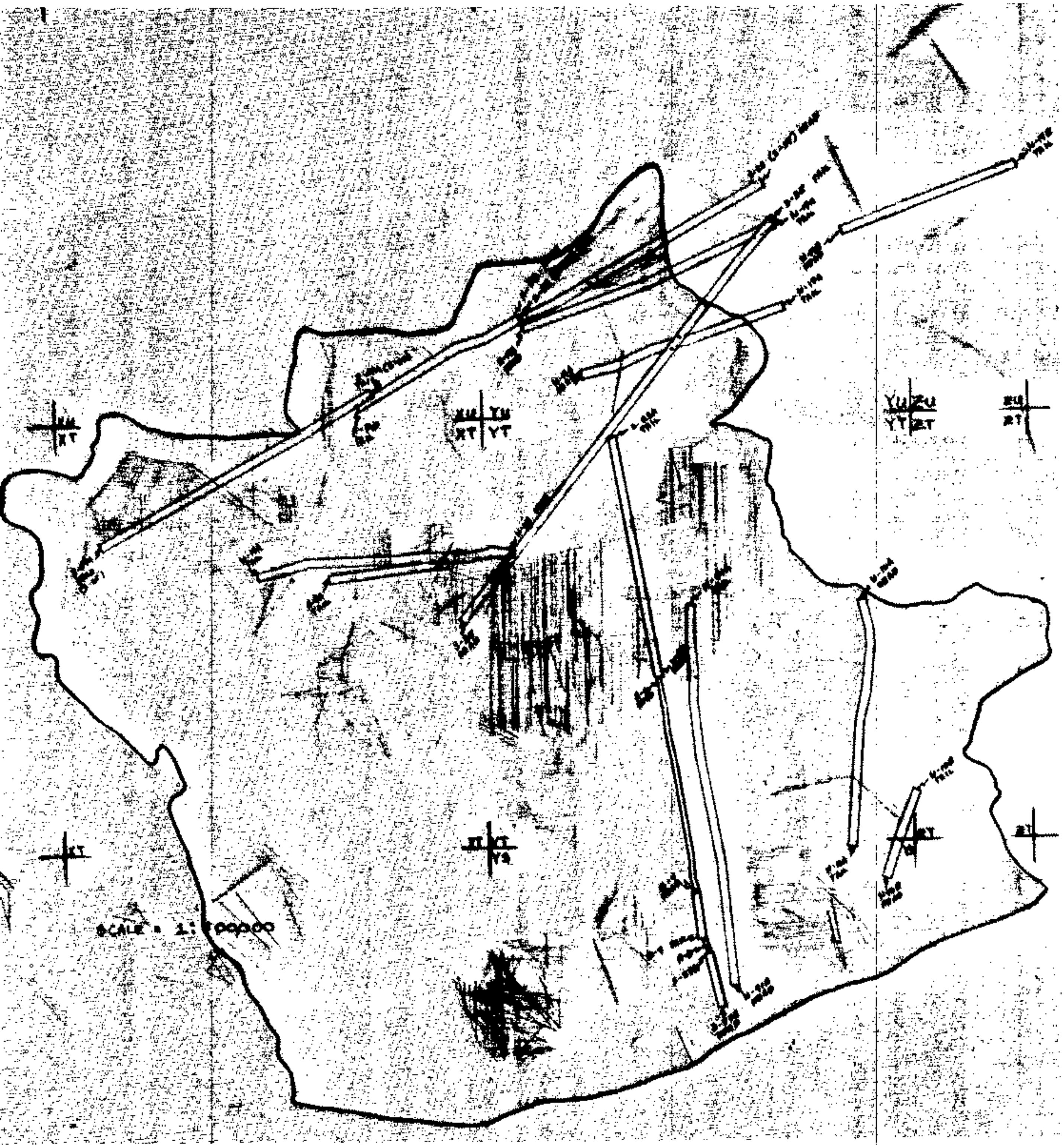

Fig. IV B-30. Map showing location of XT and YT quadrangles and the 1:5,000 scale photo samples in MR III. Lines indicate paths of defoliation missions from 1965 to 1971.

and of the degrees of damage associated with these. An analysis of the sample coverage with respect to forest types and frequencies of spray impact indicated that the samples were representative of the forests being sampled within limits acceptable in forest inventory practice.

Inventory of Non-Merchantable Volume

It is obvious from aerial photographs that much of the damage in the forests was in trees of smaller than merchantable size. An inventory of the non-merchantable volume was developed to provide a basis for assessment of damage to that component of the inland forest.

While the merchantable volume was inventoried in some detail by sampling aerial photographs for data on each forest type, the non-merchantable volume was estimated in a more appropriate way. The reasons for this are outlined below.

In Fig. IV B-31a-c are given vertical correction, or profile, diagrams representing a tropical hardwood forest. The shaded portions in Fig. IV B-31b boles (tree #1-4) represent merchantable size material of merchantable species. The merchantable stem segments are shown separately in Fig. IV B-31c to emphasize their relation to the whole stand.

The non-merchantable volume of the stand includes:

a. the boles of trees of merchantable size but not-merchantable species.

b. the stems of all trees smaller than merchantable size, of both merchantable and non-merchantable species.

c. the branch wood and stem tops of all trees of all sizes and all species.

If the procedure used in the inventory of merchantable volume was followed, it would be necessary to count the non-merchantable size trees (diameter less than 45 cm) in sample aerial photographs. This is not feasible because the smaller, more numerous crowns are too difficult to separate from one another even in a completely visible crown layer. Further, many of the smaller trees, in some types of forest, are located directly under the larger tree crowns and hence not visible in aerial photographs.

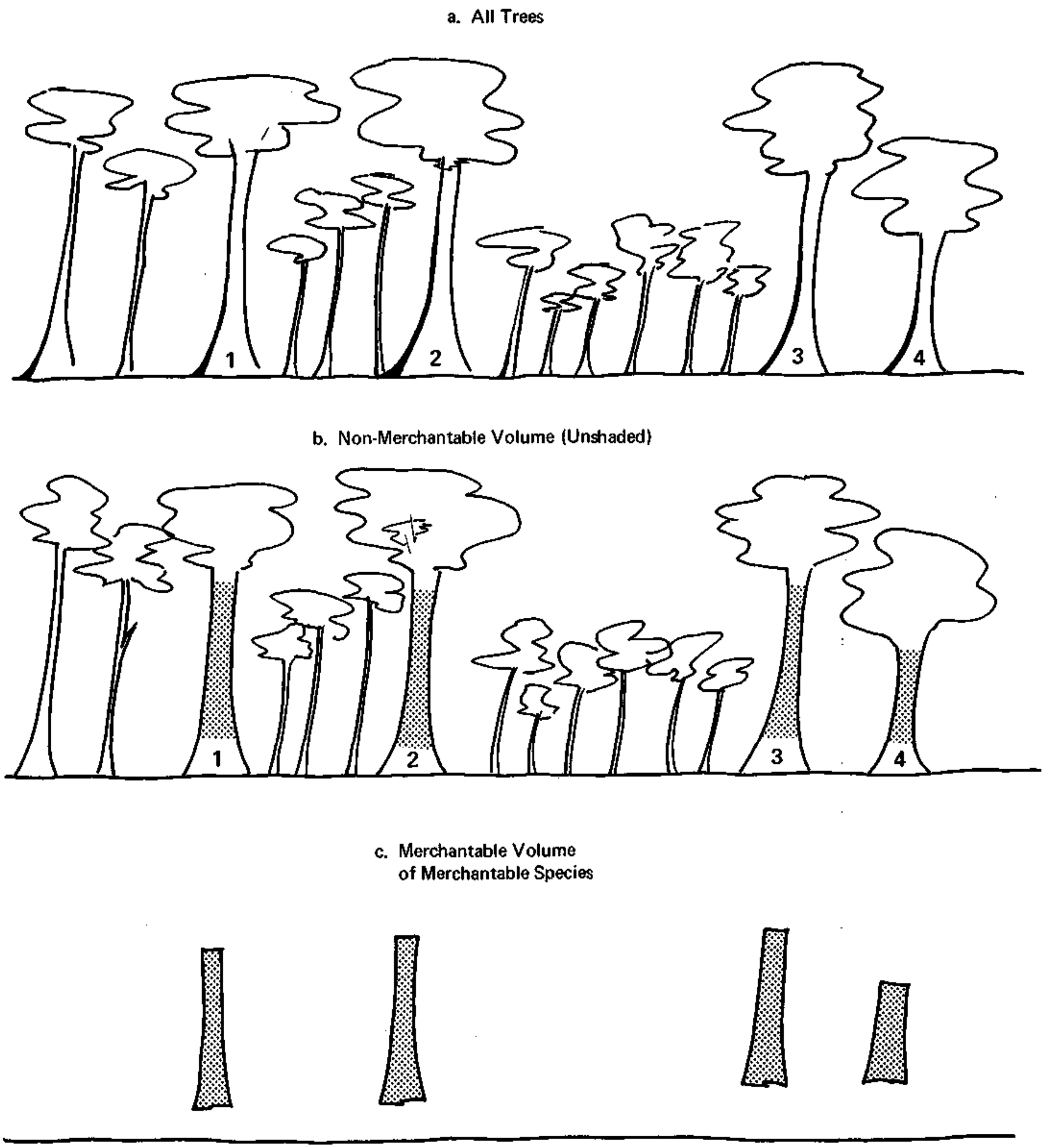

Fig. IV B-31. Profile diagrams of a tropical hardwood forest showing merchantable volume of merchantable species.

The procedures used, in brief, were as follows:

a. Volume of stems of merchantable size but non-merchantable species and quality was computed by employing the equations already given, but with fractions for the non-merchantable species and quality substituted in place of those for merchantable.

b. Volume of stems of smaller than merchantable size was estimated by analysis of forest biomass data from plots in Thailand and Cambodia, since none were available for inland forest in SVN.

c. Volume of branch wood was derived from relations between stem weight and crown (branch and top) weight of many individual tropical hardwood trees in Thailand and Cambodia, and similar data, but in terms of volume, for sample trees in Central America and Puerto Rico. The percentage relation between branch wood and stem wood for individual trees was applied to the total stem wood volumes for merchantable and non-merchantable size trees to estimate total branch and top volume.

The data for (b) above came from published analysis of biomass plot data from Cambodia (Rollet, 1962b) and from plots already established in Thailand plus others established for the Committee by faculty and staff of the College of Forestry of the University of Kasetsart, Bangkok, Thailand. The plots in Thailand were chosen to represent Moist Evergreen, Dry Evergreen, Dry Dipterocarp and Tropical Rain Forests. On these one hectare plots every tree of one inch diameter and larger was tagged, mapped, measured for diameter and height and its species identified. Analysis of these data gives excellent figures for the most dense parts of the forests which these plots represent, since they were carefully selected to give that representation. Regional inventory figures for Northeast Thailand were then used to provide reduction factors to adjust the biomass plot figures to estimate average rather than maximum volumes. It was not feasible to obtain separate non-merchantable volume estimates for the various micro-types used in the merchantable volume inventory and damage assessment. Rather, averages were estimated for all SVN forest types together, as follows:

	Tree Diameter Range (cm)			
	0-15	15-30	30-45	All
Number of stems/ha	400	60	20	480
Stem wood volume m^3/ha	4	3	10	17
Crown wood volume m^3/ha	2	1	4	7
Total non-merchantable volume m^3/ha				24

These figures correspond to roughly half the values for the trees below 45 cm diameter in the dense Dry Evergreen forest plot in Thailand and one-fourth of the non-merchantable component of the dense Moist Evergreen forest sample plot. However, the number of stems in these sizes are approximately equal to the regional inventory average across both exploited and unexploited forests in Thailand. Since the approximately one million hectares of inland forest sprayed in SVN include forest types, most of them actively exploited, ranging from the closed forest without brush, to extensive forests with substantial brush and areas of essentially non-forest vegetation, it is considered that the averages given above are appropriate to apply in approximating non-merchantable volume for the entire one million sprayed hectares.

It should be understood that while, for example, the average volume of non-merchantable stems is 17 m^3/ha, denser forest types may contain 50 m^3/ha while the most sparsely stocked forests (e.g., recently abandoned shifting cultivation areas) may contain as little as zero m^3/ha of non-merchantable volume. Similarly, the number of trees of diameter 30-45 cm (about 12-18 in) may range from 60 or more down to zero within the range of forest types.

Assessment of Damage to Non-Merchantable Wood

Damage to the herbicide treated forests of SVN was not confined to the currently merchantable component. Many trees not useful for lumber and plywood are useful for fuel. The branches and non-merchantable components of merchantable trees are potentially useful as fuel. In addition trees of less than merchantable size but of merchantable species constitute the growing stock from which the merchantable crop develops. As previously noted only a small fraction of these small trees in the growing stock can be expected to live to merchantable size. Nonetheless they are important components of the forest viewed as a continually productive renewable resource. Non-merchantable trees have other values such as forage for animals, soil builders and aesthetic values.

Damage to these non-merchantable components of the forest is real but it is difficult to evaluate under the conditions of this study. When small trees were killed by herbicides they quickly decomposed and were generally replaced by new vegetation in a short period of time. Accordingly, this damage could not be assessed from a study of aerial photographic samples representing the area several years after the herbicide treatment. Nonetheless, some judgment can be made concerning loss of non-merchantable tree components of the forest based upon knowledge of the structure of the forests, the pattern of spray applications and the effect of spraying on merchantable components of the forest. Estimates of damage to these non-merchantable components can be made with far less precision than is the case for the merchantable components. Table IV B-8 indicates the Committee's estimates of non-merchantable portions of the forest. Since they must be based upon assumptions that cannot be verified, high, medium and low estimates are given. It is the Committee's judgment that the

Table IV B-8

Estimates of Non-merchantable Wood Damage
(millions cubic meters)

Component	Range of Estimated Damage Upper (m^3)	Lower (m^3)
Merchantable size stems of non-merchantable species	.75	.25
All non-merchantable size stems	7.00	3.00
Crowns of all trees merchantable and non-merchantable	3.40	1.80
Total non-merchantable forest components	11.15	5.05

damage to non-merchantable components is within the range of 5 to 11 million m^3 of tree components. The median of this range is about 8 million m^3. Branch wood in crowns represents about 30 percent of total non-merchantable wood loss. The amount of this material that would be damaged by herbicide would depend upon a number of factors. In multi-storied forests and particularly in dense multi-storied forests, the trees in the upper stories protect those in lower stories from impact of liquid materials delivered from above.

A study of the overlapping crown structure of a dense forest in Thailand indicated that 56 percent of the trees with a 5 cm dbh and greater were completely covered by overstory trees in higher canopies. Seventy nine percent of the trees had at least half of their crowns covered by over-topping trees and 87 percent of the trees showed less than 70 percent exposure.

Semi-dense and open stands would not exhibit the same degree of canopy layering as would be the case in dense stands, hence, the non-merchantable material in the understory would be more vulnerable to aerial delivery of herbicide. The most vulnerable of the non-merchantable stands were the dense thickets of pioneer species that covered some areas of abandoned swidden. These thickets are made up of fast growing short lived species with very succulent crowns. They are commonly made up of essentially even-aged stands with relatively few tree species. In some cases they appeared to behave in response to herbicide treatment much like the mangrove forests. The areas of the inland forests that were cleared of all vegetation in strips similar to the mangrove damage were in this type.

Many areas of abandoned swidden were occupied by grasses and bamboos. The species of trees that make up the mature forest grow under these cover crops and eventually emerge from them to produce a multi-species multi-aged forest. A study made by Dr. Sabhasri and associates at the University of Kasetsart indicated that in many comparable areas in Thailand the tree species emerged from the grass cover in 6 to 26 years after abandonment. Where herbicides were applied before the trees had emerged from the grass or bamboo cover, the resistant cover vegetation protected the tree seedlings. Where the trees had already emerged they were highly vulnerable and mortality was undoubtedly great though this could not be quantitatively determined.

It is probable that the young stands that did not have appreciable quantities of merchantable size trees were more disrupted by the herbicide treatment on a short-term basis than were the older dense forests where merchantable timber losses were much higher. It should be understood that while the loss estimate ranges from 20 to 40 percent of the total non-merchantable volume on the average over one million ha, individual stands could be damaged considerably more or less than this average.

As in the case of merchantable timber damaged, substantial amounts of the non-merchantable trees were undoubtedly salvaged for fuel. The extent of these salvage operations could not be determined.

The Directorate of Water and Forest of RVN (Director of Water and Forest, 1971) reported a damage of fuelwood quality forest material of 7,583,094 steres[a]. This is roughly the equivalent of 4,500,000 m^3. This figure is less than the non-merchantable timber damage estimated by the Committee but the Committee's volume undoubtedly includes much wood that would not be considered potential fuelwood in SVN.

Interpretation of Damage Assessment Results

It is obvious from the preceding discussions of accuracy and its limitations that many possible factors may influence estimates of damage to merchantable timber. This is well known in forest survey practice and measures have been developed to minimize those factors. These steps and an extra measure of care were exercised in this assessment of loss of merchantable timber in SVN. The greatest source of error lies in sampling; the areas chosen may by chance provide estimates of overall mean damage higher or lower than the true mean. This error can be reduced either by increasing the size of the random sample, or by adopting a different design of sampling, including checks on the ground. The latter was not feasible under the conditions of this study, but our sampling of the forests of MR III would be considered more than sufficient in routine forest surveys. The Committee's estimate, according to which the total loss of merchantable timber is within the range of 0.5 million cubic meters and 2 million cubic meters, allowing for sampling errors and various factors discussed above, is in reasonable agreement with an estimate of merchantable timber loss due to herbicide treatment made by the Directorate of Water and Forest of RVN mentioned before and based upon reports from provincial Forest Services and/or Districts. This figure is 1,464,888 cubic meters, and it refers to the timber loss in forest area managed by the provincial Forest Service which is 5,908,793 ha. This includes mangrove forests and Melaleuca woodlands, which, however, contribute little if anything to merchantable timber. The loss figure is based on the amount of wood usually exploited per year without considering other, unexploited species of wood, i.e. represents the merchantable volume. Using different utilization standards, the Director of Water and Forest of RVN in the above mentioned document considers the loss figures an underestimate.

Earlier estimates of unsalvageable damage to the inland forests were expressed in terms of merchantable timber volume. Among these early estimates the most frequently quoted were those reported by Flamm (1970) and Westing (1971). While the Flamm and Westing studies were reported independently they are in close agreement on the volume of merchantable timber lost through herbicide treatment and not salvaged Flamm estimates the loss to be about 46 million m^3 and Westing about 45 million m^3. Since these estimates were so large relative to the size of the country and the area of its forest, they have become a focal point for public concern about the damage caused by herbicides, particularly the inland forests in SVN, and have been widely reported and accepted in the U.S., SVN and indeed throughout the world. Essentially no factual data were presented by the authors to substantiate

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[a] A stere is a measure of stacked roundwood commonly used in Europe. As a method of measuring wood it is comparable to the cord. In general 1 stere = 0.6 cubic meters.

their estimates of damage. Rather these estimates were based upon certain assumptions concerning the pre-treatment status of the forests and the effect of various levels of herbicide treatment. These assumptions were:

1. Inventory of Affected Forest. Both Flamm and Westing assume that the average merchantable volume of the inland forests of SVN affected by defoliation treatment was 100 m^3 per ha (40.47 m^3 per acre).

2. Area Treated. Flamm assumes that 1.35 million ha of forest were sprayed, 900,000 ha treated once and 450,000 ha more than once. Westing's figures are 2,000,000 ha, 1,500,000 ha, and 500,000 ha, respectively.

3. Growth Rate. Flamm assumes a growth rate in terms of merchantable volume of 0.5 m^3/ha/yr. Westing's assumption for the same parameter is 1.0 m^3/ha/yr.

4. Standing Merchantable Timber Damage Not Salvaged. Flamm assumes a non-salvageable loss of merchantable timber on areas treated once to be 15 percent; on areas treated more than once, 75 percent of merchantable inventory. Westing uses the figures of 10 percent and 60 percent, respectively.

5. Growth Loss. Both Flamm and Westing undertake to estimate loss of growth caused by temporary defoliation with subsequent recovery. For areas treated once Flamm assumes a 20 percent reduction in growth for ten years, for areas treated more than once a 75 percent reduction in growth for ten years, followed by a 50 percent reduction for an additional ten years. Westing assumes that "the average recovery time for a depleted stand is 15 years..."

Even allowing for the lesser precision in estimating the damage in the forest of MR I and II it is clear that the Committee's assessment of merchantable timber loss is of the order of one to four percent of that of Flamm and Craven (1972) or Westing (1971). Since these authors used Class II timber prices in computing their estimates they were presumably using lumber and plywood utilization as a merchantability basis.

The very high values obtained by these earlier observers derive from certain errors in their assumptions. The most important among these are the following:

1. The average merchantable volume of the inland forests was grossly overestimated, apparently because these observers were unaware of the extent to which the forests had been exploited previously in various ways.

2. Rollet's (1962b) estimate of growth rate for comparable Cambodian forests is 0.33 m^3/ha/yr, that is, two-thirds of that assumed by Flamm and one-third of the assumption of Westing.

3. There was no threshold of extreme damage at two applications of herbicide as postulated by the earlier observers. Damage varied progressively from very light with one application to very heavy with more than four applications (Fig. IV B-32).

4. A common form of evaluation used in earlier studies was to observe damage where it was known to have occurred but not to make observation in areas known to have been sprayed but where damage was not apparent. This system of sampling resulted in overestimation of damage.

It should be noted that there are some anomalies in the damage evidence. In a small area of the YT quadrangle south of Dong-Xoai and near the abandoned Rang Rang Air Base there are several strips of forest from which the tree cover has almost entirely disappeared. Fig. IV B-33 illustrates this area. Cleared strips such as this commonly coincide geographically with areas where four herbicide missions were flown. Other areas impacted as many or more times did not exhibit this much damage. Furthermore, study of photographic sequences over time indicated that the forest was essentially present after the first three herbicide exposures and then largely disappeared following the fourth one. The timing of the treatment with respect to season and to prior treatment can be expected to have had an important influence upon the herbicide effect. Information necessary to test this hypothesis was available to the Committee, but time did not permit us to conduct the analysis. It should, however, be noted that such areas of almost total removal of the tree cover represent only a very small fraction of the sprayed inland forest areas.

Estimation of Economic Loss

The monetary value of the damage to the forests of SVN due to herbicides was estimated by Flamm and by Westing by multiplying the lost timber volume by an assumed stumpage[a] price in piasters and converting it to U.S. dollars at the official rate of exchange (VN $118 = U.S. $1). Obviously, this monetary value, which Flamm estimated to be $490,000,000 for dead merchantable standing timber is greatly inflated because of his overestimate of merchantable timber. It is, however, also a questionable economic analysis in several other respects, even if the damage had been estimated correctly.

Determination of an appropriate and reasonable stumpage value is an important problem. In undertaking harvest of timber from forests

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[a] Price of standing timber before it is cut.

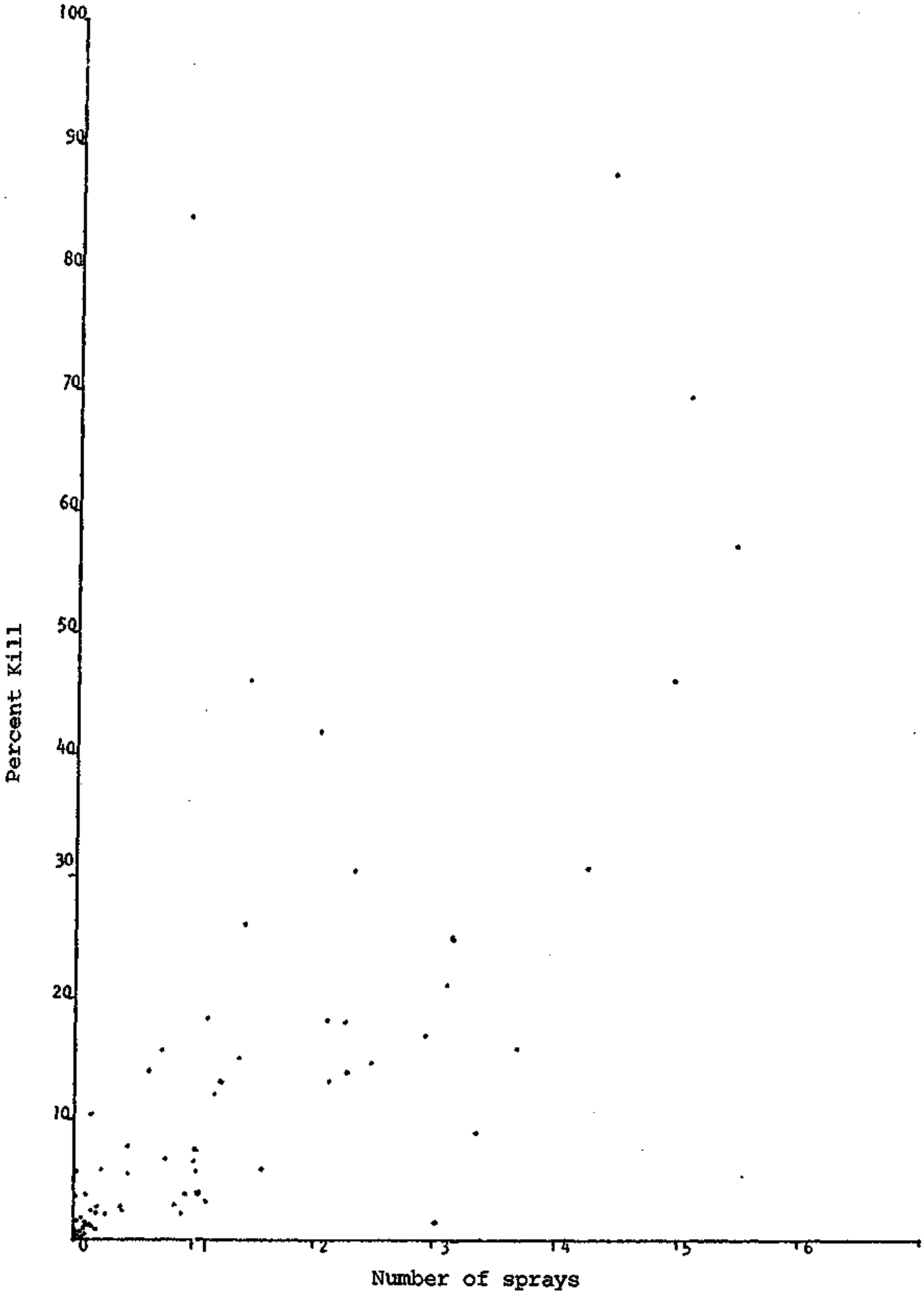

Fig. IV B-32. Distribution of mortality of merchantable size trees as a function of spray frequency. Each point represents a sample area of one photographic frame. It was not possible to find enough sample areas sprayed with uniform spray coverage (0-1-2-3 etc.) therefore areas were selected in which one spray number predominated, but the <u>average</u> spray number of the same area was used in the figure.

Fig. IV B-33. Area near Rang Rang abandoned airstrip in YT quadrangle showing heavy damage to small forest vegetation in area sprayed four times. Scattered large trees in this area were also killed.

presumed to be the property of RVN the logger is required under RVN law to purchase a cutting permit from the government. However, lack of control of the forests makes it impossible for the government to determine where in fact the cutting is being done. After the logs are harvested and loaded on trucks they are delivered to a government office for scaling and at that point another charge is made based upon log scale volume. This may be referred to as stumpage but it is in fact much more realistic to consider it as an excise tax. Loggers may also have to pay similar taxes to NLF groups and sometimes are assessed additional taxes by provincial authorities. On the other hand, many loggers avoid these payments; the volume of such "illegal logs" has been estimated to be from 50 to 100 percent of the legal harvest, and may be much greater. Under this difficult marketing system the use of a formally prescribed permit fee and excise tax is hardly a basis for assigning a value to forest damage.

A loss estimate based upon market value assumes implicitly that the demand for Vietnamese timber is perfectly elastic; that is, any amount of timber could be harvested and sold without a change in the price. In point of fact the supply-demand situation in SVN under the prevailing security conditions defies formal market analysis. The potential supply of timber in SVN far exceeds current industrial requirements but logs delivered to the mills are commonly in very short supply, due at least in part to lack of personnel for harvest and transportation of the logs, due to mobilization, immobility of workers because of security restrictions, intermittent prohibitions on logging imposed by the government on SVN for military reasons, and other war-related factors.

The use of the official rate of exchange to convert RVN license fees and taxes to U.S. dollars is also a questionable procedure. The value of the piaster on the world market is far less than is reflected in the official exchange rate used in making early projections. Ralston and Tho (1970) state that "the present foreign exchange rate of VN $118 = U.S. $1 is unrealistic and precludes exporting forest products even if production could be increased above domestic requirements."[a]

For all these reasons, the NAS Committee, after having familiarized itself with the situation, decided against any attempts at estimating monetary values of the damage to the forests. It was felt that these were not only of highly questionable value, but might be in fact counter-productive.

Summary and Conclusions

Of the approximately 10,500,000 ha of inland forests in SVN, according to the classification of Rollet (1962a), approximately 1,080,000 ha or somewhat over 10 percent were subjected to herbicide sprays. Of the total sprayed

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[a] As of March 1973, the official rate had changed to VN $425 = U.S. $1.

area, somewhat under two-thirds was sprayed once, somewhat under one-quarter twice, somewhat under one-tenth three times, and about four percent four or more times. This refers to defoliation and crop destruction operations recorded on the HERBS tape. If the area of all other recorded and estimated herbicide operations (amounting to 17 percent of those defoliation and crop destruction missions) were added to the 1,080,000 ha, the sprayed area would become about 1,265,000 ha or slightly more than 12 percent of the inland forest area. This, however, is an overestimate for the reasons discussed on page IV-71.

The loss of merchantable timber, the damage category which could be approached with the level of precision customary in forest inventory practice, was found to be in the range of 500,000 m^3 to 2,000,000 m^3. The estimated merchantable volume for all inland forests of SVN is about 82,000,000 m^3 (Table IV B-4); for the sprayed part it would thus be about 8,500,000 m^3. The loss estimate thus ranges from somewhat over six percent to 25 percent of the merchantable volume of the sprayed inland forest area, or one-tenth of these percentages for the total inland forest area. Earlier estimates of merchantable timber loss were too large by a factor of 30 to 90.

Our estimate of damage to non-merchantable timber, far less precise than that for merchantable timber, ranges from 5,050,000 m^3 to 11,150,000 m^3.

It should, however, not be assumed from these remarks that the losses of merchantable and non-merchantable timber constitute the entire damage to the inland forests or that all such damage can be expressed in numbers. The damage has been aggravated, in sprayed and in non-sprayed parts of the forest, by other war-related damage. One clear conclusion reached by the Committee is that the greatest damage which the inland forests suffered from war activities, including herbicides, has been incurred by the heavily overused open or thin forests and by the young secondary forests emerging from abandoned swidden. This damage does not appear in the assessment of merchantable timber loss since it represented loss of growing stock below merchantable size and of the early stages of forest regeneration, although it is reflected in the losses of non-merchantable timber. Loss of seed sources may also be a very critical factor in these forests even though the merchantable volume of lost seed trees was quite small. High mortality of seedlings, saplings, and young trees not reflected in merchantable timber loss has in many cases very probably resulted in setting the succession in some sprayed forest areas back for many years. But these losses--of growing stock and seed sources--though very real, could not be evaluated with the precision of the assessment of merchantable timber damage; damage to seed sources could not quantitatively be evaluated at all. Any rehabilitation efforts ought to be based upon careful on-the-ground studies of these two elements of damage.

Damage due to bombing and shelling, whether or not it was associated with herbicide treatment, may well be the most serious and long-lasting of all the war impacts on the inland forest. In the large areas cleared by bombings, not only the merchantable timber, when present, was destroyed but so was all of the growing stock in the opening. Extending far beyond the dimensions of the opening in the forest created by the bomb strike is the damage to living trees caused by shrapnel. These metal fragments in the living trees have already created serious problems for the manufacturers of forest products in SVN in terms of equipment maintenance, loss of yield, reduction in mill productivity, and serious hazards to the operating personnel, and these problems may well persist after the effects of the herbicide operations have disappeared. These problems may indeed reduce both the establishment of new wood-based industries in SVN and the opportunities to sell South Vietnamese logs in the international market, even if the fiscal position of the country improves with respect to the international monetary market so as to render this economically feasible. On a national scale, the economic loss of forest products as a result of herbicide treatment in SVN may not be great. There may be, however, acute localized effects. For example, because of herbicide damage, loggers from a village may have to go a greater distance to harvest trees. This added distance may raise their costs (in terms of money or time) to a point where alternative employment becomes desirable if not a necessity. Considering the substantial displacement of people caused by the war that is not responsive to economic factors, this effect is at present impossible to assess.

Future development of a viable forestry program in SVN, including forest management and development of utilization facilities, will have to include a study of the unusual conditions which have been caused in some forest areas by war damages, separately and in combination. Areas where growing stock and seed sources have been depleted will need to be given special treatment to restore productivity. The longer the delay in taking these measures the more difficult and costly will be the rehabilitation.

Harvesting patterns and utilization practices will have to be devised that will maximize salvage from damaged areas and speed up the development of these areas as productive forests, capable of contributing to the economic progress of the people of SVN, particularly that portion of the population that depends upon the forest and its products for its livelihood.

Since war damage from all causes has undoubtedly resulted in changes in species mix and timber quality, any plans and programs directed at rehabilitation of the damaged areas will require a greater knowledge of the regeneration and growth potential of native species and particularly of the quality and of the present and future utilization potential of these same species.

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C. Mangrove Forests

Mangrove forests form an extensive vegetative cover on sediments in salt and brackish water (see Map of Major Vegetation Types in Map Section). They are of some importance in the country's economy because of the number of products obtained from them-firewood, charcoal, timber, tannin, and dyes. They also provide a breeding place for birds, mammals, and fish, and produce organic materials that are absorbed as food by off-shore marine life and stabilize nutrient cycles, as well as provide protection against erosion.

Rollet (1962), using aerial photography taken in 1952-1953, estimated 725,000 acres (290,000 ha) of mangrove forests and 425,000 acres (190,000 ha) of *Melaleuca* woodlands (see Section II E).

Data from the analysis of photography indicate that 262,347 acres (104,939 ha) of mangrove forest have been sprayed by herbicides. This is 36 percent of the total mangrove forest of SVN. Some 12 percent of the *Melaleuca* woodlands (59,260 acres [23,704 ha]) have also been sprayed with herbicides.

In its initial study of the mangrove forests of SVN, members of the Committee made observations from helicopters and light planes. As far as security permitted, observations from the water and on the ground were made in the Rung Sat and in the Ca Mau Peninsula.

Additional studies of mangrove biomass and productivity were carried out in Thailand.

More than 40 species of trees and other plants are commonly found in the mangroves of SVN, but only a few play a major role. *Avicennia alba*, *Rhizophora mucronata* and *Sonneratia alba* are among the first species to invade newly available mud and sand banks. Next, *Ceriops tagal*, *Bruguiera parviflora*, and *Rhizophora apiculata* seedlings also take root, particularly in the *Avicennia* stands, while *Rhizophora mucronata* establishes itself in *Sonneratia* stands. *Rhizophora* and *Bruguiera* species in pure or mixed stands occupy over 75 percent of the area of a well-developed mangrove forest in SVN such as found in the Ca Mau Peninsula.

Sonneratia caseolaris and a palm, *Nypa fruticans*, are characteristic plants found on the banks of the brackish rivers that intersect the mangrove forests. Another palm, *Phoenix paludosa*, and the fern *Acrostichum aureum* become established in the intermediate zone between the inundated mangrove and the non-flooded forests. As the ground is built up and salt water tides are prevented from penetrating, a fresh-water swamp develops in which *Melaleuca leucadendron* usually becomes the dominant species.

(1) Effects of Herbicides on Mangrove Species

From observations in the sprayed mangrove areas of SVN it is clear that applications of Agent Orange and Agent White at a rate of three gallons per acre are lethal to most mangrove species.

Phoenix paludosa appears to suffer substantial damage from one spray including destruction of much of the crown, but the survival rate is high. However, numerous seedlings of Phoenix have also been found growing under the dead fronds. Ceriops and Excoecaria seem like Phoenix to be relatively resistant, as evidenced by several large trees growing in an area where Rhizophora and Bruguiera had been killed by herbicide spray. However, they are usually killed by two or three applications of the herbicide (Fig. IV C-1). Practically all the Ceriops and Excoecaria trees visible on current air photos are almost certainly survivors of herbicide treatment rather than new seedlings, since they are of large size.

One genus of mangrove trees consistently seen alive in many herbicide-sprayed areas was Avicennia (Fig. IV C-3). Surviving trees typically have a cylindrical trunk 8 to 20 in. (20 to 50 cm) in diameter and 6.6 ft (2 m) high with regeneration from the top of the trunk. At some locations in the Rung Sat, it was observed that the surviving Avicennia trees had grown from stem buds but these shoots had been trimmed for firewood. The recovered trees are no more than 10 to 13 ft (3 to 4 m) high. Several of these trees have been observed on photographs made before and after spraying, and on the ground. A number of these surviving trees, as well as Phoenix and Ceriops in herbicide-treated parts of the Rung Sat occur in a pattern suggesting streaks of incomplete overlap between parallel spray patterns. These observations suggest that Avicennia may survive a reduced dosage or even the usual spraying of 3 gal./acre of Agent Orange or Agent White. Surviving Avicennia trees were also commonly found along the banks of streams which are the sites usualy occupied by this species.

Detailed observations of mangroves in the Rung Sat and Ca Mau areas will be presented since these were the main areas of Committee work on this topic.

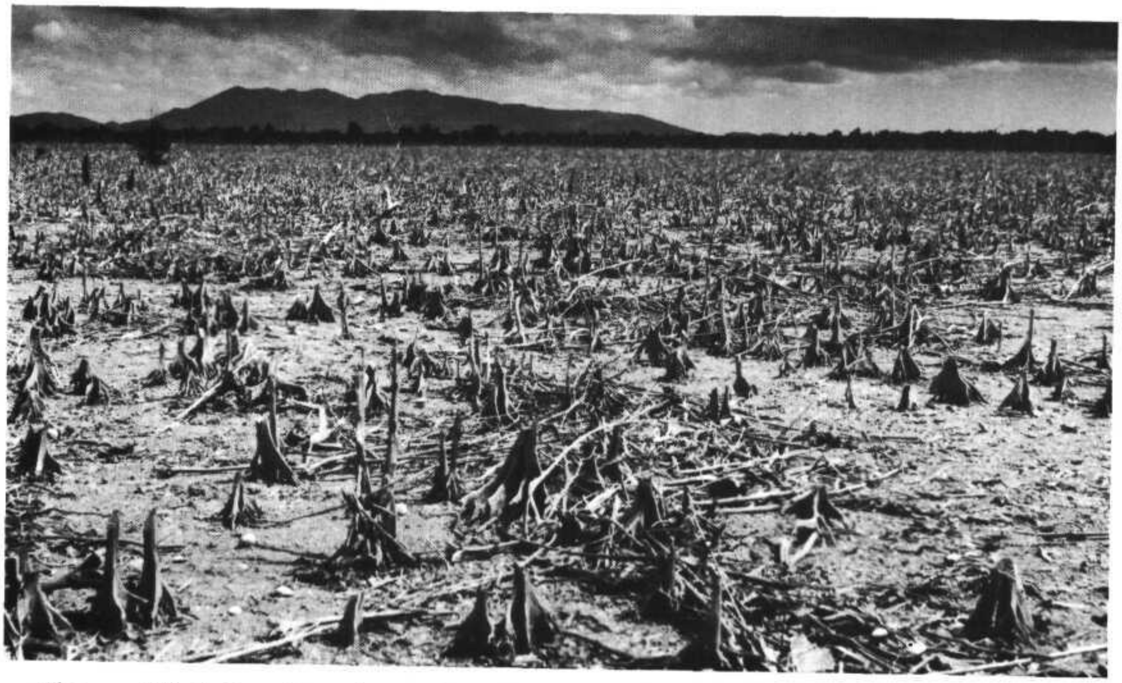

Fig. IV C-1. Remains of a dense stand of Ceriops tagal in the Rung Sat Special Zone. Dead trees were cut for firewood and charcoal. Photo taken by Dr. C. P. Weatherspoon, December 15, 1972.

Fig. IV C-2. Numerous Ceriops tagal seedlings in the Rung Sat Special Zone above edge of high tide as indicated by moist dark soil in background. Stumps are mainly Ceriops tagal. Avicennia officinalis, and Phoenix paludosa in background. Photo taken by Dr. C. P. Weatherspoon, December 15, 1972.

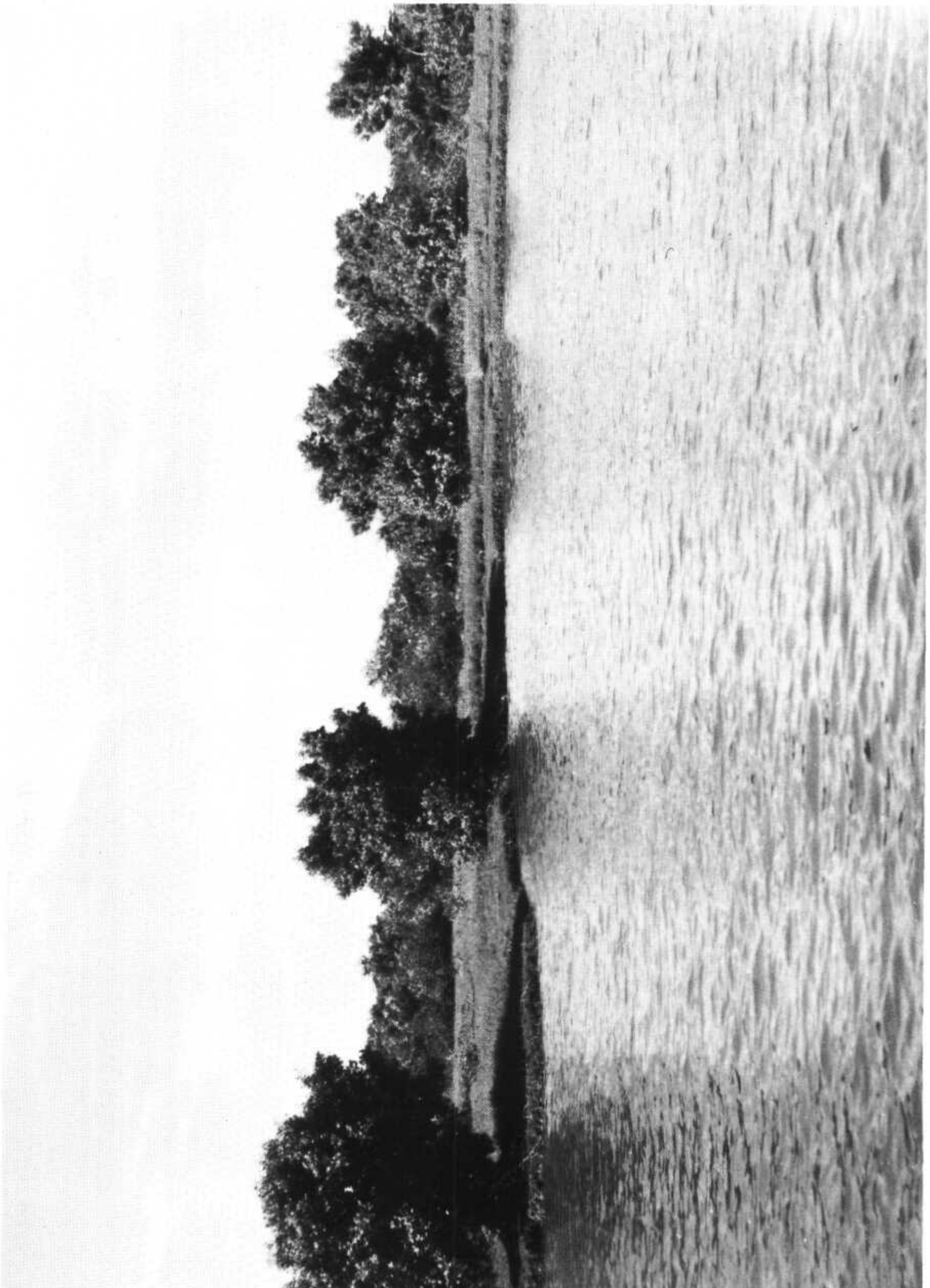

Fig. IV C-3. Surviving <u>Avicennia officinalis</u> along stream banks covered with mats of <u>Paspalum vaginatum</u> in the Rung Sat. Photo taken by Dr. C. P. Weatherspoon, December 15, 1972.

(2) The Rung Sat

The Rung Sat includes approximately 405 mi^2 (1053 km^2) of tidal swamp interspersed with many channels. Analysis of aerial photography by the Committee indicates that before the spraying of herbicides, approximately 51 percent of the area of the Rung Sat was covered by mangrove trees, 23 percent of the area covered by water, i.e., streams, 8 percent cultivated, 6 percent abandoned cultivation, 5 percent brush, 5 percent bare ground, and 2 percent cultural features. The land is so low lying that the highest tides during June-July and December-January cover the entire area. The Delta is formed of recent alluvia from deposits of the Saigon, Dong Nai, and Thi Vai Rivers and the sea. The soil is predominantly acidic clay, with large quantities of sulfides, which become oxidized to sulfates when exposed to air. A strip of sandy soils is found from Dong Hoa to Can Gio along the coast and extending some distance inland. These are often used for intensive agriculture.

The mangrove vegetation of the Rung Sat prior to the increased American military presence of the 1960's was a secondary formation, having been cut over and disturbed for many years. Rice farmers and fishermen living around the perimeter of the mangroves gathered construction wood and firewood. The only primary formations of mangroves probably were on the northern half of Phu Loi Island; these were not cut by the villagers as they were considered sacred and served as shelter from the monsoon winds (Vu Van Cuong, 1964).

Approximately 57 percent of the Rung Sat area was sprayed with herbicide between 1965 and 1970 (see Table IV C-1 and Figs. IV C-6 and C-7). In flying over the Rung Sat one gets the impression of large areas of denuded soil or mud flats with scattered trees or clumps of trees (Fig. IV C-4). In order to quantify the changes in the Rung Sat a South East to North West transect across the area was analyzed comparing 1958 World Wide Survey black and white photography (1:45,000 scale) with 1972 color photography (1:5000 scale). The transect is 18 miles (28.8 km) in length and 3750 ft (1125 m) in width (Fig. IV C-5). Eighty-five percent of the transect was sprayed from 1965 to 1970. The remaining unsprayed area, which is mainly under cultivation, is located in the northwest end of the transect.

By 1972, as can be seen in Table IV C-2, the area occupied by living mangrove trees declined from 55 percent to only 15 percent of the sprayed area of the transect, whereas bare soil with no vegetation had increased from 2.3 to 34.6 percent. The percentage of the vegetation types in the unsprayed portion of the transect has changed only little over the time period. In addition, *Phoenix paludosa* now occupies approximately 4 percent of the sprayed area of the transect and is not found in the unsprayed area of this transect.

Fig. IV C-4. Oblique photograph of the Rung Sat Special Zone and Saigon area taken January 29, 1972.

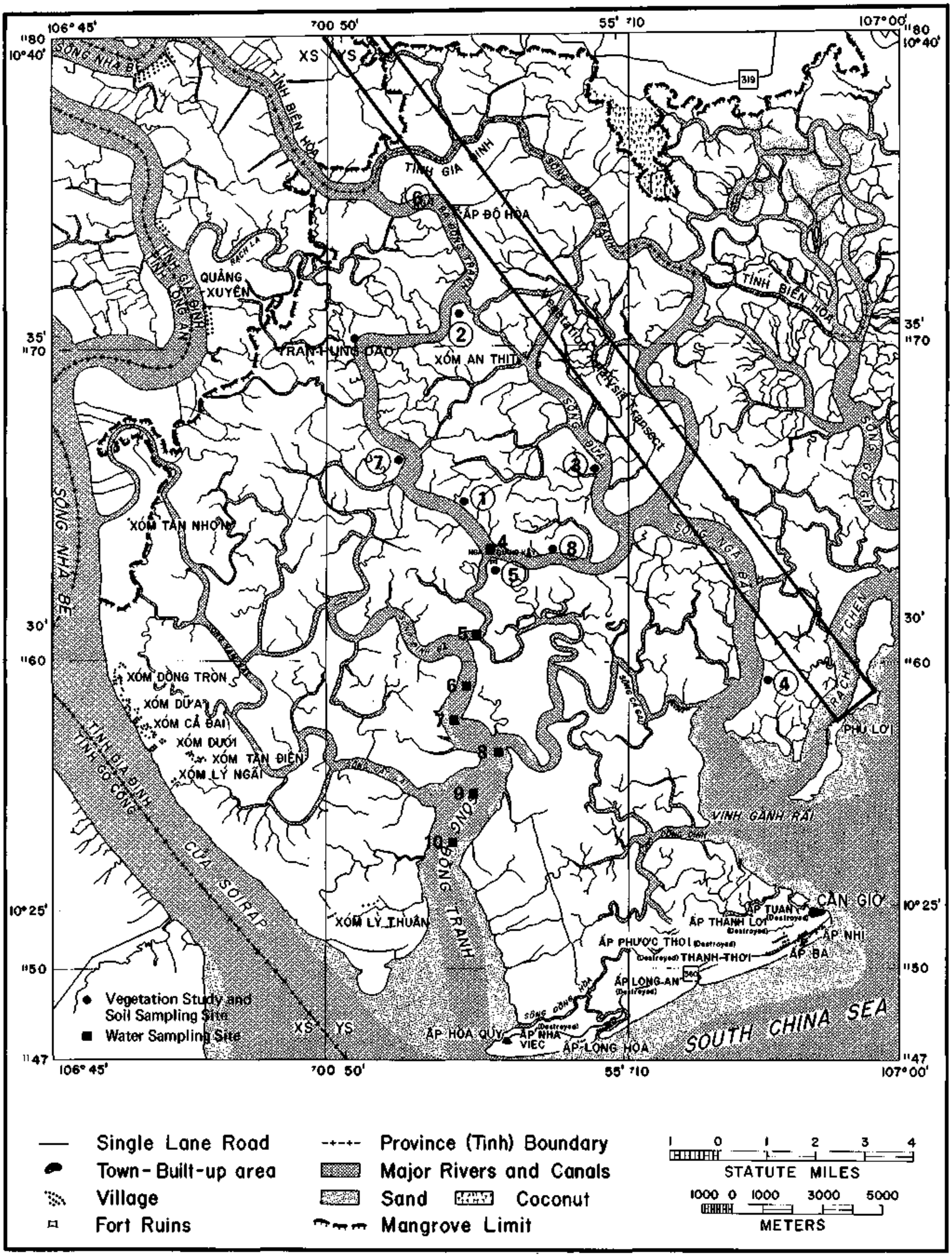

Fig. IV C-5. Soil, Water and Vegetation Study Sites in the Rung Sat Special Zone.

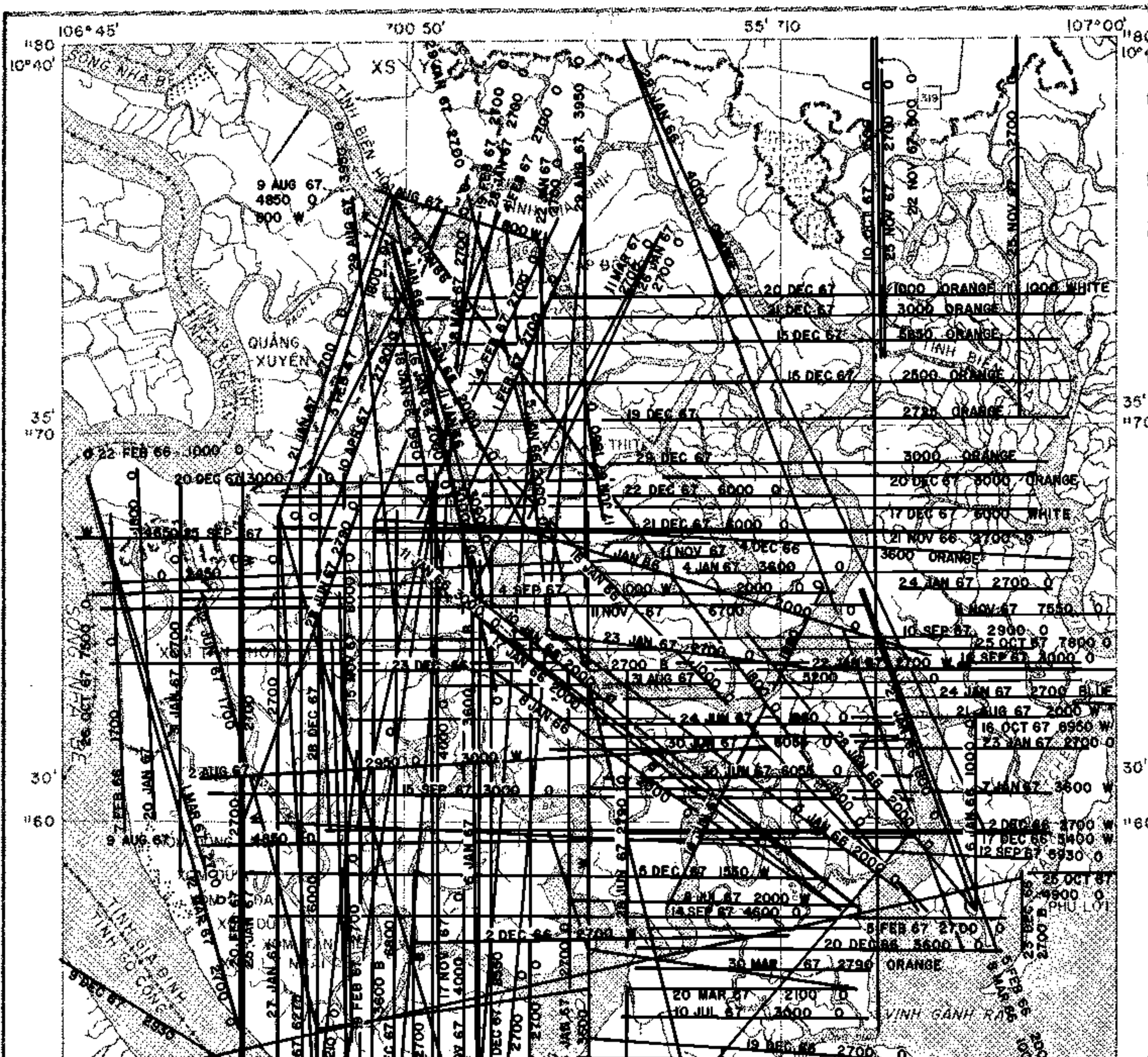

Fig. IV C-6. Herbicide Spray Missions 1966-1967 in the Rung Sat Special Zone. Data from HERBS tape includes date of mission, number of gallons, and type of Agent.

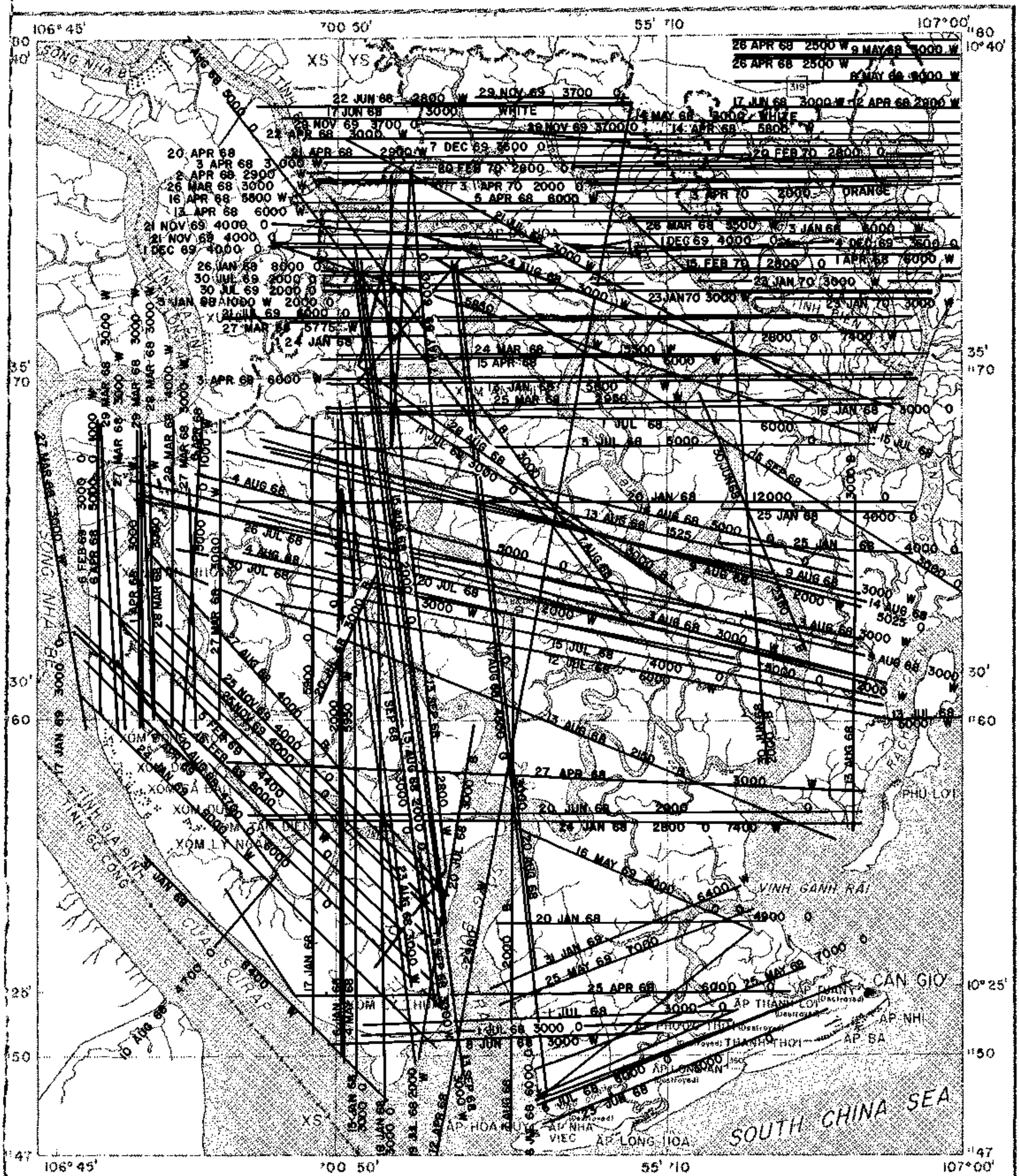

Fig. IV C-7. Herbicide Spray Missions 1968-1970 in the Rung Sat Special Zone. Data from HERBS tape includes date of mission, number of gallons, and type of Agent.

Table IV C-1

Classification of the Rung Sat with Percent Sprayed and Unsprayed

Unit	Percentage of Area in 1958	Percentage Sprayed	Percentage Unsprayed
Trees	51.2	33.5	17.7
Formerly Cultivated	6.3	2.6	3.7
Brush and Herbaceous Vegetation	4.9	3.9	1.0
Cultivated	7.9	0.8	7.1
No Vegetation (Total)	5.4	3.3	2.1
Bare Soil		0.5	0.9
Mud Flats		1.0	0.1
Tidal Flats		1.8	1.1
Cultural Features	1.6	0.1	1.5
Water (Total)	22.7	13.1	9.6
Small Streams < 40 m		4.6	3.8
Medium Streams 40-200 m		2.4	1.3
Large Streams > 200 m		6.1	4.5
Totals	100	57.3	42.7

Note. The table shows the percentages of the various surface and vegetation types ("units") that were sprayed in the course of the herbicide operations. The pre-spray composition is taken from the 1958 World Wide Survey Photography, the percentage sprayed and unsprayed from 1972 photography. Between 1958 and 1972, some non-herbicide-related changes in the units may have occurred, e.g. abandonment of additional cultivated land or conversely extension of such land. The analysis of the transect (see Fig. IV C-5) indicates however that such changes were quite small (see Table IV C-2).

Table IV C-2

Comparison of Sprayed and Unsprayed Portions of the Rung Sat Transect in 1958 and 1972
(From 1958 WWS photography, 1972 Committee photography)

Unit	Percentage of Unit in Area - 1958		Percentage of Unit in Area - 1972	
	Sprayed	Unsprayed	Sprayed	Unsprayed
Trees	55.0	5.6	15.3	6.7
Formerly Cultivated	1.9	5.5	2.1	3.0
Brush and Herbaceous Vegetation	8.2	0.5	11.6	1.8
Cultivated	--	1.1	--	2.0
Debris	--	--	0.3	--
No Vegetation (Total)	2.3	0.1	34.6	0.4
Bare Soil	0.4	0.1	20.4	0.2
Mud Flats	0.8	--	0.4	--
Tidal Flats	1.1	--	13.4	0.2
Craters	--	--	0.4	--
Cultural Features	0.1	0.1	0.2	0.3
Water (Total)	18.0	1.6	20.7	1.0
Small Streams < 40 m	4.0	1.4	4.2	0.5
Medium Streams 40-200 m	2.3	0.2	2.2	0.5
Large Streams > 200 m	11.7	--	14.3	--
Totals	85.5	14.5	84.8	15.2

Note. The table compares the sprayed and unsprayed portions of the transect, as seen in the 1972 photography, with the equivalent portions of the intact mangrove (1958 photography). The small differences in the percentage coverage reflect mainly changes in the vegetation which occurred in the 14 years between the two photo coverages. The apparent difference in total sprayed and unsprayed areas (85.5 versus 84.8 percent and 14.5 versus 15.2 percent) is due to variations in the exact scale of the photos and similar factors.

(3) Ca Mau Peninsula

The southern tip of SVN, the Ca Mau Peninsula, was almost entirely covered with dense mangrove forests up to 1968. Several large rivers, the Bay Hap, Cua Lon, Dam Doi and Bo De, drain the interior sections of the Peninsula and bring salt water from the sea by a dense network of drainage streams (Figs. IV C-8 and C-12).

Up to 1928 there was indiscriminate cutting of the mangrove for charcoal from the logs and tannin from the bark. In 1928, French foresters established forest reserves and started to manage the mangroves systematically. In 1934 a major development program was established with laws regulating cutting, with canals dug for extraction of wood, and with replanting of denuded areas, all with the aim of managing the mangrove for the charcoal and tannin industries. During the next 15 years, 38,000 hectares were replanted, mainly with Rhizophora apiculata (Moquillon, 1949).

Thus, prior to the arrival of the American Forces in the Ca Mau Peninsula, the mangrove forests were mainly even-aged stands of Rhizophora apiculata with some Bruguiera parviflora. These trees often reached 100 ft (30 m) in height and 3.3 ft (1 m) in diameter. In areas in which there was a buildup of sediments near the shore, Avicennia alba and Excoecaria agallocha were the first colonizers followed by Rhizophora apiculata and Bruguiera parviflora seedlings, which rapidly attained dominance. Recorded measurements show that Rhizophora has an annual growth of 3.3 ft (1 m) in height and 0.28 inches (7 mm) in diameter and it has been calculated that it would take up to 30 years before Avicennia was replaced by Rhizophora on newly deposited silt (Moquillon, 1949). In addition to Rhizophora, Ceriops tagal could also be grown as pure stands. Inland pure stands of Nypa palm line the small streams where the salinity is lower than in the large streams leading to the sea.

Bare or grassy swamps can be found in the interior where Rhizophora trees disappear because of stagnation of brackish water diluted by rain, accumulation of decaying organic matter, a diminished salinity, and a rise in temperature.

Herbicides were first used in the Ca Mau Peninsula in 1962, when targets along the Ong Doc River and the canals between the Cua Lon and Bay Hap Rivers as well as the banks of these two rivers were sprayed. The major spray missions in this region were carried out in 1967 (Fig. IV C-9) and the damaged swaths are still clearly visible (Figs. IV C-10 and IV C-11). Current photography (1973) of the Ca Mau Peninsula shows that approximately 52 percent of the area is bare of mangrove trees.

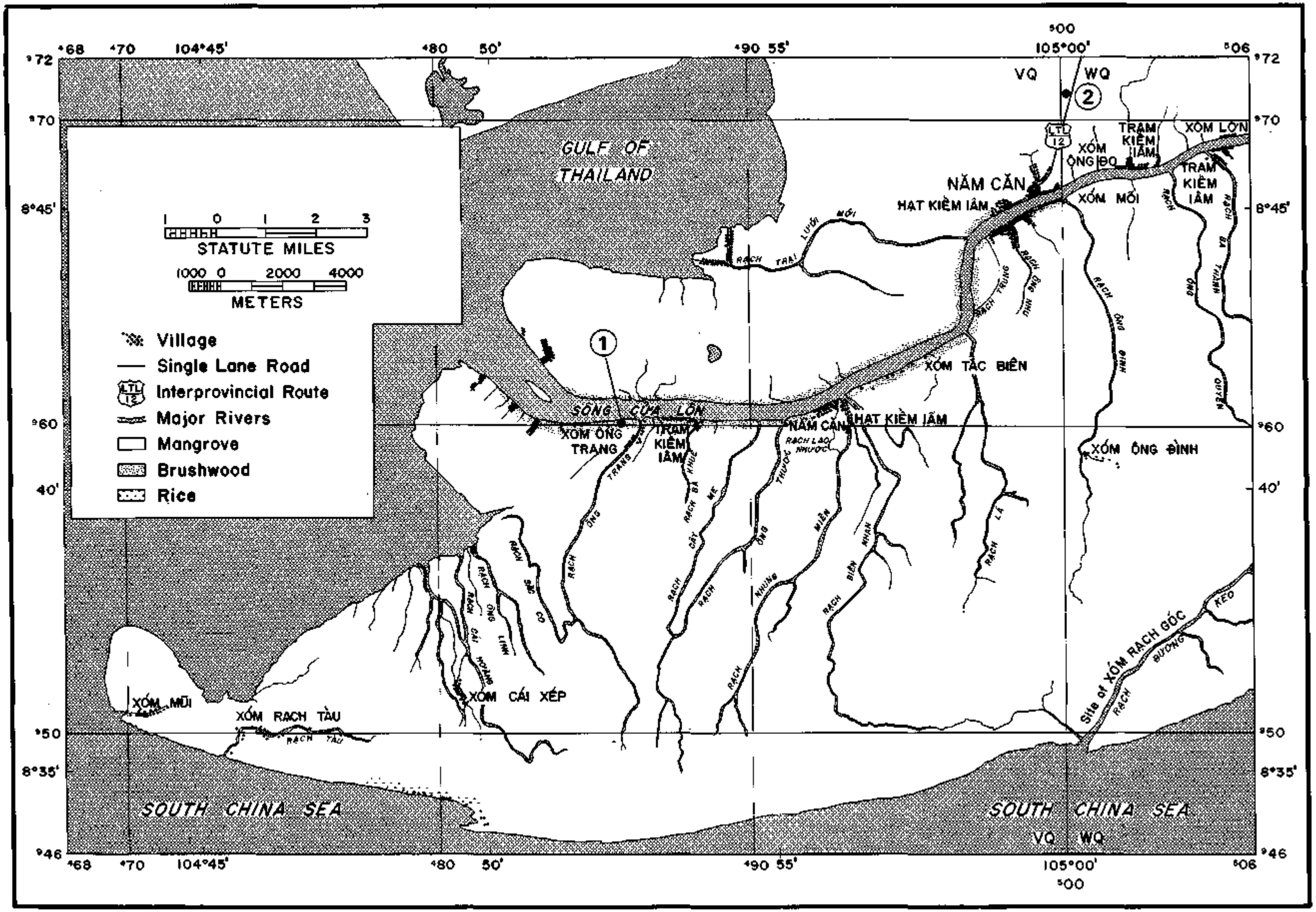

Fig. IV C-8. Tip of Ca Mau Peninsula, An Xuyen Province showing the two Committee study sites.

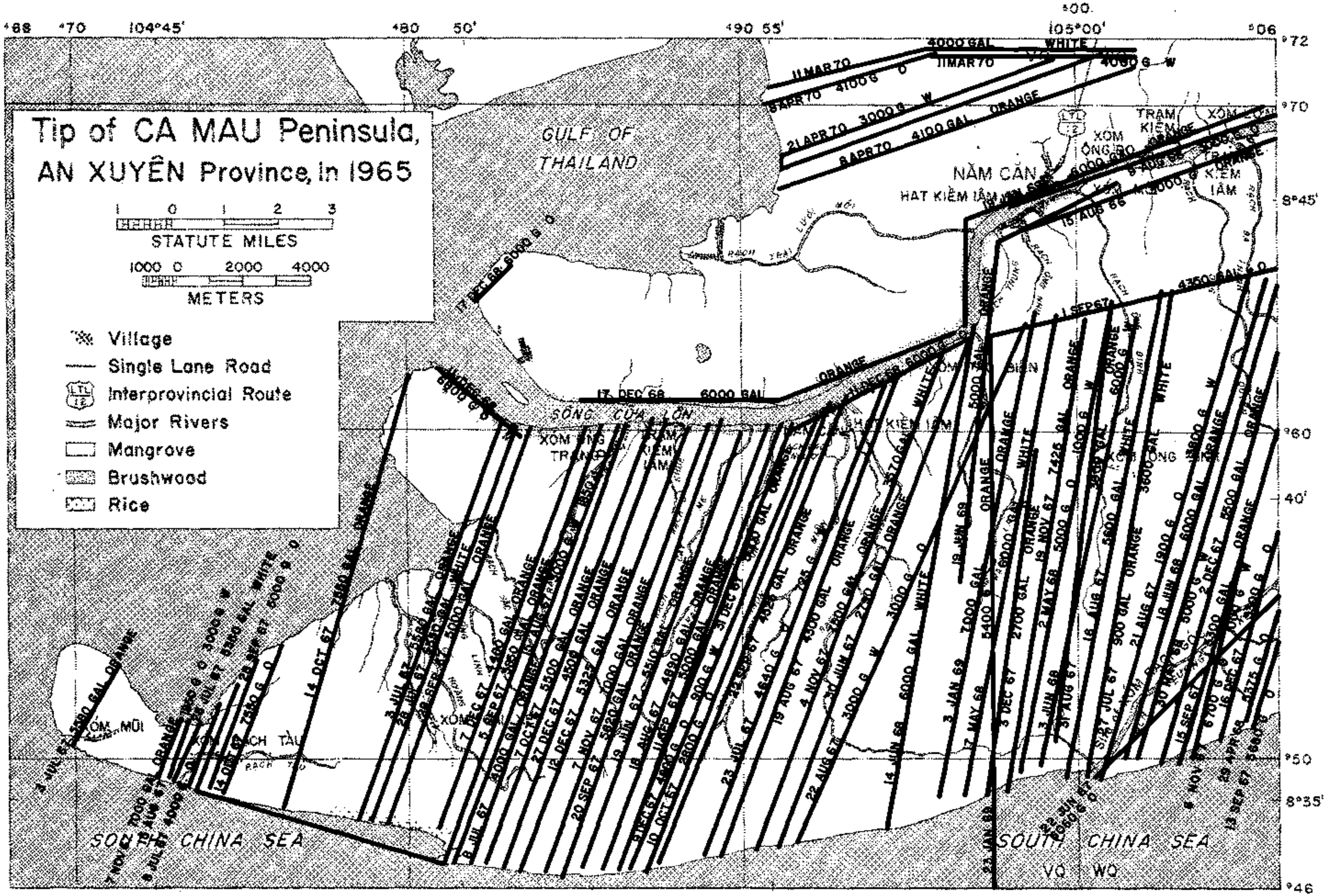

Fig. IV C-9. Herbicide Spray Missions 1966-1970 in the tip of the Ca Mau Peninsula, An Xuyen Province. Data from HERBS tape includes date of mission, number of gallons, and type of Agent.

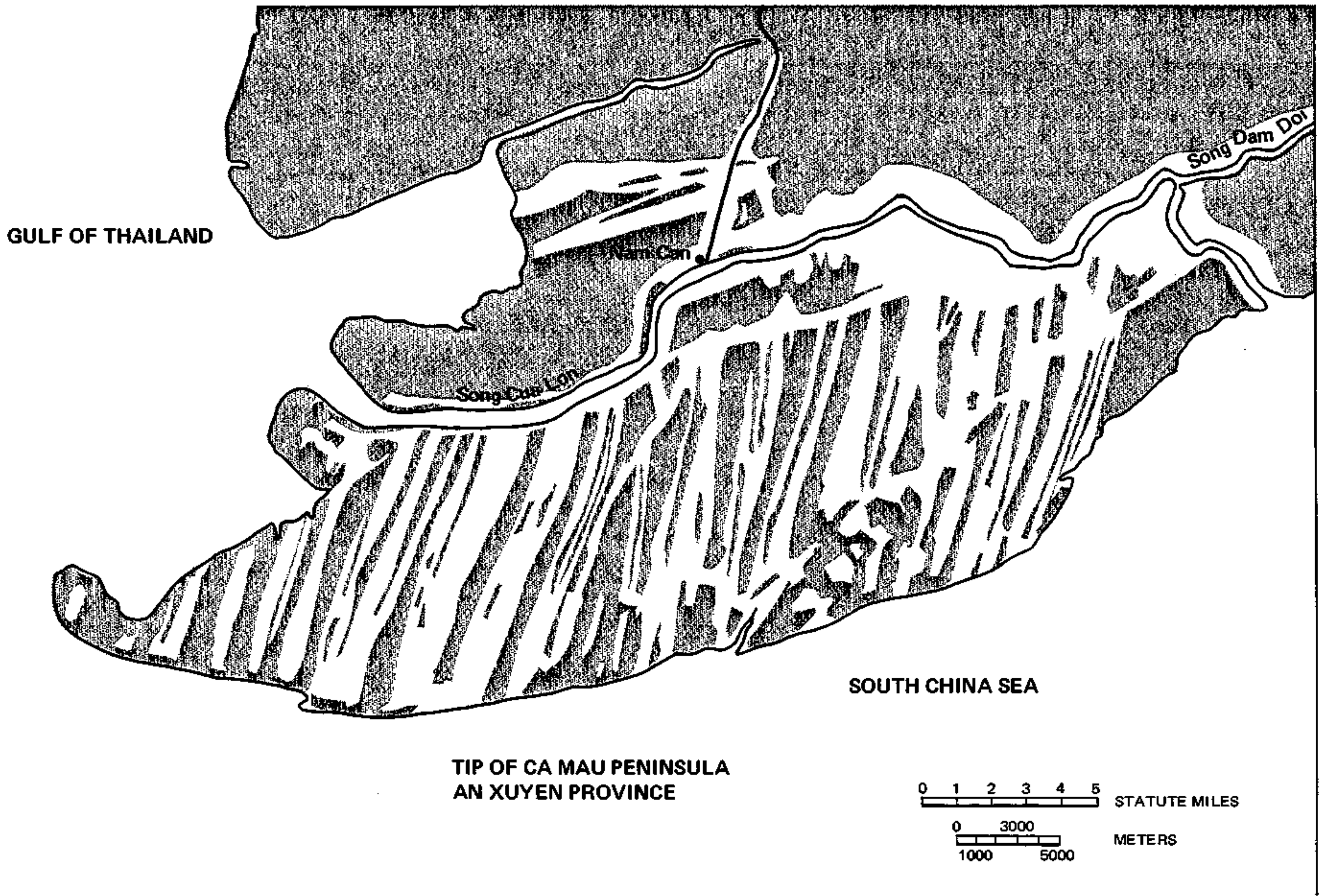

Fig. IV C-10. State of the Mangroves on the tip of the Ca Mau Peninsula, An Xuyen Province in 1972, showing bare areas from herbicide spray missions. Map drawn from 1972 aerial photography.

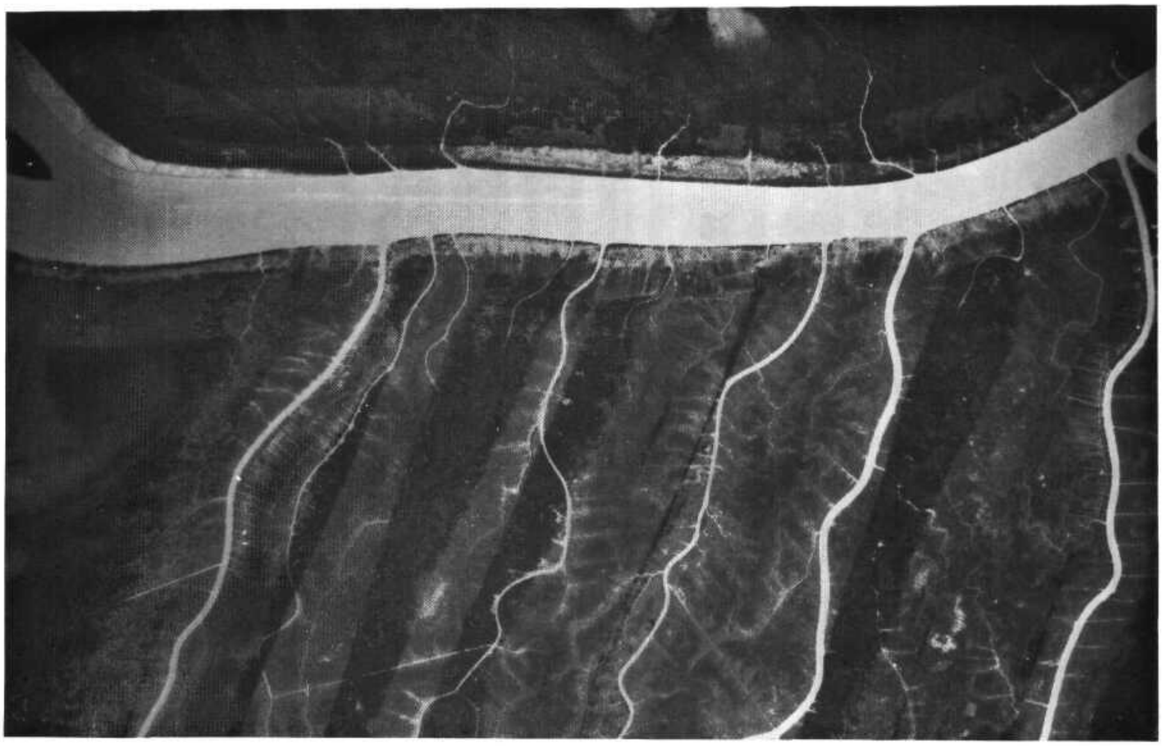

Fig. IV C-11. The Cua Lon River below Nam Can showing effects of herbicide spray missions. DOD film (U.S. Air Force) taken in May 1969.

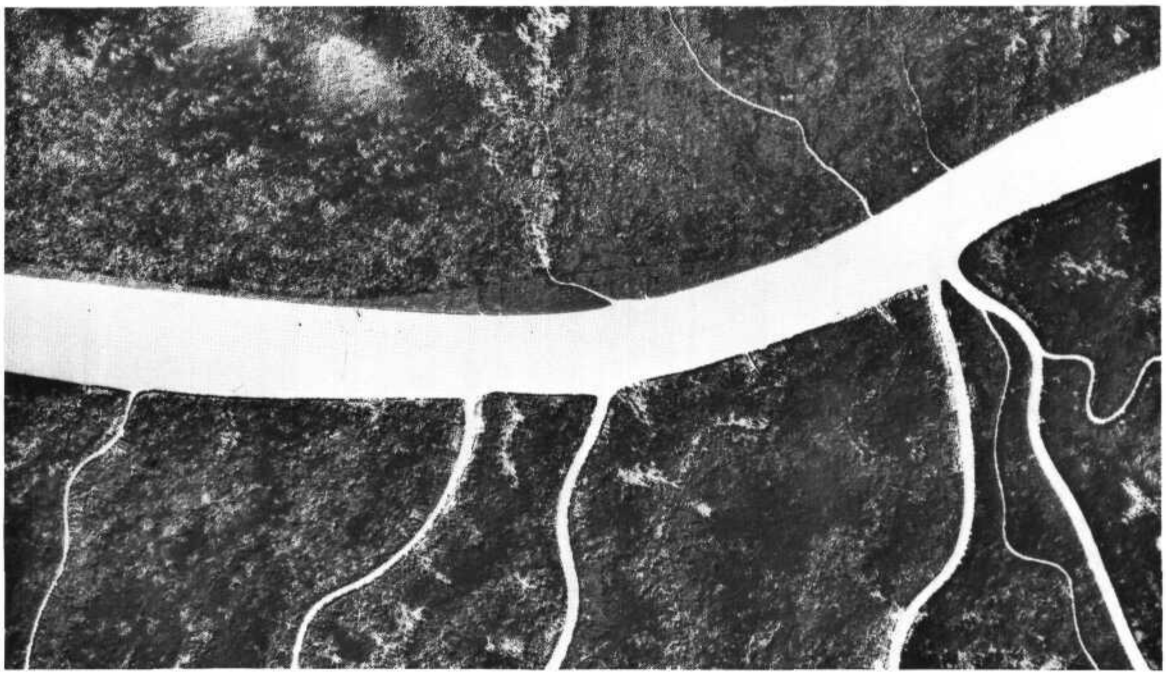

Fig. IV C-12. The Cua Lon River below Nam Can showing mangrove forests before herbicide spray missions. Aerial photo taken January 1958 by World Wide Survey.

(4) Factors in Recolonization

Revegetation comes about by two processes: the recovery of surviving damaged plants, and establishment of new plants from seedlings. Literature data and our observations suggest that success of natural regeneration in the mangrove forest depends upon depth of water, frequency of flooding, soil moisture, salinity of water and mud, nutrient availability and pH status of soil, previous occupants of the area, presence of debris on the mud surface, presence of adequate seeds and seedlings for restocking, protection of the seedlings by existing vegetation, and damage to seedlings by crabs.

Limited data gathered on depth of water, salinity and pH of the water and mud, and temperature of the mud surface suggest that these environmental conditions are in the normal range for growth of mangrove plants and should not limit regeneration according to information from various countries (Chapman, 1966; Davis, 1940; Macnae, 1966; and Watson, 1928).

The situation may be different in relatively elevated areas, which are flooded only at highest tides. Here, presumably because of high evaporation and insufficient tidal movement, higher salinity levels have been found (up to about 50 ppm, as compared to 24-32 ppm in small nearby creeks) and these and possibly also higher soil temperatures may be unfavorable for the establishment of seedlings.

Soil nutrients were found to be in a range that should not limit plant growth; in fact, the nutrient content of the soil in completely bare regions in the Rung Sat was higher than in a non-defoliated mangrove on the Ca Mau Peninsula (see Table V B), suggesting that the nutrient status of the soil was not the reason for the failure of extensive revegetation.

Herbicide determinations in Rung Sat soil and plantings of seedlings on experimental plots at different times after herbicide application to the soil, carried out by the Committee (see Section V A), showed that while there are still some herbicide residues (2,4,5-T and picloram) in the Rung Sat, they are far below levels that would inhibit seedling establishment. In fact, seedlings could be successfully planted as early as three weeks after a herbicide treatment equivalent to one herbicide mission. The experiments indicated also that the establishment of mangrove seedlings may be adversely affected if an area is cleared of vegetation. Seedling survival on such an area, cleared of vegetation by hand (with no subsequent herbicide application) was much poorer than on small plots cleared within an undefoliated mangrove. This finding can however not be generalized because survival of hand-planted seedlings in an area of the Rung Sat which had been completely denuded by herbicides was quite good (see p. IV-110).

In the Ca Mau area large quantities of stems, roots, and other trash were present on the mud surface in the bare areas and relatively few seedlings were encountered. Trash may act as a filter, preventing fruits and seedlings of mangrove plants from reaching bare inland areas, and may also cause damage to young established plants by movement of the trash through tidal wave action (Watson, 1928; Walker, 1938). On the flat banks of the larger rivers to 100 ft (30 m) inland abundant regeneration has occurred in some places.

The availability of seeds and seedlings for recolonization of the sprayed areas appears to be the major critical factor in revegetation of defoliated areas. A large number of seedlings of Bruguiera and Rhizophora were observed in floating trash on the Cua Lon River in the Ca Mau Peninsula, and many plants of Avicennia, Bruguiera, Rhizophora, and Excoecaria were observed in fruit in non-sprayed areas. These observations suggest that adequate seeds and seedlings are available for regeneration in the Ca Mau area. In contrast, relatively few seeds or seedlings were observed floating in the canals of the Rung Sat. The major remaining seed source is the northeastern area, which was not sprayed but has been heavily cut over by woodcutters. Distribution over the Rung Sat from this source would be exceedingly slow. Crabs, which were observed to be numerous, both in Ca Mau and the Rung Sat, may destroy mangrove seedlings colonizing the sprayed areas. Crab damage to mangrove regeneration in the Ca Mau is mentioned by Moquillon (1949). The Committee observed such damage to seedlings by crabs in plantings carried out near Vung-Tau, although it did not seem to be a major factor preventing establishment.

In the sprayed areas in the Ca Mau, the river and canal banks inland to 220 yards (200 m) are being naturally repopulated with the economically desirable mangrove genera, Rhizophora and Bruguiera, which should flower in four years (Fig. IV C-13). Farther inland from the canal and river banks, the process of revegetation is much slower, probably due to the trash on the ground preventing seedling distribution (Fig. IV C-14). In October 1971 this trash was in advanced stages of decay and may be gone in two or three years from then, at which time seedling dispersal over the area by water might be possible.

The Rung Sat is a different case. There are no major seed sources nearby. If allowed to develop, the living Avicennia and Ceriops--which were apparently more resistant to herbicides than other mangrove tree species--will produce seeds that will help recolonize the area (Fig. IV C-2). Given normal development, these plants should flower and fruit in a few years and would help supply seeds and seedlings. However, it appears that as soon as young trees grow to pole size they are cut and removed for firewood. The number of generations required to restock successfully the entire Rung Sat is not known. Since seed sources of the economically more valuable Rhizophora and Bruguiera are very scarce, reestablishment of a typical, mature, economically useful mangrove forest may take decades.

Fig. IV C-13. Defoliated section of canal bank of the Cua Lon River, Ca Mau Peninsula, with Rhizophora seedlings and surviving Avicennia officinalis. Area sprayed in 1967. Photograph taken October 1971.

Fig. IV C-14. Defoliated section of the mangrove forests of the Ca Mau Peninsula. Area sprayed in 1967. Photograph taken October 1971.

Because an adequate natural seed source for recolonization of the Rung Sat is not available, various methods of replanting mangrove seedlings were tested during March and August 1972 on Thanh An Island in the Rung Sat. The island had been sprayed at least once and along the west coast several times. Seedlings of *Rhizophora apiculata* and *Ceriops tagal* gathered from trees in the unsprayed areas of the Rung Sat were used in these tests. The planting tests were evaluated in December 1972. The results indicate that *Rhizophora* and *Ceriops* seedlings planted by hand in defoliated areas will survive and grow. Between 50 and 66 percent of the seedlings planted in the higher and drier areas had survived about half a year after planting; between 80 and 85 percent had survived in more moist areas.

To test a quicker planting method, seedlings of both *Rhizophora* and *Ceriops* were dropped from a helicopter. Some seedlings were packaged with sand to which a slow releasing fertilizer had been added, and were provided with "tails" (streamers of paper) assuring that they would land in an upright position. These seedlings survived and exhibited very rapid growth. Other seedlings, packaged without fertilizer or with no packaging, did not fare as well. These experiments were not extensive enough to make generalizations, and should be extended if reforestation of large parts of the Rung Sat mangrove area is considered. Together with the planting studies in the Vung Tau mangrove they suggest, however, that replanting of mangrove is possible although, if to be done on a large scale, quite a formidable task.

(5) Ecological Role of Acrostichum Aureum in the Mangrove Forest

A large fern, Acrostichum aureum is commonly found throughout the mangrove forests of the world tropics, including SVN. Usually in unsprayed or uncut mangrove forest, it occurs widely but with a small number of individuals per unit area. Concern has been expressed that this fern, which is considered a pest species, will occupy extensive areas where the mangrove trees have been clear-cut or destroyed (Figs. IV C-15 and C-16). An evaluation of aerial photos of the transect area (see above) taken before and after the herbicide operations and checked by on-the-ground observations, indicates that the area occupied by Acrostichum in the Rung Sat may have increased in this time (that is, 1958-1972) from about five to about six percent of the total area. It is however not certain whether or to what extent this is related to defoliation, since come changes in the surface "Units" (Table IV C-2) have occurred in the unsprayed part of the transect. Two-thirds of the area covered by the fern are found in the sprayed areas which were either formerly cultivated or covered with brush or herbaceous vegetation.

It is estimated that under the ecological conditions now prevalent in the Rung Sat the fern will probably not overgrow most areas where the former mangrove forest has been largely destroyed by herbicides. In some areas, the extent of which is not known, ecological conditions may well exist favoring successful germination of the fern spores, as observed at only one locality among those visited in the Rung Sat. Under such evidently uncommon circumstances, some colonization by the fern will no doubt occur; but if a year of close observation of the same sites is a valid measure of fern colonization, it will be a slow process on the bare areas. Finally, where seedlings and saplings of the woody mangrove species develop in a stand of fern, the increasing shade formed as the forest canopy is gradually restored will be expected ultimately to eliminate the fern.

Fig. IV C-15. Dense vegetation of Acrostichum aureum in the Rung Sat. Photograph taken by Dr. Howard J. Teas on November 8, 1972.

Fig. IV C-16. Acrostichum aureum in the Rung Sat. Photograph taken December 1972.

(6) Estuarian Studies in the Mangrove Forest

Studies on the effect of defoliation of the mangroves on the estuarian ecosystem were carried out in the Rung Sat Special Zone. The physical nature of the water, the plankton, and fish in the Rung Sat area and at a control site not defoliated near Vung Tau were studied in October-November 1972 and January 1973 (Fig. IV C-17). The molluscan fauna in these same areas was also examined.

A comparison of Rung Sat and Vung Tau water suggests that water temperature and pH were similar in the two areas, while dissolved oxygen was lower and turbidity was higher in the Rung Sat. As expected, turbidity was lower in the dry season, in both the Rung Sat and Vung Tau areas. Salinity in the Rung Sat also was lower, as would be expected, since there is an influx of fresh water from the Saigon and Dong Nai Rivers into this area. Salinity was also higher in the dry season in both the Rung Sat and Vung Tau areas. Plant and animal plankton samples collected suggest that both areas are rich in variety of planktonic organisms and in numbers of individuals, but the variety and number in the Rung Sat is lower than at Vung Tau. These organisms also tend to be more numerous in the wet season in both the areas. Fish eggs were more frequent in the Rung Sat, as were fish larvae, but the distribution of catches was more even in Vung Tau, and Vung Tau also had a greater variety of fish larvae (15 families in the wet season, 17 in the dry for Vung Tau versus 9 in the wet season and 11 in the dry season in the Rung Sat collections). In contrast, larger fish were more abundant in Vung Tau, but the variety of fish was about the same in both seasons. Benthic collections were difficult to evaluate and although more individuals were collected at Vung Tau the data are too limited for a conclusion of area difference (Table IV C-3).

The observations suggest that the defoliation of the mangrove forest in the Rung Sat produced for several years a large increase of decomposed organic matter which may have increased some components of estuarine life and fish production, lowered oxygen and through increased turbidity diminished some phytoplankton production. By 1973 with the dead mangrove material now removed by wood cutters, decomposed or washed out to sea, this organic source has decreased but it is uncertain whether phytoplankton production will increase enough to compensate for the lower food source until mangroves or other vegetation recovers.

The total marine (including estuarine) fish catch in SVN by motorized fishing boats has somewhat increased in the years of herbicide operations (1962-1969) although the increase was small and irregular (Table IV C-4). In contrast, the mean catch per boat has declined, except that a slight upswing is indicated in 1969. This decline may reflect economic, social, technological and other changes (e.g., increased use of motorized craft; in SVN, also decreased safety and hence reduced operation times) as much as, and possibly more than, changes in the water and biota. However, the mean catch per motorized fishing boat for Taiwanese trawlers in the South China Sea and Thai trawlers in the Gulf of Thailand increased over the same time span (Table IV C-4). Loftas (1970) reported that "the size of fish caught (by Vietnamese fishermen) has decreased until the more popular species have had to be protected by setting size limits."

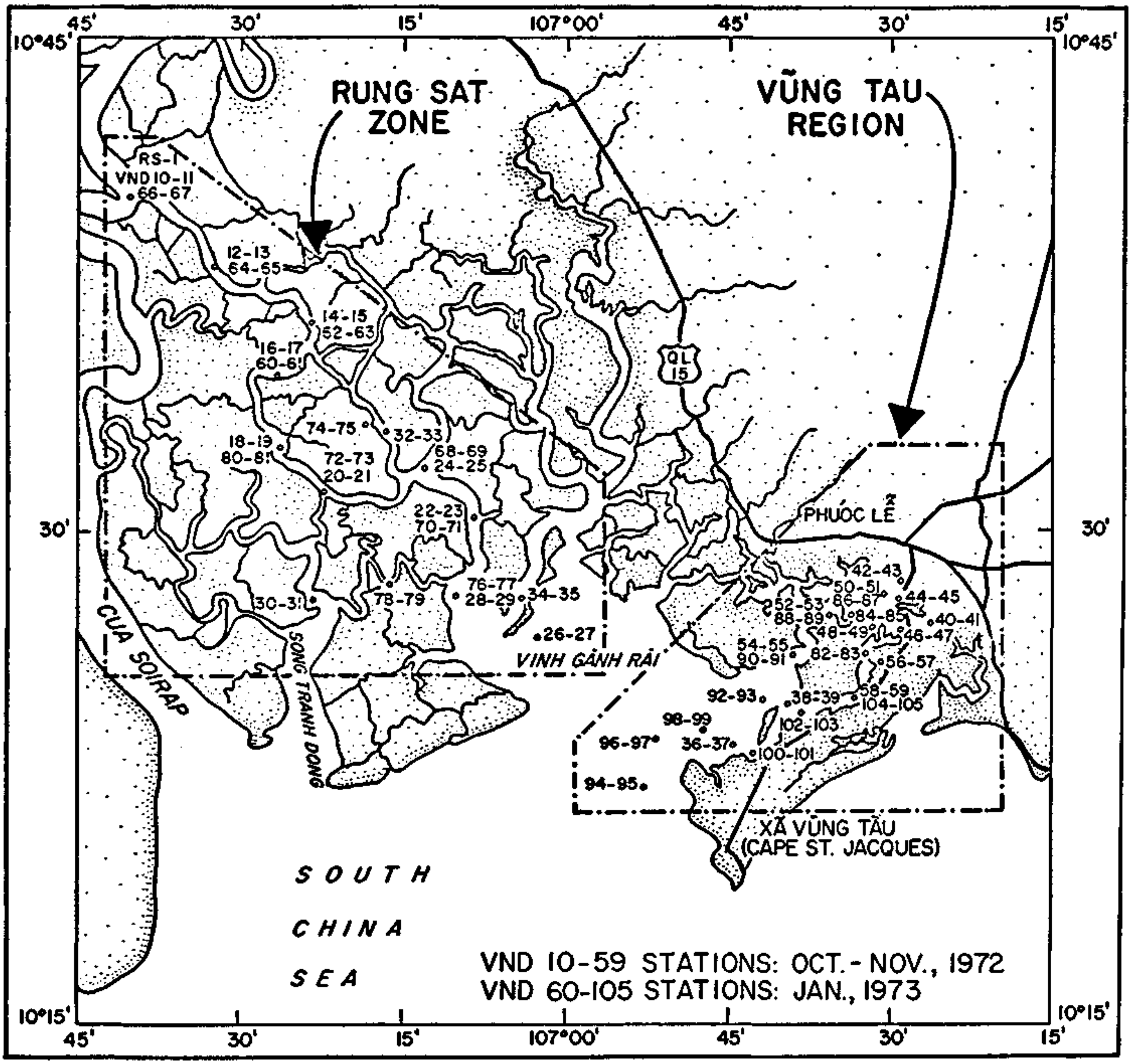

Fig. IV C-17. Location of collecting stations in the Rung Sat Special Zone and the Vung-Tau Region, SVN, 1972 and 1973.

Table IV C-3

Summary of hydrographic and biological data collected in mangrove region of South Vietnam, 1972-73. Rung Sat is defoliated; Vung Tau is non-defoliated (control region). Wet-season collections were made in October and November, 1972. Dry-season collections were made in January, 1973. Numbers are means of collections at stations shown in Fig. IV C-12.

	Rung Sat wet	Rung Sat dry	Vung Tau wet	Vung Tau dry
Average values for each area				
Temperature, °C	28.8	27.4	29.5	26.8
Oxygen, ppm	4.1	4.4	5.6	6.4
Oxygen saturation, %	67	67	90	98
Salinity, o/oo	11.5	17.0	27.8	30.7
pH	7.5	7.4	8.0	7.9
Turbidity, JTU[a]	62	55	8	4
Number of organisms				
Copepods[b]	127×10^3	117×10^3	273×10^3	114×10^3
Diatoms[b]	106×10^4	456×10^2	511×10^4	229×10^3
Fish eggs[c]	422	2,242	277	1,146
Fish larvae[c]	1,864	10,469	268	274
No. fish families[d]	9	11	15	17
Sponges	1	0	8	6
Corals, etc.	5	6	44	29
Worms	15	249+	101	66
Clams, etc.	35	11	104+	28
Crustaceans	783	2,741	1,207	1,712
No. crustacean families	13	18	19	19
Sea stars, etc.	4	2	81	28
Fish	104	215	240	250
No. fish families	17	10	17	16

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[a] Jackson Turbidity Units

[b] Organisms caught in a 15 minute tow of a 0.1 mm mesh, 0.5 m mouth diameter plankton net.

[c] Organisms caught in a 15 minute tow of a 0.5 mm mesh, 0.5 m mouth diameter plankton net.

[d] Remaining organisms in list were caught in a 15 minute tow of a stretched mesh, otter trawl trynet.

Table IV C-4

Catch (metric tons), number of trawlers, and catch per motorized fishing boat in the South China Sea and the Gulf of Thailand, 1952-1970.
Data from Brouillard (1970), Shindo (1973) and Viet Nam Statistical Yearbook (1971).

	Vietnamese vessels, coastal South Viet Nam			Japanese trawlers, South China Sea			Taiwanese trawlers, South China Sea			Thai trawlers, Gulf of Thailand		
	catch, tons x 1000	trawlers	effort	catch, tons	no. trawlers	effort	catch, tons	no. baby trawlers	effort[a]	catch, tons x 1000	no. trawlers	effort
1952	-[b]	-	-	3,079	14	219	-	-	-	-	-	-
1953	-	-	-	11,730	30	391	-	-	-	-	-	-
1954	-	-	-	12,045	31	388	2,214	468	4.3	-	-	-
1955	-	-	-	8,171	23	355	2,623	558	7.8	-	-	-
1956	-	-	-	8,389	30	279	3,657	685	7.8	-	-	-
1957	-	-	-	10,283	29	354	4,802	867	6.9	-	-	-
1958	-	-	-	16,461	74	222	4,837	862	7.6	-	-	-
1959	-	-	-	8,155	23	354	5,518	918	8.8	-	-	-
1960	-	-	-	5,647	14	403	6,040	962	9.1	-	-	-
1961	-	-	-	1,007	10	101	7,122	1,044	9.1	123	201	612
1962	-	-	-	384	4	96	6,984	964	12.7	151	976	155
1963	299	9,220	32	166	2	83	8,529	1,195	14.2	277	2,026	136
1964	314	9,710	32	0	0	0	11,905	1,386	15.5	372	2,360	158
1965	289	12,240	24	0	0	0	13,666	1,501	20.8	393	2,396	164
1966	287	16,770	17	0	0	0	16,857	1,756	28.2	449	2,695	166
1967	319	23,195	14	0	0	0	23,310	1,979	32.0	583	3,077	189
1968	321	29,968	11	0	0	0	30,061	2,374	29.1	784	3,182	247
1969	355	39,001	9	0	0	0	32,886	2,278	33.9	908	3,185	285
1970	442	42,603	10	0	0	0	34,751	2,129	40.8	-	3,114	-

[a] Annual total per gross ton
b Data not available.

The molluscan fauna on the land near the water locations were also studied. While the collections were very limited in time, number, and area, the data indicate a rich molluscan fauna in the region of interest. The molluscs presently characteristic of the Rung Sat are those able to tolerate the heat on the mud flats, and which can obtain food under the open conditions. Where grass and trees occur, the molluscan fauna is richer and it may be expected that the fauna will recover fully if the forest is reestablished.

(7) An Estimate of Requirements for Restoration of Defoliated Mangroves

The preceding discussions have considered various individual components of the mangrove separately. In conclusion, it will be useful to consider the mangrove and its environment as a single system.

As was shown in Table IV C-1, before herbicide spraying about 51 percent of one of the major mangrove areas of SVN, the Rung Sat, was forest and 23 percent was water; the rest was bare soil, brush, and cultivated land. Fish, shrimp and other food chain organisms in the waters were receiving organic matter from three sources: (1) three inflowing rivers, (2) the mangrove itself, and (3) photosynthesis of phytoplankton. Organic matter influx from these sources is typical of all mangroves. A vigorous tide exchanged most of the estuarine waters with the South China Sea every few days. Oxygen levels in the water were apparently between 5 and 6 ppm, which is slightly below saturation but is expected where there is high oxygen consumption by organic matter coming in from rivers and swamp. Acidity was in the range of pH 6-7 in low salinity zones, gradually going up to the usual value of pH = 8.2 in the open sea. The waters were slightly turbid, as is characteristic of a river delta region.

After spraying, and as examined in 1972, defoliation and other changes such as increased river traffic, dredging, and more use of motorized fishing vessels had affected the mangrove and aquatic ecosystem in several ways. Increased turbidity of water due to organic detritus from decomposing mangrove and to greater siltation evidently contributed to decreased phytoplankton and zooplankton, thereby lowering oxygen levels to between 3 and 4 ppm. There was no significant change in pH during this period. These effects may also have influenced the fish and other higher organisms in the system, although we do not know what part of the decline in fish catch per unit effort was due to loss of mangrove habitat, to overfishing, increased water turbidity, or other factors.

Because some of the foods for aquatic life in the estuary are being sustained by decomposition of the dead mangroves in the sprayed areas a continuing decline in this fraction of the estuary's nutritional status may be anticipated. If revegetation of this area is delayed, there will be a delay in restoring the mangrove component to the fishery food chains. However, if the fraction of organic matter that comes from the rivers does not change, the phytoplankton may increase again as turbidity decreases, and its contribution to aquatic productivity may increase.

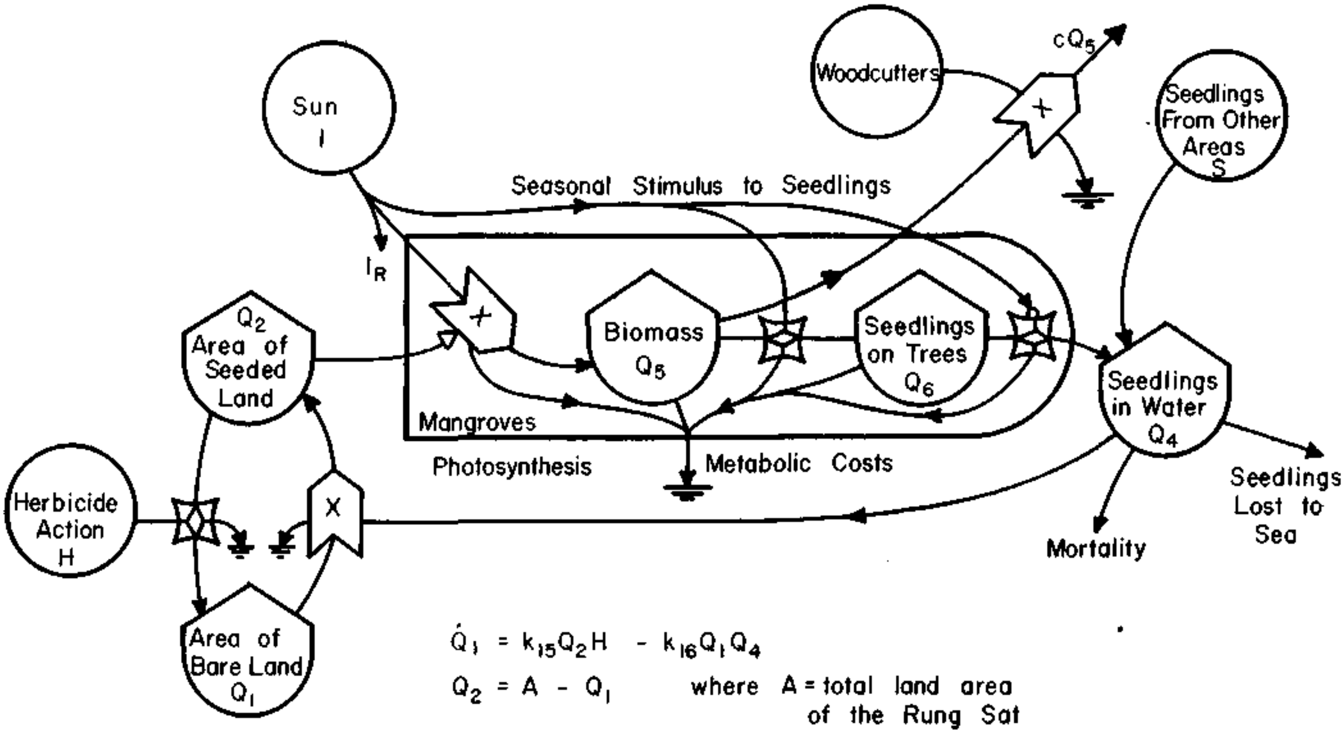
These considerations suggest that not only the mangrove forest, which of itself has some economic value, but also the estuarine systems may depend on recolonization of the sprayed mangrove forest. One major impediment of recovery in the Rung Sat is the availability of seeds and seedlings. Some mangroves, e.g., Rhizophora, reproduce by means of large seedlings which do not drop from the parent tree until they are eight inches (20 cm) long or more; others, e.g., Avicennia, by nut-like fruits. In all types of mangrove trees the seedlings or nuts float, and are dispersed by tidal water. In managed Rhizophora mangrove forests the recommended practice for artificial regeneration is to start two seedlings per square meter (about 11 square feet). In the Rung Sat, far too few trees have remained to supply that quantity of seedlings or fruits. The undefoliated mangrove areas to the East, in Phuoc Tuy province, are not large enough to provide sufficient seedling and fruit numbers either and are moreover so located in relation to the Rung Sat that the fruits or seedlings which are released into water do not effectively reach the bare areas. Cutting for firewood keeps the trees moreover scrubby, with large specimens producing high seed yields relatively few. There is also a large mortality of fruits and seedlings between the time of their release and establishment of a sapling tree.

Following from these considerations, a calculation was made of the number of seedlings required to reestablish an acre (0.4 ha) of mangrove forest under various management plans over a series of years. This was done with the aid of a model of mangrove reforestation simulated on a computer. The model and the principal equations entering into it are shown in Fig. IV C-18. The derivation of the model is given in the working papers which form part of the background material for this Report. As should be noted the model shows that the main factors controlling the reestablishment of mangrove in bare areas are supply and survival of seedlings. As new trees grow up they begin to produce seedlings and those from trees along channels are contributed to the general pool in tidal waters. If woodcutting is as extensive as it now is, with few large seedling trees remaining, then seedling shortage may continue for many years. The figures actually used in the calculations, and their sources, are given in the upper part of Table IV C-5. Where no information from the Rung Sat, or SVN in general, was available, data from mangroves in other countries were used. The calculations were made for Rhizophora, because certain data (seedling production, planting density for reforestation) are available mainly for this genus and because this is the economically most valued genus of mangrove trees in SVN. The results are given in Table IV C-5, lower part, and Fig. IV C-19.

The results show that in the central Rung Sat, the number of seedlings becoming established is only a tiny fraction of that required for rapid reforestation (Table IV C-5). To achieve full stocking--that is, coverage of the entire defoliated area with mangrove trees or seedlings--in 50 years, 15 surviving seedlings per acre are estimated to be needed each year from seed producing trees or from areas outside the defoliated acre. Given the various assumptions and approximations in Table IV C-5, calculation of the rate of natural revegetation under existing conditions without introduction of seedlings from the outside suggests that revegetation would require as much as 120 years (Fig. IV C-19). Artificial revegetation methods such as aerial or hand planting could reduce the time required to reach full stocking. Thus, 100 years could probably be saved by broadcast of 1000 seedlings per acre per year, and about 70 years by using one-fifth of this number (Table IV C-5, Fig. IV C-19). If seedlings were hand planted, fewer would be required.

The Committee is aware and has already pointed out that artificial revegetation of large mangrove forest areas is a formidable task. The whole Rung Sat is about 1053 km^2 or about 260,000 acres in size. Fifty-seven percent or about 150,000 acres have been defoliated. Thus, 150,000,000 seedlings or the seedling yield of over 5000 to 10,000 acres (over 2000 to 4000 ha) of mangrove forest would be needed annually. Such numbers may only be obtainable from other parts of Southeast Asia where there are active management programs, adding to the money and manpower requirements. The above calculations are however not made in order to imply that a revegetation program of this scale should be started as soon as possible, but to provide a measure of the time and effort needed for restoration of destroyed mangrove. It should also be borne in mind that the above calculations involve a number of assumptions the degree of accuracy of which is uncertain. Thus, we have assumed 65 seedlings to be naturally established by 1972 per acre in the Rung Sat, but on our visits to different parts of the area we found a great variation in this number, including areas of at least one acre with not a single mangrove tree seedling. If such areas are extensive, natural revegetation will clearly require even more time than in our estimate. With artificial revegetation methods, however, the effect on the estimates would be small because the naturally established seedlings represent in any case but a small fraction of the introduced ones. On the other hand, we have assumed a survival of only 10 percent (Table IV C-5, item "Number colonizing bare areas"). In our own planting experiments in the cleared area near Vung Tau (see Section V A-3) survival was indeed of this magnitude, but in hand plantings in a completely defoliated area in the central part of the Rung Sat it ranged between 50 and 85 percent (Section IV C-4). If survival should be closer to the latter figures, recovery with artificial planting would take less time than estimated above, or alternatively less seedlings would have to be introduced to accomplish recovery in a given time. The use of the Rung Sat as the example probably also overstates the entire case insofar as this is the mangrove region with the largest continuous areas with little if any vegetation left. In other mangrove regions like the Ca Mau Peninsula, individual defoliated areas are relatively smaller and intermingled with intact ones (see Figs. III B-8, IV C-10, and IV C-11), and this should improve the prospects for natural revegetation and reduce the effort or the time which would be needed for artificial replanting.

One question that arises in any reforestation problem is the availability of plant nutrients in the soil. Herbicide operations in the mangrove were often followed by woodcutters who removed the remaining above-ground parts of the dead mangrove trees, and at least in some areas even the stumps are being dug out. Thus, nutrients present in the wood are removed from the system. However, soil analyses in intact, defoliated and hand-cleared mangrove (Section V B) suggest that changes following removal of vegetation have been at the most small. Phosphorus seems to be supplied in considerable amounts by the riverflow each year. Thus, lack of soil nutrients does not appear to be nearly as serious a factor as seedling supply.



$$\dot{Q}_1 = k_{15}Q_2H - k_{16}Q_1Q_4$$

$$Q_2 = A - Q_1 \quad \text{where } A = \text{total land area of the Rung Sat}$$

$$I_R = I - k_2Q_2I_R$$

$$\dot{Q}_4 = k_{11}Q_6 - k_{12}Q_4 - k_{13}Q_1Q_4 + S$$

$$\dot{Q}_5 = k_3Q_2I_R - k_6Q_5 - k_7Q_5 - cQ_5$$

$$\dot{Q}_6 = k_8Q_5 - k_{10}Q_6 - k_9Q_6$$

Fig. IV C-18. Model and equations used for estimating seedling and time requirements for revegetation of defoliated mangrove (Rhizophora) as shown in Fig. IV C-19.

Symbols:

= energy inputs into the system from the outside

= energy storages within the system

= multiplier control actions for one factor onto another

= on-off switching actions

= energy leaving the system after its work has been done

In the diagram, energy is shown going into mangrove biomass in proportion to the area of seeded land and the intensity of sunlight. Mangrove biomass losses occur through several pathways including woodcutting, growth of seedlings on trees, respiration, and mortality. The storage of seedlings is balanced by an inflow of mangrove biomass and losses due to metabolism and seasonal release into the water. The seedlings floating in the water are the balance of those falling from the trees, those from other areas, those washed out to the sea, mortality, and those colonizing bare land to form seeded land. Seeded land is shown to become bare land in proportion to herbicide action. These relationships are written also in equation form.

Explanation for the Items in the Equation for the Model in Fig. IV C-18

A. Forcing Functions (outside influences)

- I = Solar energy flux hitting the mangroves of the Rung Sat
- H = Herbicide application to mangroves of the Rung Sat by the U.S. military
- S = External seedling source that may be needed to regenerate the mangroves

B. State Variables (levels considered important in the model)

- Q_1 = Mangrove land that has been converted to bare land by herbicide spraying
- Q_2 = Land occupied by mangroves in the Rung Sat
- Q_4 = Seedlings that are present in the water at any chosen period in time for the entire Rung Sat
- Q_5 = Total biomass of the Rung Sat mangroves
- Q_6 = Seedlings that are present on the mangroves of the Rung Sat

C. Process Variables (rate coefficients)

- k_2 = Light utilization ($1.43 \times 10^{-3} km^{-2}$)
- k_3 = Photosynthetic conversion ($7.54 \times 10^{-6} kcal^{-1}$)
- k_6 = Respiration ($5.85 \times 10^{-1} yr^{-1}$)
- k_7 = Growth of seedlings on trees ($1.311 \times 10^{-1} yr^{-1}$)
- k_8 = Production of seedlings (5.17 seedlings $kg^{-1} yr^{-1}$)
- k_9 = Seedlings fall into water ($2.02 \times 10^{-1} yr^{-1}$)
- k_{10} = Seedlings remain beneath parent tree (1.0 yr^{-1})
- k_{11} = Seedling availability to colonize ($2.15 \times 10^{-3} yr^{-1}$)
- k_{12} = Loss of seedlings in water (1.05 yr^{-1})
- k_{13} = Seedlings colonize new areas ($4.2 \times 10^{-2} yr^{-1}$)
- k_{15} = Conversion of seeded land to bare land ($4.8 \times 10^{-7} liters^{-1} yr^{-1}$)
- k_{16} = Conversion of bare land to seeded land ($2.56 \times 10^{-8} seedlings^{-1} yr^{-1}$)
- c = Wood cutting ($3.06 \times 10^{-2} yr^{-1}$)

Table IV C-5

Seedlings Numbers for Reforestation of *Rhizophora*

Data on Seedlings	Seedlings per Acre
Recommended planting for reforestation[a]	8,000
Spontaneously established in central Rung Sat by 1972[b]	65
Number produced on an acre of large, well-nourished trees[c]	28,000
Number surviving within a scrubby, cut-over forest in Vietnam[d]	14,400
Number reaching open water from seed source areas[e]	450
Number colonizing bare areas by calculation[f]	12
Computer Simulations (see Fig. IV C-18)	
Number of seedlings starts from outside that must survive each year to achieve full canopy in 50 years[g]	15
Number of seedlings starts from outside that must survive each year to achieve full canopy in 15 years	75

[a] Moquillon (1944), Noakes (1955).

[b] Counts of seedling in 50 ground photographs taken in 1972.

[c] Counts from Puerto Rico, Florida and SVN.

[d] Counts at Vung Tau, March 1972.

[e] Seedlings produced on the edge of tidal canals where ratio of canal margin to swamp area is about 2 m/100 m^2 and 83 seedlings overhanging per meter of canal per year; seedling area 100 m^2 (Rookery Bay, Florida).

[f] One-quarter reaching bare areas and 10 percent of these surviving.

[g] Assumes that seedlings are intorduced from outside each year, and that the stated number of seedlings survives at least to the end of the first year, thereafter to be subject to normal mortality. Regeneration will be to an extent determined by land uses.

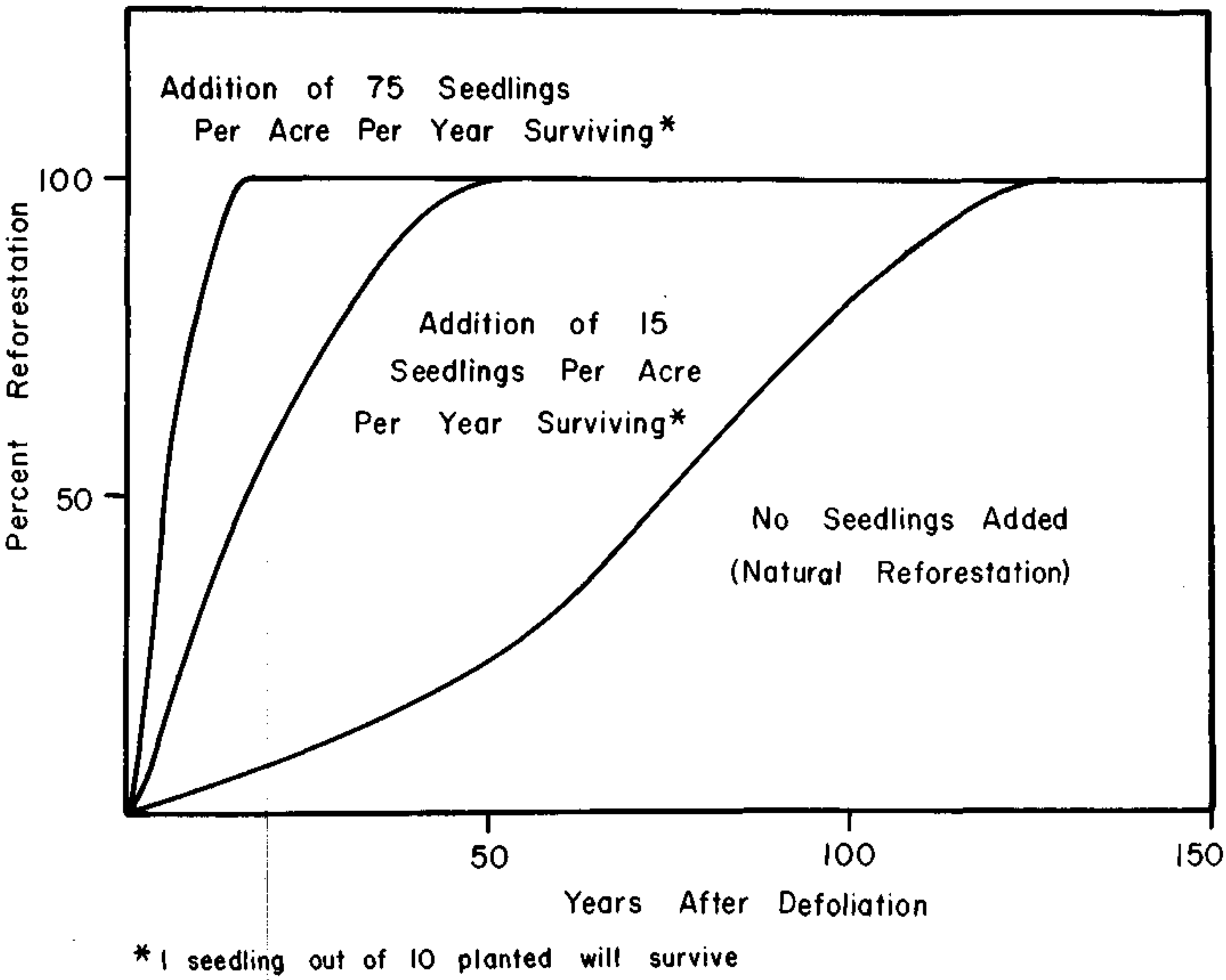


Fig. IV C-19. Computer prediction of reforestation of Rung Sat mangroves with and without planting by man. Woodcutters harvest 3% of forest each year. Productivity of the forest is 16 tons per acre per year (1360 gms per m^2 per year).

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V. EFFECTS ON SOILS

Our studies on soils fall into two categories: (1) on persistence and disappearance of herbicides, and (2) on changes in soil properties and processes which may affect nutrient storage of a soil. They were done in South Vietnam, Thailand, and the Philippines.

A. Persistence and Disappearance of Herbicides

How long will a herbicide that has been introduced into the environment persist, how soon will it disappear? This is an obvious question, particularly when herbicides have been used at levels considerably higher than are usual in agricultural practice. There are also ecological implications. Where effects of defoliation persist, as in the mangrove, one wants to know whether this is because the herbicides have remained active, or because other changes were induced by the herbicides even though the latter themselves may have disappeared.

The Committee approached the problem of herbicide persistence in two ways: (1) by collecting and subsequently analyzing soil samples (and a few water samples) from areas which had been sprayed during the war, as far as possible selecting sites which had received particularly high doses; and (2) by spraying the soil surface with herbicides at known rates after it had been cleared of all vegetation, and then studying the change in concentration of the compounds over a period of time. The second approach was necessary because the number of samples that could be obtained in heavily defoliated areas was limited by security problems. Also, the Committee started its work a year and a half after the cessation of large-scale defoliation, and it seemed essential to observe the early stages of the behavior of the herbicides in the soils of SVN and similar regions.

The spraying equipment used was calibrated to apply the volume of liquid per unit area required and to give as uniform coverage as possible. Checks of actual dosages applied, determined by chemical analysis, verified the accuracy of our application.

Samples were taken either from the soil surface to a depth of 5 in. (12.5 cm) with metal cans, or with special samplers 30 or 36 in. (75 or 90 cm) long. The latter samples ("cores") were usually divided by depth into two or three sections. The total number of soil samples analyzed was about 750. Herbicide residue levels were determined either chemically or by "bioassay." Chemical determinations were carried out with the most up-to-date techniques for residue analysis (electron capture gas chromatography). Most of the analyses were done at the Huntingdon Research Centre in England, and selected samples were cross-checked at the Gulf South Research Institute, New Iberia, Louisiana. In the mangrove soils and in all samples with low residue levels, near the detection limit, the agreement between the two determinations was satisfactory, but in forest soil samples with higher levels, the GSRI values were considerably lower than the HRC values. In the following, we use the HRC results as their control tests (samples taken immediately after spraying) were very close to the theoretical values. The results are here expressed as pounds of herbicide (acid equivalents) per unit surface area (acre). Three gal./acre of Orange correspond to 12 lb/acre of 2,4-D and 13.8 lb/acre of 2,4,5-T; 3 gal./acre White to 6 lb/acre of 2,4-D and 1.6 lb/acre picloram. The concentrations resulting in soil and water from these application rates are given in Table II C-1. The bioassay techniques consisted of sequential plantings of various crop species, or in the case of mangrove forest soils, of seedlings of mangrove species, and subsequent observations on the development of any herbicidal symptoms.

(1) <u>Analysis of Soil from Areas Sprayed during the Military Herbicide Operations</u>

Soil samples from areas sprayed during or in connection with the military herbicide operations were obtained in two sites in Thailand near Pran Buri, and in four locations in SVN. The Thai sites were:

(a) An experimental forest plot that had been sprayed by aircraft in 1965 with 9.1 lb/acre Orange and 0.5 lb/acre picloram. (Eight samples were collected in September 1971.)

(b) The "Calibration Grid" which had been used for calibrating aerial herbicide spray equipment, and the center of which had received truly formidable amounts of herbicide in 1964-65: ca. 840 lb/acre 2,4-D, 960 lb/acre 2,4,5-T, 57 lb/acre cacodylic acid, and 20 lb/acre picloram. (Eight samples were collected in September 1971.)

The locations in SVN were:

(a) A "dump site" in the Di-An District, Bien-Hoa Province, on which the entire load of an airplane (1000 gallons Orange) had been released in December 1968 from a height of 1800 ft (540 m), an altitude over ten times higher than in regular herbicide missions. The location of this dump was confirmed by villagers. (Five samples were taken in October 1971.)

(b) One inland forest site near Cau Muoi-Mot, ca. 8 miles or 11 km northeast of Dong-Xoai, Phuoc-Long Province which had been sprayed once with White and once with Orange in 1968-69. This is the same site on which studies of the condition of the forest on the ground were made and soil samples taken for nutrient content analyses (Section IV B and V B). (Four samples were collected in October 1971.)

(c) Five different mangrove sites (see map, Fig. IV C-5--Study Sites 1, 5, 7, 8, and 9) in the center of the Rung Sat Special Zone which had been sprayed quite heavily. Herbicide mission records indicate that between 1965 and 1968 one of the sites (No. 1) received about 86 lb/acre 2,4-D, 79 lb/acre 2,4,5-T, 3 lb/acre picloram and 9 lb/acre cacodylic acid, and possibly more. (Three surface samples were taken in October 1971, 17 core samples were taken in October 1971 and March and August 1972.)

(d) Two sites in the mangrove of the Ca-Mau Peninsula. One of these, immediately outside Nam-Can Naval Base (see map, Fig. IV C-8) had been sprayed with unknown amounts of Orange. The other (Site 2 on the map, Fig. IV C-8) about 3 miles (5 km) to the north northeast had been the target of a Purple mission in 1962 (not shown on that map) and an Orange and two White missions in March-April 1970, a year and a half before sampling. (Three samples each were collected in October 1971.)

The results were briefly as follows:

(a) Of the six samples (about 26 to 32 in. = 65 to 80 cm deep) from the Pran Buri Calibration Grid, all contained picloram at 0.24 to 1.09 lb/acre; four contained 2,4,5-T at 0.06 to 1.35 lb/acre; and two contained 2,4-D at 0.16 and 0.19 lb/acre[a]. The higher picloram and 2,4,5-T levels are sufficient to cause severe damage and death in many broadleaf plants. Except in one sample, which contained high levels of picloram throughout its whole length, high levels of both herbicides were limited to the uppermost part of the cores, i.e. the top 10 or 20 in. (25 or 50 cm) of the soil.

(b) Of a total of 17 core samples (nominal length, 30-36 in. or about 75-90 cm) of Rung Sat mangrove soils, 11 contained 2,4,5-T in at least one of the parts of a three-section core. Two out of three surface samples also contained measurable quantities of 2,4,5-T. Of all 20 samples, four contained picloram, usually in all sections. The levels of 2,4,5-T ranged between 0.02 and 0.24 lb/acre (detection limit in different analyses, 0.006 to 0.04 lb/acre), those of picloram from 0.002 to 0.01 lb/acre (detection limit, 0.001 to 0.008 lb/acre). On the basis of published information, for a combination of certain soils and sensitive species, these quantities may be expected to cause herbicide symptoms but they are generally at the lower limit of effect.

(c) No herbicides were detected in the soil samples from the experimental forest plot at Pran Buri, the Di-An dump site, the Dong-Xoai forest site, and the two Ca-Mau mangrove sites (detection limits: 2,4,5-T, 0.005 lb/acre; picloram, 0.001 lb/acre).

(2) <u>Analyses of Water</u>

Some water samples collected in August 1972 from the lower part of the main shipping channel to Saigon (Song Dan-Xay, Song Dong-Tranh) were analyzed for picloram (sampling sites see map, Fig. IV C-5). Suspended sediment (mostly soil) was separated from the water by filtration, and the

[a] The 2,4-D was found in two samples taken from a site considered as being outside the perimeter of the Calibration Grid.

two fractions analyzed separately. No herbicide was found in the filtered water (detection limit 0.001 ppm), but the sediment of four out of eight samples contained amounts ranging from about 0.07 to 0.03 parts per billion if computed for the original volume of water, and from about 2.2 to 0.8 parts per million of dry weight of sediment. If all the herbicide in the sediment were to become available in the water, the levels would be far below the dose known to affect even the most sensitive species, but if only the sediments are considered the levels are somewhat higher than those found in the Rung Sat soil (maximum 0.01 lb/acre = 0.05 ppm). Herbicide in water is usually associated with suspended material if present, and turbid water may contain more herbicide than clear water, but the relatively high picloram content in the Rung Sat sediment is unexpected.

(3) Experiments on the Behavior of Herbicides in Tropical Soils

Experiments on the persistence of herbicides in tropical soils were carried out (a) on agricultural sites in the Philippines (Alabang near Manila) and in SVN (Ban-Me-Thuot); (b) forest soils in the Philippines (near Los Baños) and SVN (Ban-Me-Thuot); (c) mangrove soils near Vung-Tau. In all cases, the soil was cleared of vegetation by hand and was sprayed with 3 gal./acre Orange or White. Additional plots at Ban-Me-Thuot and Alabang received 1 gal./acre and 1/3 gal./acre of each agent.

In the agricultural experiments, persistence of herbicide effects was determined by planting rice, maize, sorghum, sweetpotato, mung bean, peanut, and soybean as test plants at intervals after spraying. The main criteria used were the weight of plants after four to five weeks of growth, and presence or absence of morphological symptoms characteristic of the herbicide in question, such as discoloration and distortion of the leaves, curling of the leaf margins, and curvature of stems and petioles. In the experiment with rice in the Philippines the plants were grown to maturity and the yield in threshed seeds was used to determine herbicide effects if any.

In forest soils, the herbicide levels were determined chemically, and in mangrove soils both chemically and by bioassay, making sequential planting of seedlings of two mangrove species. The mangrove experiment was done in two different ways. In one series, a relatively large area (174 by 96 ft or 50 by 30 m) was cleared, sprayed, and planted; in the other, small (one square meter or about 10.76 ft^2) plots within the forest were used so that the seedlings developed in a relatively undisturbed mangrove environment.

The principal results may be summarized as follows:

(a) The effects of herbicide residues persisting in the soil on field and vegetable crops disappeared after different periods of time, depending on the crop. Data for the application rate of 3 gal./acre are shown in Table V A-1, with lower rates (1 and 1/3 gal./acre) disappearance was, as to be expected, at least as fast and generally faster. In cereals (rice, maize, sorghum) the effects disappeared more rapidly than in broadleaf crops (sweetpotato, legumes). Effects of White on sensitive species

Table V A-1. Time in weeks between herbicide application to the soil and the first planting in which no herbicide effects were observed.

Agent, crop	Philippines Experiment: No effects on plant growth	Philippines Experiment: No morphological symptoms	Ban Me Thuot Experiment: No effects on plant growth	Ban Me Thuot Experiment: No morphological symptoms
Orange, 3 gal./acre				
Maize	4	4	4	4
Rice	6	6	10	10
Sorghum	4	4	10	10
Sweetpotato	15	15	10	10
Mung bean	4	15	17	17
Peanut	15	15	10	17
White, 3 gal./acre				
Maize	15	15	10	10
Rice	3	3	10	10
Sorghum	15	15	>10[a]	>10[a]
Sweetpotato	15	24	24	31
Soybean	--	--	24	31
Mung bean	15	24	31	31
Peanut	15	24	24	>31[a]

[a] Experiment discontinued after this planting.

persisted longer than effects of Orange; the difference is very probably due to the greater persistence of picloram, a component of Agent White. These results are in very good agreement with extensive general experience on persistence and disappearance of these herbicides in soils of temperate climates, and also with the much more limited experience with soils of warm climates. It appears that at the very latest one year after application of 2,4-D, 2,4,5-T, and picloram at the doses used in herbicide missions even highly sensitive crops such as legumes can be safely planted on sprayed soil. In the case of 2,4-D and 2,4,5-T and of less sensitive crops such as cereals the waiting time after herbicide application is considerably less.

(b) When the herbicides were applied during the dry season, they persisted in the soil without apparent loss until the onset of the wet season. Disappearance is thus dependent on a minimum water content in the soil.

(c) In forest and mangrove soils, the levels of the herbicides dropped, at first very rapidly, then more slowly, and by the end of the experiments (about 150 to 250 days) were near or below the chemical detection limit (0.02 to 0.03 lb/acre for 2,4,5-T; 0.002 lb/acre for picloram) and the limit of biological activity. An example is shown in Fig. V A-1. In agreement with these findings, the forest sites revegetated rapidly; the vegetation included highly sensitive plants. The disappearance of 2,4,5-T and picloram followed quite a similar time course, but since the initial dose of picloram was much less (1.6 lb/acre versus 13.8 lb/acre for 2,4,5-T) this means that the persistence of picloram was greater. The disappearance of the herbicides is mainly attributable to activities of microorganisms. In laboratory experiments, four soils from SVN, including mangrove soils, were found to be capable of degrading 2,4,5-T to carbon dioxide; the process exhibited similar characteristics to soils from temperate regions.

(d) Mangrove seedlings planted at different times after spraying the soil with herbicide became established as well as seedlings on unsprayed soils, nor were there any differences in growth (height) (Table V A-2). This was even true of plantings made as early as three weeks after spraying. The soil still contained measurable herbicide quantities at three weeks (see Fig. V A-1), and some of the seedlings planted on White-treated soil showed some picloram symptoms, but most of them recovered and became undistinguishable from control seedlings.

(e) Survival in the first plantings on the large cleared mangrove plot (experiment A in Table V A-2) was quite poor because the seedlings had been stored for some days and were in unsatisfactory condition. For later plantings (and all plantings on the small plots) seedlings collected on the day of planting were used, and survival was considerably better. However, even if this difference in seedling material is taken into account, the survival of the mangrove tree seedlings was much better on the small plots made in an otherwise intact mangrove than on the much larger plot that had been cleared of all vegetation (Table V A-2, compare experiments A and B)[a].

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[a] Walsh et al. (1973) have recently reported experiments on the effect of

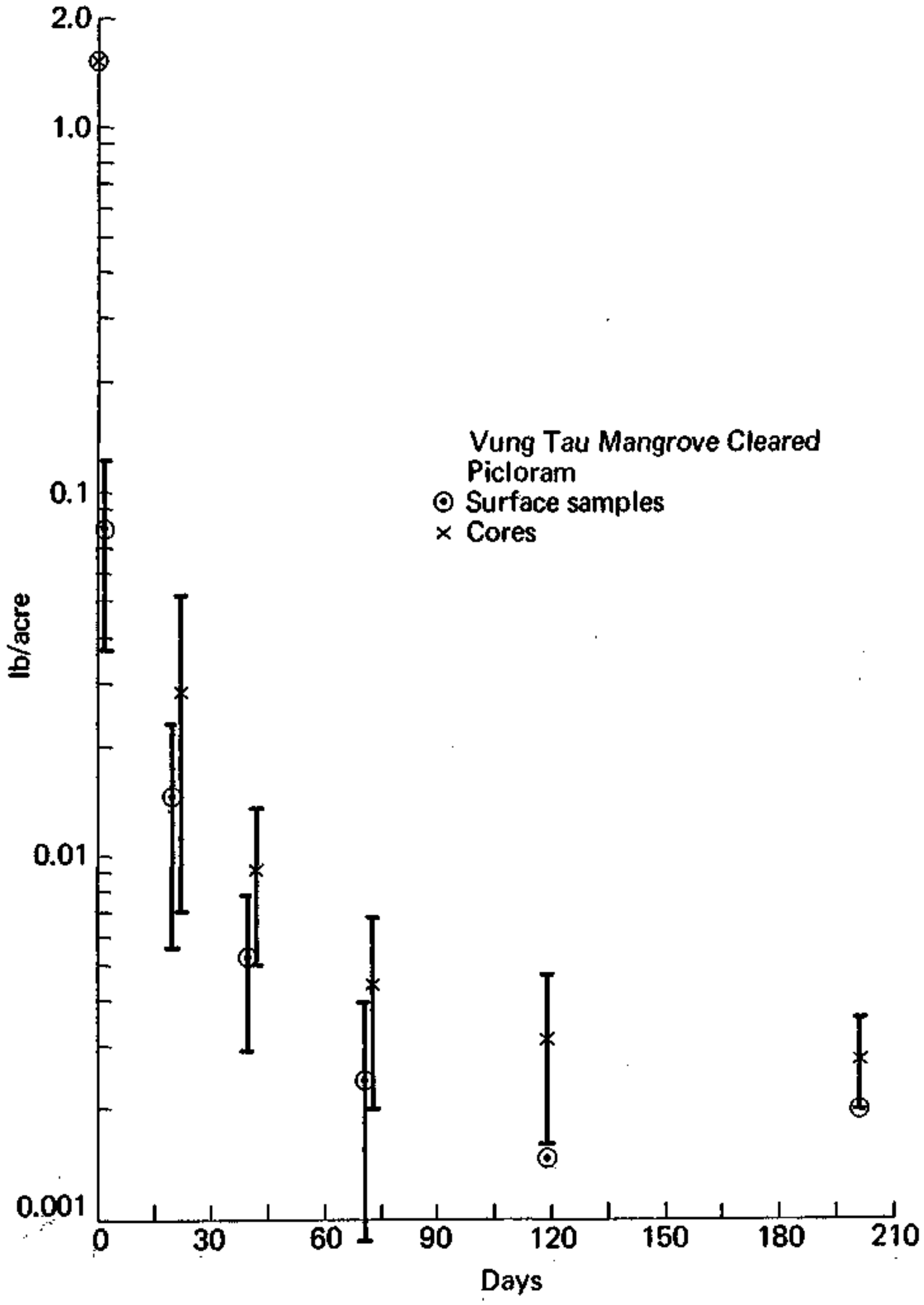

Fig. V A-1. Disappearance of picloram from mangrove soil cleared of vegetation. Application rate 1.6 lb/acre. Surface samples taken with 5 in. high metal cans, cores with a soil sampler 30 in. long, but the cores were mostly shorter because of compression of the soil during insertion of the sampler and removal of the core from the latter, and because of occasional loss of part of the core. Ordinate = remaining herbicide in lb/acre; abscissa = time after application of herbicide to soil. On vertical bars the x or the o represent mean values, the upper and lower end points of the vertical bars represent 95% confidence limits. Note that the ordinate is on a logarithmic scale which tends to minimize the differences.

Table V A-2 Survival and growth of seedling of *Rhizophora apiculata* on mangrove plots treated with Agent Orange and Agent White at a rate of 3 gal./acre.

A. Experiment on large cleared area

Observation (Weeks after soil treatment)	Seedlings planted 3 weeks after soil treatment			Seedlings planted 6 weeks after soil treatment			Seedlings planted 10 weeks after soil treatment			Seedlings planted 17 weeks after soil treatment		
	Control	Orange	White	Control	Orange	White	Control	Orange	White	Control	Orange	White
29 weeks: percent survival	4.7	4.2	2.7	5.5	5.3	3.3	7.7	8.7	6.3	18.7	18.5	21.7
35 weeks: percent survival	3.8	3.0	2.6	3.0	2.5	2.3	7.3	4.0	7.0	13.8	10.8	19.5
50 weeks: percent survival	3.0	3.0	1.6	1.0	2.5	2.7	6.7	3.0	3.0	10.4	6.0	10.7
height in inches	NR	NR	NR	NR	NR	NR	16.2	15.5	16.4	14.8	14.8	16.6

B. Experiment with small plots in undisturbed mangrove

Observation (Weeks after soil treatment)	Seedlings planted 3 weeks after soil treatment			Seedlings planted 6-1/2 weeks after soil treatment			Seedlings planted 12 weeks after soil treatment		
	Control	Orange	White	Control	Orange	White	Control	Orange	White
12 weeks: percent survival	76.7	84.1	79.1	87.5	95.0	94.2	--	--	--
19 weeks: percent survival	70.0	81.7	80.8	84.2	89.2	90.0	94.1	85.8	82.5
34 weeks: percent survival	71.6	70.8	79.1	74.2	90.8	89.2	78.3	85.0	71.7
height in inches	14.4	13.4	14.1	NR	NR	NR	16.5	15.8	15.9

The number of replicates in experiment A was 4 to 6; the number of plants per replicate was 25. In experiment B there were 40 plants in each of 3 replicates.

NR = not recorded

Height = total height in inches from soil surface to tip of topmost leaf.

(4) Agent Blue

The Committee did not undertake studies on persistence, or the lack thereof, of cacodylic acid, the active ingredient of Agent Blue. Analyses of soil from areas that had been sprayed with Agent Blue during the military use of herbicides at least a year and a half after that use had been terminated, and experiments of the kind we conducted with Agents Orange and White appeared to be equally unrewarding for the following reason. Arsenic is a natural constituent of soil, water, minerals, plants, and animals. The average content in soil is about 5 ppm, with variations from 1 to 40 ppm, in natural fresh and sea water between 0.003 and 0.05 ppm. Crystalline rock contains on the average 2.0 ppm, table salt 2.71 ppm, most plants in their edible parts between 0.1 and 1.0 ppm, but sometimes going up to about 3 ppm and higher (dry weight basis). Fish may contain between 0.2 and 15 ppm, shellfish around 1.5 to 3 ppm. (Data as elemental arsenic; from Liebig, 1966, Schroeder and Balassa, 1966; anon., 1971; and Frost, 1973). Arsenic undergoes a cycle in nature; in an agricultural ecosystem this involves input with fertilizers and arsenic herbicides, uptake by the plant and consumption by the animal, release by plant and animal, binding by and release from soil, transfer between soil and water, etc. Although the pentavalent (arsenate) form is the more stable one and generally tends to accumulate, conversion to the trivalent (Arsenite) form may also occur when conditions favor reduction, as, e.g.,

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Tordon 101, a herbicide formulation similar to Agent White, on seedlings of *Rhizophora mangle*. The formulation was added to estuarine mud in plastic boxes at the rates of 0.39, 3.93, and 39.3 lb/acre 2,4-D and 0.14, 1.43, and 14.3 lb/acre picloram, and seedlings were planted three days thereafter or later. The lowest dose used retarded development but caused no death; the two higher doses resulted in marked disruption of growth and subsequent death. The intermediate dose is of the same order as used in the herbicide operations in SVN (6 lb/acre 2,4-D and 1.62 lb/acre picloram) and seems to have been considerably more toxic than in our experiments at Vung-Tau. There are, however, major differences between the conduct of the two investigations. Firstly, different species of *Rhizophora* were used. Secondly, Walsh *et al*. used a closed system and a constant environment (constant temperature; light from fluorescent lamps for 12 hours a day) whereas at Vung-Tau it was an open system subject to fluctuations in tides, water table, and weather. Thirdly, planting at Vung-Tau was made at greater intervals after herbicide application to the soil, and interpolation in our decay curves indicates that at the time of the first planting (3 weeks) the levels of 2,4,5-T and of picloram in the soil of the microplots were about 0.7 and about 0.2 lb/acre, respectively. If one considers that the initial rate of 2,4,5-T (that in Agent Orange) was about twice that of 2,4-D in Agent White, and that 2,4-D most probably breaks down more rapidly than 2,4,5-T, the amount of herbicides left in the soil at our first planting was equal to or somewhat below the lowest dose used by Walsh and his colleagues.

in anaerobic soils. To determine, years after the fact, whether arsenic found in soils of herbicide-sprayed areas came from the herbicides, from other sources, or was present in the soil prior to the sprays seemed an impossible task. Analyses of a small number of samples of rice, fish and shellfish, a worm, and water and soil collected in or near a community in the Rung Sat which had been exposed to at least one Agent Blue mission between 1964 and 1969 gave arsenic levels within the normal ranges for such materials (see Section VII C).

As regards persistence of effects of cacodylic acid deposited on soil, available evidence indicates that it is considerably less than that of 2,4-D, 2,4,5-T, and picloram. On January 27, 1972, some members of the Committee made an overflight of the Song-Re Valley, Quang-Ngai Province, which had been sprayed with Agent Blue August 9, 1970. They observed extensive rice fields and some vegetable plots all of which, as far as they could be judged from a low-flying plane, appeared normal.

(5) Conclusions

Extent and detail of our sampling for herbicide residue determinations were considerably greater than in many previous studies, and represent a significant contribution to the knowledge of herbicide behavior in tropical soils, including mangrove soils where, to the best of our information, the problem has not been studied before. Obviously, the sampling design could have been further improved. For example, it would have been very desirable to get soil samples from the heavily sprayed inland forests of War Zones C and D, and to conduct persistence experiments with the alluvial soils of the Mekong Delta. Nevertheless, considering the distribution of samples selected in areas sprayed during the war and the diversity of soils represented in our own experiments, our results have considerable internal consistency, and agree very well with data from the literature.

The behavior of herbicides in the soils of SVN, and soils of similar tropical regions, appears similar to that in soils of temperate regions. Herbicide levels capable of causing severe damage to many plants were found only in the Pran Buri Calibration Grid--a unique site as it had received amounts of herbicides far higher than ever applied in SVN. Successful replanting is possible even in areas which received heavy military herbicide spraying, in no more than a year after the last spray mission and usually in much less time. The main conclusion of this part of our studies is that the persistence of herbicide residues in the soils of SVN is not a significant factor in subsequent growth of vegetation. Claims that the herbicides used in the herbicide operations have rendered the soil permanently "sterile," i.e. unfit for any plant growth, are not supported by our chemical and biological studies of herbicide persistence in the soils of SVN and are contrary to world-wide experience with the herbicides used.

Our data, taken in their entirety--that is, both those from areas sprayed during the military herbicide operations and those from our own experiments--offer little evidence for extensive vertical movement of the herbicides. The most striking case in this respect is the Pran Buri Calibration Grid which consists of sandy soil generally prone to leaching, and was literally drenched with 2,4-D and 2,4,5-T but where their residues were nevertheless limited mostly to the upper 10 to 20 in. (25 to 50 cm). Picloram, which is a more "mobile" compound (see Section II C[1]), was present also in greater depths, but mostly only in small amounts.

An interesting observation was made on the survival of mangrove seedlings on a relatively large area, cleared *in toto* of vegetation, as compared to small plots laid out in an otherwise intact mangrove. Under the latter conditions, and even when differences in the quality of the seedling material had been taken into account, survival was markedly superior, indicating that removal of vegetation created conditions unfavorable to the reestablishment of mangrove. These conditions are not, however, due to persistence of the herbicides, and they do not operate in all mangrove sites since survival of seedlings planted on a denuded area in the Rung Sat was as high as 50-80 percent (see p. IV-110).

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B. Effects of Herbicides on Soils of South Vietnam

Since soils are an integral part of terrestrial ecosystems, changes in the vegetation may cause changes in the chemical and physical properties of these soils, and in the processes which underlie these properties. In the case of SVN there have been reports that the defoliation and killing of vegetation in the military herbicide operations may have caused adverse effects on soil fertility and irreversible deleterious changes such as laterization and soil erosion.

The purpose of our studies was to document the possible changes that may occur to soil due to herbicide treatment of the vegetation. The data presented are the results of several months of field work in various areas in SVN and Thailand, with more than 3600 laboratory analyses on 304 soil samples. Soils in sprayed and non-sprayed areas were compared and soil samples were obtained for standard physical and chemical measurements in the laboratory; the results were then used to test hypotheses about the effects of defoliation on soil properties. The elements in the soil that were investigated were total carbon, total nitrogen, and the exchangeable cations: calcium, magnesium, potassium, sodium, and manganese. Phosphorus was determined in soil water extracts. In addition, the pH of the soil and its cation exchange capacity[a] were determined. The analyses were carried out using standard analytical techniques used in soil science, and the data have been calculated as total storage of the elements in the top 5 cm (2 in.), and as the storage of elements in the total soil profile to the one-meter (3.3 ft) depth, expressed in grams per square meter (g/m^2).[b] Soil properties are known to vary widely, even in a limited area, and all sample areas represented soils with a range of properties. Therefore, soil samples were taken to represent surface variability of the soil and to characterize the variation with depth of the soil; vegetation samples were taken to evaluate the vegetation weight (biomass) and the amount of nutrient elements stored in the vegetation on representative areas.

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[a] Cation exchange capacity is the capacity of the soil to hold elements in their positive charged or cation form. This is the most important storage capacity in tropical forest soils for such elements as calcium, potassium, and magnesium; but a common fertility problem is the saturation of this capacity with elements that may be toxic or not required by vegetation such as hydrogen and aluminum.

[b] One square meter = about 10.76 square feet; one gram = about 0.035 oz. Multiply grams per square meter by 8.9 for pounds per acre.

(1) Inland Forests

The study was divided between the effects of defoliation on the soils of inland and of mangrove forests, corresponding to the two main types of affected vegetation. Sites in inland forests were in 12 locations in Thailand and in one in SVN (near Dong-Xoai, Phuoc-Long Province). The locations represented Open and Closed forest (see Section II E). A considerable range of soil types (podzolic, regosol, latosol, laterite, and alluvial), various soil histories (primary and secondary forest, secondary succession to bamboo, an old village reserve forest) and various vegetation types (*Dipterocarpus alatus*, *Hopea-Shorea*, mixed dipterocarp, *Quercus-Castanopsis*, etc.)

Fertility Properties of Closed Forest

The surface soils of the Closed Forest are more fertile in some respects than those of the Open forest (Table V B-1). There is more organic matter (represented by carbon content), more nitrogen, and a greater cation exchange capacity for storing nutrients and other competing cations. However, soils associated with the Open forest tended to have more calcium and magnesium stored in them, but were lower in potassium storage. The soil in the Closed forest, having a greater stored quantity of carbon and nitrogen, and a greater cation exchange storage capacity should have a larger capacity to buffer changes in the soil nutrient status brought on by changes in the forest cover, including those by defoliation.

A large proportion of the total site fertility in tropical forests may be stored in the vegetation, relative to the soil. An assessment of two typical sites in the Closed forest showed vegetation storage of nutrient elements in the forest vegetation relative to the forest soil was highest for potassium and phosphorus, and lower for nitrogen. The foliage and woody portions of an old forest in Thailand, on an acre basis, had 1,139 lbs of nitrogen, 172 lbs of phosphorus, and 1,371 lbs of potassium. The proportion of nutrient elements in the Closed forest foliage may range from more than 20 percent of total forest storage (soil + vegetation) in the case of potassium, to one to six percent in the case of nitrogen. Hence, a critical aspect of the effect of defoliation on the fertility of the site, and of the soil in particular, would be the disposition of the nutrient elements contained in the foliage subject to defoliation. These will be returned to the soil, where they can be either stored and used by plants or lost by leaching. The situation will be more critical in the case of an element like potassium of which a large proportion of the total in the entire ecosystem is stored in the foliage.

Table V B-1. Storage of nutrient elements in the surface 5 cm of soil of unsprayed Closed and Open forests and of mangrove. (Average values based upon all samples in each category)

Element	Closed Forest	Open Forest	Mangrove
Carbon (g/m^2)	287	184	333
Nitrogen (g/m^2)	23	9	16
Carbon/nitrogen ratio	12	20	21
Cation exchange capacity[a]	1.10	0.81	1.88
Calcium[a]	0.28	0.60	0.40
Magnesium[a]	0.13	0.21	1.23
Potassium[a]	0.05	0.03	0.12
Sodium[a]	0.005	0.005	2.02
Manganese[a]	0.03	0.02	0.01
pH	4.5	6.1	5.5

[a] Equivalents per square meter to 5 cm depth.

The fate (whether stored in the soil or lost) of nutrient cations entering the soil as a result of defoliation depends upon the cation exchange storage capacity of the soil. In addition, the adsorption of a cation such as potassium may be reduced by other elements added from the foliage or already present on the soil exchange complex. The following cation quantities expressed in gram equivalents per square meter of soil surface to a depth of one meter are characteristic of the Closed forest:

		Cation Exchange Capacity	Calcium	Magnesium	Potassium
Vegetation:	Foliage		1.1-0.2	1.0-0.2	1.3-0.2
	Wood		8.7-5.0	1.4-0.8	2.6-1.5
	Total		9.8-5.2	2.4-1.0	3.9-1.7
Soil (average)		59.1	7.0	3.6	2.1

Thus, if the foliage is removed from the trees and deposited on the soil, eventually from 3.4 to 0.6 gram equivalents of cations will be entering the soil cation exchange complex with a capacity of 59.1 gram equivalents. This soil exchange capacity is only partially saturated with 12.7 equivalents of calcium + magnesium + potassium (very little sodium is present in these soils) and these represent only 21 percent of the cation storage capacity of this average Closed forest soil. These data indicate sufficient storage capacity on the exchange complex to adsorb the 3.3 to 0.6 equivalents of exchangeable cations that will be released from the foliage drop in the defoliated forest. However, there is a grave risk of losing the potassium if the levels of the other elements are too high in the soil, or in the recycling elements of the leaves shed as a result of defoliation.

Fertility Balance of Secondary Succession with Bamboo

When disturbance of a forest results in a secondary succession of bamboo the soil-plant fertility balance of the site is adversely affected. This is indicated by studies in an area in Thailand where bamboo had taken over a disturbed Closed forest. The analyses indicated a much lower vegetation weight, and correspondingly lower nutrient storage in the bamboo than in the forest which it had replaced. Also a large proportion of the nutrient elements were in the underground portions of the plants. These observations suggest that the bamboo maintains a lower reserve of nutrients on a site, and in a form that would be difficult to return to the soil unless an effective way of killing the underground parts and suppressing further bamboo growth is perfected.

Comparison of a Defoliated and Non-Defoliated Forest

A comparison of a defoliated and non-defoliated forest area was possible only in one case, a secondary forest in Thailand, at the former herbicide test site near Pran Buri. The defoliation treatment was applied in 1965 with 9.1 lb/acre Orange and 0.5 lb/acre of picloram, and no longer contained measurable quantities of herbicide (see Section V A). Significant differences in nitrogen and available phosphorus in the surface soil were noted. The available phosphorus content was in the sprayed site nearly one-half and the nitrogen content 10 percent less (nearly 80 lb/acre and 62 lb/acre, respectively [in the surface 5 cm]) than in the unsprayed site. The soil was more acid in the former than the latter site (pH 6.0 and 7.0, respectively). There were no statistically significant differences in the defoliated versus undefoliated areas in carbon, in exchange capacity, and in exchangeable calcium, magnesium or potassium. However, exchangeable sodium, even though low in both areas in absolute terms, was significantly higher in the defoliated area than in the non-defoliated one.

Laterization

Laterization is a process wherein lateritic soils are formed by the leaching of silica and the accumulation of secondary oxides of iron and manganese. Upon exposure to air, this material may harden into a durable, brick-like substance which inhibits vegetation growth. Concern has been expressed that this hardening of the soil of defoliated areas is one of the deleterious effects of the military herbicide operations in SVN.

The hardening of laterite material has to take place from an already existing lateritic soil that has developed to the stage where it can form hard laterite when exposed to drying and high temperatures. This occurs only on limited areas in the inland forests. Aerial observation, interpretation of aerial photos, information from South Vietnamese soil scientists, and limited ground observations in defoliated forest areas and of Rome-plowed roadsides indicate, however, that hardening of laterite on a major scale, which would be apparent as areas devoid of vegetation, has not taken place. Defoliation in inland forests evidently did not keep areas bare long enough to appreciably affect the process of laterite hardening, and if there are areas which have undergone laterization as a consequence of defoliation they are of minor extent. The worst case we observed was the so-called Calibration Grid near Pran Buri, Thailand, which had been used for calibrating herbicide spray equipment and had received about 840 lb/acre 2,4-D, about 960 lb/acre 2,4,5-T and smaller quantities of other compounds. It exhibited bare areas covered with a hard lateritic crust which, however, was not yet thick enough to prevent recolonization (see Fig. V B-1).

Fig. V B-1. Bare areas in the Pran Buri, Thailand Calibration Grid. Photo taken by Dr. Paul Zinke in September 1971.

(2). Mangrove Forest Soils

Soil and fertility studies in the mangrove were conducted in the Rung Sat Special Zone, in an area north of Vung-Tau, and in the Nam-Can area of the Ca-Mau Peninsula. Most of the mangrove soils in SVN were silts deposited by the Mekong and the Saigon rivers, with some peat deposits in basins on this delta material. The soil samples taken in the Rung Sat area were all from defoliated and now barren areas; those in the Vung-Tau area were from the center of the clearing made for the Committee's herbicide persistence experiments (see Section V A); those in the Nam-Can area were from both defoliated and non-defoliated mangrove forest, at sites located along a main canal northeast of Nam-Can, and at the west end of the Nam-Can airport. For comparison, a mangrove forest was sampled at Khlung, near Chantaburi, Thailand, an area that had not been disturbed by defoliation. The total number of locations was 14 with 146 soil samples. Total overall nutrient reserve in the mangrove forest, in both vegetation and soil, was determined at Vung-Tau and at the site near Chantaburi.

The average results of all analyses of the mangrove forest soils indicate some special characteristics of these soils, as compared to the other forests (see Table V B-1). The mangrove soils are moderately acid. The average pH of 5.47 is lower than that in the Closed forest soil but higher than that of the Open forest soil. The mangrove soils have more organic matter (as indicated by carbon content) with less nitrogen storage than Open forest soils, and a resulting higher carbon/nitrogen content than the Closed forest soils. The exchange capacity in the top five cm of the soil is markedly higher than in Open forest soils, and in this exchange capacity are retained higher quantities of exchangeable nutrient cations, and high amounts of magnesium and sodium are retained, as is to be expected due to the regular flooding with sea water.

Effects of Defoliation and Clear-Cutting in Mangrove Forests

The effects of defoliation were studied by comparing soil properties in a defoliated and a non-defoliated mangrove area northeast of Nam-Can (Ca-Mau Peninsula), and by soil analyses of six heavily defoliated, barren sites in the Rung Sat. For comparison, the effect of a clear-cutting treatment on soil characteristics was also studied, making use of the control (unsprayed) portion of the mangrove site near Vung-Tau which had been hand-cleared (and the cut vegetation removed) for the Committee's herbicide persistence experiments (Section V A).

The soil of the defoliated mangrove forest near Nam-Can was found to have slight increases in carbon, nitrogen, the carbon/nitrogen ratio and exchangeable calcium, and slight decreases in magnesium, potassium, sodium, and manganese, as compared to an adjacent non-defoliated mangrove forest. There was a considerable decrease in soil pH from 7.2 to 6.3; and a large increase in phosphorus content attributable to defoliation. The results are summarized in Table V B-2. This area had been defoliated with Orange and/or White about a year and a half before the soil sampling.

Table V B-2. Comparison of properties of surface soil (5 cm = 2 in) in defoliated and non-defoliated mangrove near Nam-Can, Ca-Mau Peninsula, and in bare areas of former mangrove in the Rung Sat.[a]

Treatment	Ca-Mau Defoliated	Ca-Mau Non-defoliated	Rung Sat Denuded
Carbon (g/m^2)	210	173	1688
Nitrogen (g/m^2)	15.3	14.8	86.8
Carbon/nitrogen ratio	14	12	19
Phosphorus as PO_4 (g/m^2)	7.7	5.9	NA[c]
Cation exchange capacity (equivalents/square meter)	2.2	2.2	10.7
Calcium[b]	0.56	0.51	2.5
Magnesium[b]	1.13	1.28	6.9[d]
Potassium[b]	0.16	0.21	0.6
Sodium[b]	2.09	2.64	9.8[d]
Manganese[b]	0.03	0.05	0.05
pH	6.32	7.18	6.1
Bulk density	0.98	0.94	0.16

[a] The defoliated area in Ca-Mau had been subjected to a Purple mission in 1962 and to one Orange and two White missions in 1970. The Rung Sat area received herbicides of the order given in Section V B.

[b] Equivalents per square meter to 5 cm depth.

[c] Not analyzed.

[d] Saturated due to ocean water.

Similar results were obtained from the clear-cut mangrove plots at Vung-Tau. Here, there was a very significant (at the one percent level) increase in bulk density, and decrease in pH as a result of clear-cutting the mangrove forest six months prior to the measurements. Nitrogen and magnesium storage in the soil of the clear-cut site was decreased (significant at the five percent level), and the quantity of available phosphorus was reduced by 50 percent (significant at the one percent level). This reduction in available phosphorus may present a tie-up in unavailable form at the lower pH which had resulted from clear-cutting the vegetation. These results indicate that the normal forest harvest operations in mangrove forests may produce effects on soil fertility properties that are similar to the effects of defoliation.

In soils from defoliated, denuded sites in the Rung Sat, there was nearly twice as much carbon and nitrogen as in soils from the intact mangrove near Vung-Tau (Table V B-2). The Rung Sat soils had a greater cation exchange capacity, and a larger amount of calcium and potassium on this exchange complex. One can conclude from this at least that the defoliated areas visited in the Rung Sat have soil fertility levels that are considerably higher than the non-defoliated mangrove forest at Vung-Tau and Ca-Mau. Alternative uses, such as tropical polders, should be a possibility for these lands.

<u>Summary</u>

Studies were made of forest soil in Southeast Asia that involved the effects of defoliation on soil properties related to soil fertility. These properties were content of carbon, nitrogen, exchangeable calcium, magnesium, potassium, sodium, and manganese. Also water soluble phosphorus, soil pH, and soil exchange capacity were determined. The study concentrated on 12 inland forest sites with 304 soil samples; and 14 mangrove forest locations with 146 soil samples. Vegetation and foliage storage quantities were obtained at 3 of the inland forest sites and at 2 of the mangrove sites.

An analysis of the variability of soil properties at any one location indicated that analyses of large numbers of soil samples would be needed to support or disprove any hypothesis regarding defoliation effects.

In the inland Closed forest areas it was found that the foliage subject to return to the soil by defoliation contained from 0.6 to 3.4 gram equivalent weights per square meter of basic elements such as calcium and magnesium. The soil had an available capacity to absorb 46.4 equivalents of these elements. However, despite this large capacity, there is a major risk of loss of potassium. Secondary succession of bamboo vegetation was found to have a lower fertility storage than the Closed forest. At one study site, with sufficient samples obtained to satisfy statistical conclusions, eight years after defoliation the

Closed forest soil was found to have 10 percent less nitrogen storage and a 50 percent reduction in water soluble phosphorus quantities and the soil was more acid than the soil in the adjacent undefoliated control area. Other fertility elements measured were not significantly changed. In mangrove forests areas studied, the defoliated area soils were found to have increased content of carbon, nitrogen, and water soluble phosphorus, and were more acid than the non-defoliated areas. However, the total nutrient content of soil in one defoliated area was considerably higher than that of soils in other non-defoliated mangrove areas.

The hardening of laterite of serious enough extent to render areas barren has not occurred extensively in defoliated areas of SVN. Presumably, this is because of the rapid regrowth of vegetation following defoliation.

VI. EFFECTS OF HERBICIDES ON ANIMALS

Little quantitative information is available about animal populations in SVN. There are no baseline data that would permit a comparison between prespray and post-defoliation population numbers.

Two studies were conducted to determine relative diversity and frequency of certain animals in herbicide treated and untreated mangrove. No studies could be carried out in the inland forest. One of the studies in the mangrove was concerned with mosquitoes, some of which are the carriers of malaria. The results are reported in Section VII A-3. The second study dealt mainly with animals (fish, plankton, molluscs) in the water of sprayed mangrove in the Rung Sat Special Zone and unsprayed mangrove near Vung Tau. A brief discussion of this subject is included in the section on mangrove forests (Section IV C).

Some perceptive responses of the Vietnamese people about effects of herbicides on animals are reported in the section on socioeconomic effects of herbicides on people (Section VII B).

VII. *EFFECTS ON HUMANS*

A. Biological Effects

Potential effects of herbicides on humans may be biological, socioeconomic, and psychological. Biological effects which could result from exposure to herbicides as to any chemical compounds possessing a certain biological activity include direct toxic effects of the chemicals or their contiminants or decay products, when ingested, inhaled, or deposited on the surface of the body. These effects could result in illness or death; or they could appear as alterations in reproductive performance, either in fetal wastage (miscarriages or stillbirths) or in birth defects such as cleft lip or cleft palate following exposure of pregnant women to herbicides or their contaminants; or they could consist in alterations of genes and chromosomes and in this case be transmitted to later generations. Less direct biological effects could result from herbicide-induced changes in man's environment, by favoring the propagation of disease organisms or the vectors (carriers) or reservoirs of disease organisms, such as mosquitoes or rats, and/or by decreasing the availability of food or other economic resources, thus leading to malnutrition or starvation and to changes in the social situation of the people. Psychological impact may be looked for in the perçeptions of people exposed to herbicides, feelings people in SVN had about herbicides, their recollection of herbicide effects on people and on the environment.

Given the limitations of time, resources, and safety under which the Committee was working in SVN it was not possible to investigate whether all these potential effects had or had not occurred, nor was it always possible to separate effects of herbicides from the effects of the complex of war-related changes in recent years in Vietnam. However, we were able to detect certain medical-ecological, economic, and psychological effects on humans which had persisted beyond the time of spray and beyond the disappearance of the herbicides in most soils (see Section V B), and to initiate analyses of certain other potential medical effects. The report will progress from biological to socioeconomic and psychological effects. Also reported is a study of one community in the Rung Sat mangrove area where an attempt was made to obtain, in one place, an integrated ecological picture of herbicide and other war-related effects.

The toxic effects of the herbicides used in the Vietnam war including that of TCDD, the highly toxic contaminant of 2,4,5-T and hence Agent Orange, the most widely used agent in that war, have been discussed elsewhere in this report (Sections II B and C). Because of the absence of adequate medical records from the time and locations of the herbicide operations, the length of time which had passed since extensive herbicide spraying had been carried out, and the likelihood that direct toxic effects would be relatively transient, we could not conduct medical studies of any immediate toxic effects of herbicides in SVN. Perceptions and reports of people who had been exposed to herbicide sprays, or thought to have been, are summarized in later chapters of this section (B-2 and B-3). Near the end of our studies in SVN, we found a well-defined group of 45 to 50 Vietnamese military personnel who had been handling herbicides (transferring them from the containers in which they arrived, to other containers and to the aircraft) for many years and thus appear to represent a population, although a relatively small one, uniquely suited for studies of any long-term medical effects. That such studies should be made features as a recommendation of the Committee.

(1) Reproductive, Teratological, and Genetic Effects of Herbicides Used in SVN

Proposals or speculations put forward in previous publications included the following: (a) exposure to herbicides leads to chromosomal changes; (b) exposure to herbicides leads to an increase in fetal wastage (stillbirths, miscarriages); (c) exposure to herbicides leads to an increase in rates of congenital malformations including cleft lip with or without cleft palate, cleft palate, neural tube defects (spina bifida, anencephaly), and Down's syndrome (mongolism).

Literature on the relationship of herbicides to chromosomal changes, fetal wastage, and birth defects was examined, including studies reported from SVN and from elsewhere in the world, and a pilot study was initiated designed to collect data which would allow comparison within a population of hospitalized children to see if there was any correlation between history of herbicide spraying in the reported areas of residence of their mothers and the nature of their illness (congenital or non-congenital).

(a) Chromosomal Abnormalities

In a study from the DRVN (Ton That Tung et al., 1971; see Tables II and III) chromosomal abnormalities after exposure to herbicides were reported, based on a study of 179 persons who had lived in regions of spraying for from two months to four years or who were "direct victims of spraying," out of a total of 903 refugees from SVN who had moved to the DRVN. Exposure and medical histories were collected, and medical examinations were conducted, and reported symptoms of illness associated with spraying were recorded. Reports are given on examination of chromosomes of "normal persons" (no number given in tabulation), three "persons having lived in SVN but not yet victims of sprays," three "victims of sprays without apparent after-effects," three "victims of sprays with important after-effects 'asthenia, ocular lesions'," and three "children born of mothers who were victims of sprays." As compared with the unsprayed "controls" those sprayed were reported to have a higher frequency of chromosome abnormalities, mostly breaks or gaps. However, this study is inadequate in several regards: The frequency of breaks or gaps in the sprayed individuals was of the same order of magnitude as that reported for several North American "control" populations, for instance those used in studies on the possible chromosomal effects of LSD (Corey et al., 1970), whereas the control figures were much lower than those usually observed in control populations (ibid.). Furthermore, the types of abnormality reported were mostly not those expected from chromosome damage occurring some months or years previously. No attempt was made in this study to distinguish between herbicide exposure and other agents, such as viral infections, known to cause chromosome abnormalities, and the study is inadequate in terms of statistical requirements.

Studies in the U.S. on chromosomes of workers in a plant manufacturing 2,4,5-T indicated no increase in frequencies of breaks or other chromosomal aberrations in samples from 976 exposed workers. Controls were 1922 workers tested pre-employment, 2143 workers from another Dow plant, and data from literature (Kilian, 1973). A more critically controlled study would be desirable.

In conclusion, there is a lack of well-controlled studies on the chromosomal effects of TCDD, 2,4,5-T, and other herbicides in primates and exposed human beings, and these should be done. Furthermore, it appears that TCDD is a potent mitotic poison and possibly a mutagen in lower organisms. Studies should be done using modern methods of testing for mutagenicity in human cells to evaluate this potential hazard to man.

(b) Fetal Wastage

A U.S. Army medical team (Cutting et al., 1970) analyzed the records on stillbirths and hydatidiform moles in three Saigon and 22 provincial and district hospitals for the years 1960-1969 to establish any relation to exposure of women to herbicides. They concluded there was a decline in stillbirth rate, and no increase in malformation rates during this period which includes the years of heaviest herbicide operations.

Meselson et al. (1972) examined midwife record books and hospital records and concluded that the decline in stillbirth rate had occurred only in Saigon, while rates in the rest of the country rose from about 20 per 1,000 livebirths in 1962 to a peak of about 53/1,000 in 1967, and then declined again to about 37/1,000 in 1969. In Tay-Ninh Province, the northern part of which was heavily sprayed, they reported the stillbirth rate was 58/1,000 in 1968 and 101/1,000 in 1970. These are high rates as compared with the 37/1,000 reported in 1969 for SVN outside of Saigon, or the 18/1,000 reported by Emanuel et al. (1972) in six hospitals in Taipei.

An apparent increase in the number of patients with some particular birth defects, e.g., cleft palate without cleft lip, relative to other birth defects was noted by Meselson et al. (1972) to appear to have been associated with the periods of herbicide spraying. As shown in Table VII A-1, when the same data are expressed, instead, in terms of the frequency of each of several classes of birth defects per thousand unselected admissions to that hospital, the years of maximum incidences of various defects were quite inconsistent. Such a distribution does not support the suggestion that herbicide spraying may have engendered birth defects nor does the incidence of total malformations in the same population. It is regrettable that a sufficient body of reliable data concerning malformations per thousand births, from both sprayed and unsprayed areas, is not available. Additional information in this regard may become available from the still incomplete study, by the Committee, intended to correlate the incidence of birth defects in children treated in the Cho Ray Hospital with the exposure of their mothers to herbicide spraying during pregnancy.

Table VII A-1. Frequencies of selected malformations per 1,000 admissions to a Saigon Children's hospital. (Highest frequency underlined). From data in Le-Anh (1970)

	1962	1963	1964	1965	1966	1967	1968
Megacolon	9.2	6.9	<u>13.8</u>	9.9	7.9	13.7	8.6
Imperforate anus	17.6	<u>20.0</u>	17.9	17.6	13.6	15.5	10.3
Cleft lip + cleft palate	18.5	16.5	<u>40.6</u>	20.6	17.8	30.0	15.1
Isolated cleft palate	0.4	0	1.6	0.5	2.6	<u>5.5</u>	2.6
Neural tube malformations	2.7	1.7	2.9	2.4	1.5	<u>3.8</u>	3.4
All malformations	128.0	123.0	198.0	165.0	143.0	160.0	111.0
Total admissions	2612	1151	3127	4030	4553	4169	4974

(c) Committee Activities in SVN

Members of the Committee concerned with human effects planned a series of studies to investigate the relationships between spraying and reproductive failures. The objectives were to evaluate the feasibility of getting reliable information from hospital and vital statistics records on fluctuations in frequency of malformations that could be meaningfully related to herbicide spraying; to attempt identifying populations from sprayed and unsprayed areas that were otherwise comparable and from which data on malformation prevalence, chromosome breaks, etc., might be collected; to plan for and identify resources necessary to carry out the collection of such data; and to make recommendations concerning the feasibility and worth of such studies. It was also our intention to recheck the Tay-Ninh figures reported by Meselson *et al.* (1972). This and most of the other plans were frustrated by the North Vietnamese Spring 1972 offensive with heavy military action around Tay-Ninh city and greatly reduced security elsewhere in the country.

We attempted to check the general accuracy of stillbirth and malformation records as they might be related to systematic reporting errors. Several persons concerned with medical statistics in Saigon confirmed the fact that stillbirths might go unreported, or that liveborn children who died within a short time after birth might be reported as stillborn in order to avoid the necessity of filing two reports. This kind of underreporting would presumably vary inversely with the quality of medical services, and directly with the amount of social upheaval in the locality and it would be impossible to sort out effects possibly resulting from spraying from fluctuations due to these and other factors. With congenital malformations, one faces similar problems.

We confirmed the statement in the report by Meselson et al. (1971) that such malformations might not be recorded in the primary birth record or vital statistics for cultural reasons, since having a deformed child means loss of face to the parents. Thus anywhere but in a good maternity hospital data on frequencies of congenital malformations at birth may be untrustworthy, and good maternity hospitals are not likely to be found in areas of spraying.

If we assume a relationship between the amount of herbicide sprayed and birth defect rates, we would predict a rise in malformation rate paralleling, or if we assumed a time lag between time of spray and the appearance of birth defects (since teratogens ordinarily cause such birth defects as cleft lip and palate only early in pregnancy) somewhat lagging behind the increase in amount of herbicide sprayed. Depending on whether the teratogenic substance persists or accumulates, or whether it disappears rapidly, we would predict a continued high level or continued increase in malformation rates, or a decrease in relation to reduction and cessation of the herbicide operations.

In order to test these hypotheses we should compare reliable rates from the pre-spray period with rates from the spray and post-spray periods. Table VII A-2 was prepared from data in the Annual Reports of Tu Du Hospital, one of the major Saigon maternity hospitals, as far as these reports were available to us. Unfortunately, these data are inadequate for a rigorous test of a relation between herbicides and birth defects, for two reasons. First, there are too few records. We have data for only two of the heaviest spray years (1967, 1969), and have none for the years when herbicide operations were phased out and the post-spray years (1970 and following). Second, the total number of births for 1967, and perhaps for 1966, appears to be in error, the former being much too high in comparison with the preceding and following years. If the numbers of malformations are correct, this would give malformation rates which are too low for 1967 and possibly also for 1966.

Keeping these difficulties in mind, the only evidence of association between amount of spray and malformations in the Tu Du records is the increase in cleft lip and palate reported for 1969, to the highest level in the reported series. In contrast, the 1969 club foot rate is lower than for 1966 (and lower than 1967, if total births were erroneously reported for 1967), anencephaly rate in 1969 is up from the level calculated for 1967, but is lower than 1966, and the total malformation rate in 1969 is lower than in four of the seven years for which the Annual Reports are available. Thus, the data in the available Tu Du Annual Reports do not show a consistent relationship between amounts of herbicide sprayed and rates of malformations, but they are not sufficient for firm conclusions.

Table VII A-2. Malformations and Malformation Rates per 1,000 Births, from the Annual Reports of Tu-Du Hospital, Saigon (Highest frequency underlined).

Malformation		1962	1963	1964	1965	1966	1967	1968	1969
Cleft lip and palate	No.	20	32	29	32	37	36	NA	112
	Freq.	1.69	2.64	1.79	1.65	2.49	1.05	NA	3.79
Anencephaly	No.	18	12	24	28	42	20	NA	48
	Freq.	1.52	0.99	1.48	1.44	2.82	0.58	NA	1.62
Club foot	No.	NA	NA	NA	NA	7	8	NA	9
	Freq.	NA	NA	NA	NA	0.47	0.23	NA	0.30
All malformations	No.	123	125	142	115	166	144	NA	253
	Freq.	10.40	10.32	8.76	5.91	11.16	4.19	NA	8.56
Total births		11,831	12,111	16,218	19,452	14,875	34,345	NA	29,562

NA = not available or not appearing in tabulations.

On visiting the other major maternity hospital in Saigon, Hung-Vuong, we found that they were publishing an annual report, beginning in 1969, with a computerized system that provides data on many parameters, including rates of congenital malformation. The data we were given on that visit indicated frequency of major malformations rose from 57/13,244 (4.7/1,000) in 1969 to 114/13,111 (8.7/1,000) in 1970; the frequency of cleft lip from 1 in 13,244 in 1969 (0.07/1,000) to 28/13,111 (2.1/1,000) in 1970. Since the 1969 cleft lip frequency is far below that of any well-documented population, the increase in 1970 must be in a large part due to improved documentation.

The Committee decided that to test the question of association or lack of association between herbicides and malformations with adequate accuracy it was essential to collect data specifically for that purpose. An ideal research plan was designed which would allow comparison of heavily sprayed and unsprayed populations, but considerations of safety and practical difficulties involved in defining, locating, and studying appropriate populations in wartime, in a country where a very large proportion of the people had been displaced, led us to give up this plan. Instead we began a pilot study, with careful examination of the records on one hospital unit (the Barsky Unit, Cho-Ray Hospital, Saigon-Cholon) which had treated a very large number of cleft lip and palate patients, and which had fairly comprehensive records, covering a sizeable proportion of the total number of babies born with cleft lip and/or cleft palate in SVN since the unit was established. This study has not yet been completed, mainly because of the time required to compare all information. The results will be reported when available. The analyses we could complete so far provide no evidence of an increase in congenital malformations related to herbicide spraying. It must be pointed out, however, that the circumstances were such that an appreciable increase in the malformation rate in the offspring of sprayed individuals could have remained undetected by our investigation.

(2) The TCDD Problem in South Vietnam

TCDD in Soil and Fish and Shellfish from Southeast Asia

TCDD (see Section II C[4]) occurs as a contaminant of 2,4,5-T; the herbicide most widely used in the Vietnam war. This Section briefly reviews the present status of the TCDD problem in SVN.

When the Committee's field studies were being planned and carried out we were not in the possession of information regarding the extent and distribution of the use of Agent Orange and thus the possible distribution of TCDD in SVN. Nor were there methods available to detect it at the low levels of concentration which might be found after spraying in soils, plants, and animal tissues. Analyses were carried out for the soil samples from the Pran Buri Calibration Grid which had received a total of almost 1000 lb/acre of 2,4,5-T in 1964-65 (see Section V A). The analyses were conducted by the Huntingdon Research Centre, using the method described by Woolson et al. (1973), and the results, compared with data on 2,4,5-T, are shown in Table VII A-3. Three of the six samples contained TCDD. Two of these also contained 2,4,5-T, but the third did not, nor was TCDD detected in the sample with the highest 2,4,5-T content (No. 3). Two samples from a site which was as far as could be ascertained, outside the Calibration Grid perimeter contained neither compound. Assuming firstly that no degradation of the TCDD took place, and secondly that the recovery was 100 percent, the original concentration of the TCDD in the Agent Orange (2,4,5-T ester) sprayed on the Calibration Grid would range from <3 to 50 ppm. The soil of the Calibration Grid was sandy, and therefore favorable for leaching, but the high persistence of TCDD in soils of this type agrees with the results of experimental tests (see Section II C[4]).

At a time when the Committee was reaching the end of its investigations, Baughman and Meselson (1973) developed their new, highly sensitive analytical method for the compound and reported to have found TCDD in fish and shellfish from SVN. Their results are shown in Table VII A-4. The highest concentrations were found in fish samples from the Dong-Nai River above Bien-Hoa. Lesser quantities were found in fish and shellfish samples from the Saigon River north of Saigon, and from the seacoast at the Can-Gio District, in the southeastern end of the Rung Sat Special Zone. All samples were collected in 1970 and analyzed in 1973. The watershed of the Dong-Nai River includes the heavily sprayed War Zone D north and northeast of Saigon. The Saigon River drains parts of War Zone C, to the west of War Zone D. The number of samples studied by Baughman and Meselson (1973) is quite small and no samples were taken from rivers in SVN which did not drain heavily herbicide-sprayed areas, nor from locations elsewhere in Southeast Asia. The only control used was a fish from Cape Cod; no TCDD was detected in this material (limit, 0.000003 ppm). However, the pattern of the TCDD levels found is consistent with origin in Agent Orange. Baughman and Meselson (personal communications) analyzed their samples also for hexachlorodioxin and 1,3,6,8-tetrachlorodioxin which should be present

Table VII A-3

Results of TCDD Analyses in Soil Samples from the

Calibration Grid near Pran Buri

Sample No.	TCDD ppm	TCDD lb/acre	2,4,5-T ppm	2,4,5-T lb/acre
1	<0.0012	<0.003	<0.02	<0.03
2	0.0135	0.042	<0.02	<0.03
3	<0.0012	<0.004	0.61	1.35
4	0.0233	0.060	0.43	0.96
5	<0.0020	<0.006	0.02	0.06
6	0.0052	0.016	0.04	0.09
Controls				
1	<0.0012	<0.003	<0.02	<0.02
2	<0.0012	<0.003	<0.02	<0.02

Only the top portions (ca. 20 cm) of the cores were analyzed for TCDD. The center portion of Core No. 2 contained no detectable TCDD (<0.0012 ppm).

Table VII A-4

TCDD in fish and shellfish from SVN.
(After Baughman and Meselson, 1973)

Collection Site	Fish or Shellfish	Mean TCDD level (ppm wet body weight)
Dong Nai River, north of Bien Hoa	Carp (Cyprinidae)	0.000540
	Catfish (Siluridae)	0.000814
	Catfish (Tachipuridae)	0.000522
Saigon River, north of Saigon	Catfish (Schilbacidae)	0.000070
	River prawn (Palaemonidae)	0.000042
Can Gio District (seacoast)	Croaker (Sciaenidae)	0.000079
	Prawn (Penaeidae)	0.000018

Collections were made in August-September 1970. The entire fish or shellfish was ground and kept frozen until analysis. Values corrected for recovery.

in pentachlorophenol (see Section II C[4]), and tested whether TCDD might arise from 2,4,5-T or 2,4,5-trichlorophenol during the preparation of the fish material for analysis. The results were negative, indicating that pentachlorophenol was not the source of the TCDD found, nor that TCDD was formed during the analytical procedures.

TCDD Content in Agent Orange Used in SVN

The levels of TCDD occurring in Agent Orange varied from less than 0.05 ppm (the detection limit of the analytical method used) up to 47 ppm (analyses carried out for DOD by Dow Chemical Company). These figures are based on determinations in stocks that were returned from SVN (Table VII A-5) and stocks that were procured but never shipped to SVN (Table VII A-6). As far as the Committee could ascertain no records were kept on which brand of the Agent was used on which herbicide missions in SVN and at which time. Thus, only the total arithmetic means can be estimated; for the stocks listed in Tables VII A-5 and VII A-6, these are somewhat less than 2 and 3 ppm, respectively.

A total of about 10,630,000 gallons were shipped to and used in SVN, according to procurement and shipping records. This figure does not, however, agree fully with that of 11,262,000 gallons used on herbicide missions as recorded on the HERBS tape for the period August 1965 to February 1971 (see Section III C). If we use the above arithmetic means and the gallonage of the procurement records, we can calculate that about 220 to 325 lb of TCDD were released over SVN; if we use the HERBS tape gallonage (which does not include pre-August 1965 missions, some helicopter missions, some dumps, and some other although relatively minor uses) the figures become about 235 to 360 lb. However, in view of the limited sample numbers and the uncertainty about use of different stocks, these values are no more than estimates of the order of magnitude.

Future Needs

Baughman and Messelson's (1973) findings caused much concern in SVN and led Japanese authorities to impound frozen shrimp from SVN exported to Japan, resulting in a serious potential setback for a rapidly developing industry of SVN. Thus there is evidence that TCDD persisted, at least about half a year after termination of the military use of Agent Orange, in fish and shellfish of SVN, and longer in soils which had received extremely high amounts of 2,4,5-T. The biological significance of these observations is not known and work on this problem is, therefore, urgently needed. The data of Baughman and Meselson should be confirmed by independent analyses, if possible including a different technique. If they are confirmed, further and expanded research will be urgently needed including a systematic program of sampling in SVN. Even though Baughman and Meselson's data point to Agent Orange as the most likely source of the TCDD found, a search should be made for other potential sources. Another activity appears no less essential and urgent. The finding of a TCDD content in fish of close to 1000 ppt (0.001 ppm) is disturbing. However, while the sensitivity of analytical methods has been greatly improved, permitting the detection of materials which were previously

Table VII A-5

2,3,7,8-Tetrachlorodibenzo-para-dioxin (TCDD) analyses on 200 random samples from Agent Orange stocks presently stored on Johnston Island (returned from SVN).

(Source: DOD; analyses carried out by Dow Chemical Company)

Results are given as ppm by weight. The accuracy of all values is ± 20 percent of the amount reported. Several samples contained significant interferences. For these samples, a maximum value for the amount which could be present is given.

TCDD, ppm	Percent of Samples
< 0.05	12.5
0.05-0.1	21.0
0.11-0.5	35.0
0.51-1.0	8.5
1.1 -2.0	4.0
2.1 -3.0	3.0
3.1 -5.0	5.0
5.1 -7.0	2.5
7.1 -10.0	6.0
10.1 -20.0	1.0
> 20.0[a]	1.5

Arithmetic mean of all samples: 1.91 ppm

[a] Three samples of 22, 33, and 47 ppm.

Table VII A-6

TCDD Analyses on Agent Orange Samples from Different Suppliers Remaining at Gulfport, Miss.

(Source: DOD; analyses carried out by Dow Chemical Company)

Manufacturer	Gallons Procured	Percent of Total Procurement	Dioxin (TCDD) Concentration, ppm[a]	
			Mean	Range
A	2,406,041	18.7	< 0.05	all < 0.05
B	4,022,534	31.1	0.12	0.1-0.2
C	333,685	2.6	0.17	0.1-0.3
D	1,036,475	8.1	0.32	0.3-0.4
E	3,561,040	27.7	7.62	6.9-9.3
F	696,685	5.4	8.62[b] 14.4	8.0-9.7 12.0-17.0
G,H,I	817,288	6.4	-	-
Total	12,873,748	100.0	-	-
Arithmetic mean[c]	-	-	2.99	-

[a] Analysis based on six random samples each.

[b] Two different production lots.

[c] Of all samples for which analyses are available.

suspected to be present in the environment, we remain quite ignorant as to the biological significance of such residues. Although there is now substantial work on the toxicology of TCDD it has been largely limited to mice, rats, and other rodents. It is, therefore, crucial that thorough toxicological and teratological work on TCDD is undertaken, using materials and procedures which may provide as much information applicable to man as possible. It is also no less important that comprehensive work be undertaken on the behavior of TCDD in the ecosystem, particularly, possible bio-concentration in the food chain.

Toward the ends discussed above, a Task Force on Dioxin has been formed and has had several meetings to discuss the latest information from experimental studies, the state of analytical procedures, and the state of the dioxin problem in SVN. The Task Force felt strongly that because there is an indication that dioxin may be present in the food and water of SVN and may present a hazard to the health of the Vietnamese people, studies of the concentration and distribution of dioxin in the SVN environment must be carried out as soon as possible. Discussions are being held with the U.S. Agency for International Development (USAID), Department of State, for support of the studies.

(3) Epidemiological Effects of Ecological Change

Vector-borne diseases, particularly malaria, constitute a major cause of morbidity and mortality in SVN and other parts of Southeast Asia. As of 1960-1961, over 400,000 cases of malaria were reported in SVN (World Health Organization). MacKenzie (1969) states that in Thailand and other areas of Southeast Asia, malaria "has long been recognized as the greatest impediment to community progress." Other vector-borne diseases which constitute a major health problem in this part of the world are filariasis, arboviruses (dengue, viral encephalitis), which like malaria are transmitted by mosquitoes, and plague and various forms of typhus transmitted by arthropod ectoparasites of rodents.

Each insect vector of these infections requires specific enviornmental conditions for breeding and other activities essential to their life cycle. For example, mosquitoes are very precise in selecting exactly the right kind of water in which the larvae of their species are best adapted to develop. Some species deposit their eggs in brackish water, others in flowing, sunlit mountain streams, others in rice paddies, while still others utilize small ground pools of rain water. The Committee considered the possibility that the ecological changes consequent to the application of herbicides could result in new environmental conditions better or less well suited to the breeding and development of vectors and reservoirs of infectious diseases. The constraints of military security, available time, and funds permitted the Committee to investigate this hypothesis in only one affected ecosystem, the mangrove forest. Moreover, because of these constraints and the potential magnitude of the malaria problem, the Committee focused upon this particular disease. Some information on the rodent population in intact and defoliated mangrove forests was also collected.

The results of this study indicate that few, if any, anopheline mosquitoes are present or breed in intact estuarine and coastal mangrove forests. As a consequence, malaria is not present in human communities living within this ecosystem. Destruction of the estuarine mangrove forest by herbicide application did not directly result in ecological conditions suitable for the propagation of anopheline mosquitoes. However, following defoliation, a series of events occurred that is believed to have led to the introduction of anophelines and transmission of malaria. The estuarine mangrove southeast of Saigon, in the Rung Sat Special Zone, became relatively secure after herbicides were applied and subsequent deforestation. Immigrants from the Delta and some of the indigenous population who could no longer pursue woodcutting as a means of livelihood, turned to rice farming. Anopheles sinensis and A. lesteri seem to be breeding prolifically, at least during the rainy season, in the newly created rice fields. Malaria, probably brought in by the immigrants and also possibly by the NLF, is now being transmitted and is endemic in the communities in this region.

There is also some evidence that the rat population has increased following destruction of the mangrove forests.

The results of these studies are summarized in Table VII A-7.

Intact and Defoliated Estuarine Mangrove

The Rung Sat, an estuarine mangrove forest in which approximately 57.3 percent of the area had been sprayed with herbicides (see Section IV C), was selected as a study site. Unfortunately no relatively secure comparable unsprayed, intact estuarine mangrove forest could be found in SVN to serve as a "control" study site. This lack of a control mangrove area constituted a serious impediment to conducting a scientifically valid study. The deficiency was compounded by the fact that the mangrove ecosystem has been almost entirely neglected by medical zoologists and epidemiologists; thus there was very little background information available on the species of mosquitoes/reservoir hosts or the kinds of infections which occur amongst the inhabitants of the mangrove forests of Southeast Asia. It was, therefore, decided to search for a congruent area in Thailand that could serve as a control study site. An appropriate study area was found in Chantaburi, Thailand (see Fig. VII A-1). Visits to the area by Committee members and consultants indicated that the botanical composition in this area was similar to that in the Rung Sat prior to herbicide application. Medical studies in the Thai mangrove carried out with the collaboration of the staff of the Bangkok School of Tropical Medicine, Mahidol University, included collections of adult and larval mosquitoes, estimations of rat populations by trapping, collection of ectoparasites from rats, and a survey of malaria. Botanical work by members of the Faculty of Forestry, Kasetsart University, confirmed the general similarity of the vegetation with that of the Rung Sat.

The field work was carried out in November-December 1972 at the end of the rainy season, a time when a high mosquito population was expected. The work was done first in Thailand and then in SVN.

Table VII A-7

Summary of findings in intact and deforested mangrove ecosystems of South Vietnam and Thailand

Area	Mosquitoes				Rodents
	Predominant species composing population	Medical importance	Comment	Malaria	
Intact estuarine mangrove (Chantaburi, Thailand)	Aedine: Aedes dux	Not known	Breeds mainly in fresh water found in tree holes. Readily bites man.	Not present. No positive blood films in 384 children surveyed. No enlarged spleens detected.	Rattus losea predominant species. Trapping results indicate rat population not very high in dense mangrove forest.
	Aedes taenorhynchoides	Not known	Known breeding places are ground pools. In current survey, found in brackish pools in middle of mangrove swamp. These mosquitoes readily attack man.		
	Aedes long rostris	Not known	Known breeding places are pools in mangrove swamps and in crab holes. Found in brackish pools in mangrove in current survey. Does not attack man readily.		
	Culicine: Culex sitiens	No known disease relationships.	Breeds in brackish water in coastal areas, breeding habitats includes ground water as well as artificial containers such as water collected in boats, barrels, etc.		
	Ficalbia: Ficalbia hybrida	No known medical importance.	Tree hole breeder. Does not readily bite man, most specimens caught in light trap.		

Table VII A-7 (Continued)

Area	Mosquitoes				Rodents
	Predominant species composing population	Medical importance	Comment	Malaria	
Herbicide-deforested estuarine mangrove (Rung Sat, S. Vietnam)	Anopheline: <u>Anopheles sinenses</u>	Vector of malaria in China. Can also transmit Bancroftian filariasis.	This species is normally a zoophilic species but it was found to bite man readily in the Rung Sat and will fly indoors to do so. Suspected larval habitat is in standing water of rice fields. This is its normal breeding habitat.	<u>Present</u>. Six positive cases in 84 children examined (7%). Surveys by USAID (1969) and Vietnamese malariologists indicate mesoendemic malaria to be present in Rung Sat.	No collections made. Farmers complain of high rat population destroying rice.
	<u>Anopheles lesteri paraliae</u>	Unknown	Often appears to be associated with coastal brackish-water conditions.		
	Culicine: <u>Culex sitiens</u>	See above.	Found breeding in brackish water of "salt marsh" and in brackish water collected in boats.		
Intact coastal mangrove (Cholburi, Thailand)	Aedine: <u>Aedes dux</u>	See above.		Not known. Presumably not present.	<u>Rattus rattus</u> only trapped but relatively few in number.
	<u>Aedes taenorhynchoides</u>	See above.			
	Culicine: <u>Culex sitiens</u>	See bove.			
Cut-deforested coastal mangrove (Cholburi, Thailand)	Aedine: <u>Aedes taenorhynchoides</u>	See above.		No people residing as yet in area, but presence of potential vector constitutes a hazard when settlement takes place.	<u>Rattus rattus</u> only collected. Four times as many rats trapped than in adjacent intact mangrove.
	Anopheline: <u>Anopheles subpictus</u>	Malaria vector in some areas of Indonesia, but not in India or rest of S.E. Asia. Has also been found infected with <u>W. bancrofti</u>.	Breeding site found to be exposed salt marshes. Also breeds in ground pools. Man is not a preferred host of this species.		

The main results in the intact estuarine mangrove (the "control" area, Chantaburi, Thailand) were as follows:

(1) The ecology of the intact mangrove forest as exemplified in Chantaburi provided few identifiable suitable breeding habitats for anopheline mosquitoes (Table VII A-7). Presumably these were the conditions in the Vietnamese estuarine mangrove before herbicide spraying. The predominant mosquitoes present in the Chantaburi mangrove forest are members of the Aedine, Ficalbia and Culicine groups. Aedes dux, Ae. taenorhynchoides, and Ficalbia hybrida were found to breed mainly in tree holes and Culex sitiens in brackish ground pools. Ficalbia, because of its reluctance to bite man, is of no potential medical importance. The aedine and culicine mosquitoes readily fed on humans. Their role in transmitting arbovirus infections is not considered important, although little is known regarding their role as vectors.

(2) Malaria does not appear to be present in these mangrove communities; there were no positive blood films or enlarged spleens in any of the 384 school children examined. The absence of malaria transmission is notable since the foothills bordering Cambodia about 10 miles from the "control" mangrove study area is one of the "hottest" malaria areas in Thailand.

(3) Trapping results in the Chantaburi mangrove indicate that rodent populations are not high in intact estuarine and coastal mangrove forests. The predominant species in the estuarine mangrove was Rattus losea. Little is known regarding the role of this species as a reservoir of disease but very few ectoparasite vectors, such as the chigger mite (transmitter of scrub typhus), were found on the trapped animals.

In the defoliated estuarine mangrove in the Rung Sat, the investigation was confined, because of security conditions, to a single study site, the hamlet of Tran-Hung-Dao (see Figs. VII A-2 and A-3). Although the area was relatively secure, collections could not be made from some potential mosquito larva breeding sites because of the possible presence of NLF forces; nor could light-trap collections outside the village be made because of the possibility of their being booby trapped during the night. It was possible, however, to make a collection of mosquitoes biting human bait and to make a limited blood survey of 84 school children for malaria.

Two follow-up visits were made to this site by the medical anthropologist Committee member, who obtained information on the history of the hamlet, farming practices before and after defoliation (see Fig. VII A-4), and other data that bear on ecologically related factors influencing the kind of disease vectors and reservoirs in the area (see Section VII C).

The following results were obtained:

(1) The vast majority of the mosquitoes obtained by night-biting collection from human bait and light traps were Anopheles sinensis and the related A. lesteri. These mosquitoes readily flew indoors and avidly

Fig. VII A-1. Estuarine mangrove forest near Khlung, Chantaburi Province, Thailand. Photo taken August 1972 by Dr. Peter Kunstadter.

Fig. VII A-2. Tran-Hung-Dao Hamlet in defoliated area of Rung Sat showing rice fields. Photo taken December 20, 1972 by Dr. Peter Kunstadter.

Fig. VII A-3. Defoliated area of Rung Sat showing Tran-Hung-Dao Hamlet on main shipping channel. Photo looking south taken January 6, 1970.

Fig. VII A-4. Harvested rice fields near Tran-Hung-Dao Hamlet. Photo taken January 2, 1973 by Dr. Peter Kunstadter.

Fig. VII A-5. Hand-cleared coastal mangrove forest near Cholburi, Thailand. Photo taken August 1972 by Dr. Peter Kunstadter.

sought a human blood meal. Examination of many pools of water in the defoliated area adjacent to the hamlet failed to reveal the larval breeding sites of these mosquitoes. Since it is known from other areas of Southeast Asia where these Anophelines occur that they breed mainly in rice paddies, it is believed that in our study area the larval breeding site is in the water associated with the newly-introduced rice cultivation. However, it was not possible to confirm this because security conditions prevented us from making collections in the rice paddies which were situated about a quarter of a mile from the hamlet.

With the exception of *Culex sitiens* none of the mosquitoes found in the intact, control mangrove area were found in the deforested study site.[a]

(2) A blood survey carried out in the study community gave a malaria point-prevalence rate of 7 percent amongst the 84 randomly selected school children examined. There was no opportunity to carry out fever detection or a spleen rate survey but it is believed that these methods would have indicated an even higher malaria prevalence.

Information provided by the Malaria Section of USAID/Saigon showed that although malaria in the Delta and Saigon-Gia Dinh areas is ordinarily of very low prevalence there have been outbreaks of malaria in the Rung Sat since, at least, 1969 of sufficient severity to require the attention of the Malaria Service of the RVN Ministry of Health. This was the year people living in Tran Hung Dao reported that they began farming in the vicinity of the hamlet. It appeared to us, from aerial observations and study of aerial photographs, that our study site was typical of the Rung Sat. However, further study would be required to ascertain that the factors governing transmission of malaria in this site are operative in other areas of the Rung Sat.

Malaria was probably introduced into the Rung Sat by migrant "carriers" coming from or through endemic areas, including NLF and North Vietnamese soldiers. Military medical intelligence reports indicate that malaria has been a considerable problem in both of these forces.

In all probability malaria transmission occurs only during the rainy season and ceases when the rice fields, the breeding habitat of the Anopheline vector, dry out in the dry season. A survey for malaria vectors in the dry season could not be carried out but members of the community studied informed us that very few mosquitoes were present during this period.

(3) It was not possible to collect rats in the Rung Sat. Local farmers reported that the rat population has increased so enormously in

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[a] Excluded from this discussion is *Aedes aegypti*, an ubiquitous species breeding in fresh water containers. Its presence is obviously not affected by the ecological conditions under consideration.

recent years that rats are destroying half the rice crop. They attribute the increase in rat population to the grass and debris, suitable breeding habitats, which have replaced the mangrove forests. We have been unable to collect epidemiological data regarding the presence of reservoir-associated diseases (plague, leptospirosis, typhus) in the Rung Sat.

Intact and Deforested Coastal Mangrove (Cholburi, Thailand)

It was not possible to investigate the impact of herbicide spraying on ecology-epidemiology in a coastal mangrove ecosystem such as that present in the Delta region of SVN. However, a typical coastal mangrove forest was identified in Thailand, near Cholburi town (see Fig. VII A-5). An extensive part of this forest had been deforested by cutting to make way for a housing project although no construction had yet been started. This offered an opportunity for studying epidemiological-ecological effects of removal of mangrove vegetation by means other than herbicides.

The study carried out in the coastal mangrove of Cholburi provides another indication that deforestation of mangrove can lead to anophelism. In the intact forest the predominant species of mosquitoes were similar to that of the Chantaburi estuarine mangrove (*Aedes dux*, *Ae. taenorhynchoides*, and *Culex sitiens*). Very few *Anopheles* were caught and these were considered to be "strays" breeding in adjacent rice fields and deforested areas. *Anopheles* breeding sites were not found in the intact mangrove forest.

In the adjoining cleared area the mosquito population was distinctly different. Here the predominant species were *Anopheles subpictus malayensis* and *Anopheles subpictus subpictus*. These were found breeding, along with *Culex sitiens*, in the exposed salt marshes and ground pools that formed after deforestation. No settlement of this area has yet taken place nor is the capacity of the particular local strains of *Anopheles subpictus* as a vector known. The species is a vector of malaria in Indonesia and India. The potential menace of malaria transmission when housing and settlement are developed must be seriously considered.

Trapping results suggest that the rodent population, predominately *R. rattus* (a known potential reservoir of plague and other infectious diseases), was four times higher in the deforested coastal mangrove than in the adjoining intact mangrove forest of Cholburi.

(4) Discussion

Although the limitations under which our studies, particularly those in SVN, were conducted did not allow them to meet all exacting demands of scientific inquiry and were relatively narrow in scope, the data indicate the possibility that ecological alterations caused by defoliation may result, directly or indirectly, in a new set of environmental conditions highly suitable for breeding and propagation of insect vectors of disease when these are introduced. We have focused upon malaria and its vectors not only because it was the infection most readily accessible for study but also because malaria has a tragically long history in Southeast Asia of debilitating large population groups. The potential danger of the situation is further compounded by the fact that in recent years strains of malignant tertian malaria (Plasmodium falciparus) resistant to the mainstay chemotherapeutic antimalaria agents have emerged and become widespread in that region. We have not investigated other vector-borne diseases, but there is a suggestion that rats, potential reservoirs of plague, typhus and leptospirosis, have proliferated in deforested mangrove areas.

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B. Socioeconomic and Psychological Effects

This Chapter of the Section on effects of herbicide operations on humans in SVN is composed of three units. A question addressed in each is the economic impact of herbicides in human communities. The sources of data used are photography, published records, and interviews with people. The first unit takes a broad look at this issue by analysis of aerial photography, and presents data from a sample of sites covering different land-use types scattered throughout SVN. The next two units are ground studies, the first of which concerns the lowlands (Mekong Delta and Terrace Regions) and the second the highland parts of the country. Some of the photo-interpretation sites complement the studies where people were interviewed and documents consulted.

In addition to the economic question, the last two units also take up a number of topics about which Vietnamese people were asked to tell how they perceived the effects of the herbicide operations. These topics concern, for example, human health, injury to plants and animals, compensation, and attitudes about the use of herbicides as a tool of war.

(1) Herbicide Effects on Settlement Types as Shown by Aerial Photography

Aerial photographs have been taken in large numbers for many years over the area of SVN. Interpretation of these photographs can provide: (1) estimates of population size (through counts of inhabited dwellings), (2) information on the kind and extent of agricultural and other economic activities (by examining fields in or out of cultivation), and (3) information on the presence or absence of effects of herbicide operations (by noting spray swaths across damaged or destroyed vegetation). By comparing photographs of the same settlement and its adjacent cultivated fields taken over a period of years it is possible to describe the changes in population size, in settlement forms, and in agricultural activities, and to assess the effects of herbicide missions and of other war-related activities: bombing--from craters present; spraying--from damage or destruction to cultivated tree, bush, and field crops; and ground combat--from tracks of vehicles, from the shelling and burning of houses leaving only house walls or foundation platforms remaining, from the cutting of trees and bushes, and from the presence of fortifications, gun placements, and trenches.

(a) Sites Selected and Methods Used

Using aerial photographs, a study was made of 18 areas representing six different types of settlements and land use. The purpose of the study was to determine the changes in population, in settlement form, and in land use as a result of exposure to herbicides. The study areas were selected on the basis of a map survey comparing the general locations of sprayed areas with settlements and information on the socioeconomic conditions of the Vietnamese and aboriginal Highland peoples (Montagnards) of SVN.[a] Originally, 25 areas were selected, but seven of them had to be eliminated because evidence from

[a]One exception to this mode of selection was Study Area 10 (see below).

the aerial photos indicated that other war-related activities (bombing, ground action) had resulted in depopulation of the areas before herbicide operations over the areas were begun. The locations of the 18 study areas interpreted in detail are shown on Fig. VII B-1 and listed in Table VII B-1. In the table, those areas that coordinate with studies reported elsewhere in this report are identified by cross-references. These 18 areas were not, however, the only places containing settlements exposed to spraying; many others could have been selected, the number 18 being determined by the limitations of resources and time. Each study area had to be covered by aerial photography at a scale adequate for interpretation taken at times before, during, and after herbicide spraying. The results of the aerial photo interpretation indicate general patterns or consequences of the application of herbicides on settlements, land use, and other economic activities for the areas studied, but because of the sampling method the findings cannot be used to obtain (or extrapolate) a nationwide quantitative estimate of these effects.

Using 1:50,000 scale topographic maps obtained from DOD, base maps were constructed of each of the selected study areas (see sample, Fig. VII B-2). On the maps all settlements are represented as they were in the immediate pre-spray period (usually 1965). This latter information was verified by interpretation of aerial photos taken prior to the beginning of spraying. On an overlay to this pre-spray base map for each study area, the location, dates, scales, and print numbers of all vertical aerial photographs were plotted from information supplied by the U. S. Army Engineer Topographic Laboratories. In order to select photographs of those parts of the study areas that had been sprayed with herbicides, another overlay was constructed on which was plotted the locations of the centerlines, dates, agents, and quantities of all herbicide missions as recorded on the HERBS tape printout. This printout included only herbicide missions from August 1965 to February 1971 but covered the majority of the herbicide operations (compare Section III A-3).

From a correlation of these two overlays (aerial photos and herbicide missions), orders were placed for the aerial photos needed (selected for largest scales available, for maximum extent of areal coverage, and to provide a time sequence of different seasons over as many years as possible). Each run, or sequence, of photographs had sufficient overlap or sidelap to allow stereoscopic (three-dimensional) interpretation. Fig. VII B-3 is an example of a base map of a study area overprinted with the aerial photo runs selected for use in interpretation of that study area, and Fig. VII B-4 an example of a base map for a study area overprinted with all of the herbicide spray missions. Figs. IV C-6 and IV C-7 in the section on the mangroves show the herbicide missions in the study area of Fig. VII B-3.

The aerial photography available for this study was not always ideally suited for the purpose. Only unclassified black-and-white vertical photos were available for the period prior to October 1972. Of the 7,179 black-and-white photographs received, 30 percent were at a scale of 1:30,000 or smaller, useful for mapping general features of the landscape, but of limited value for interpretation; only 32.5 percent were at a large enough

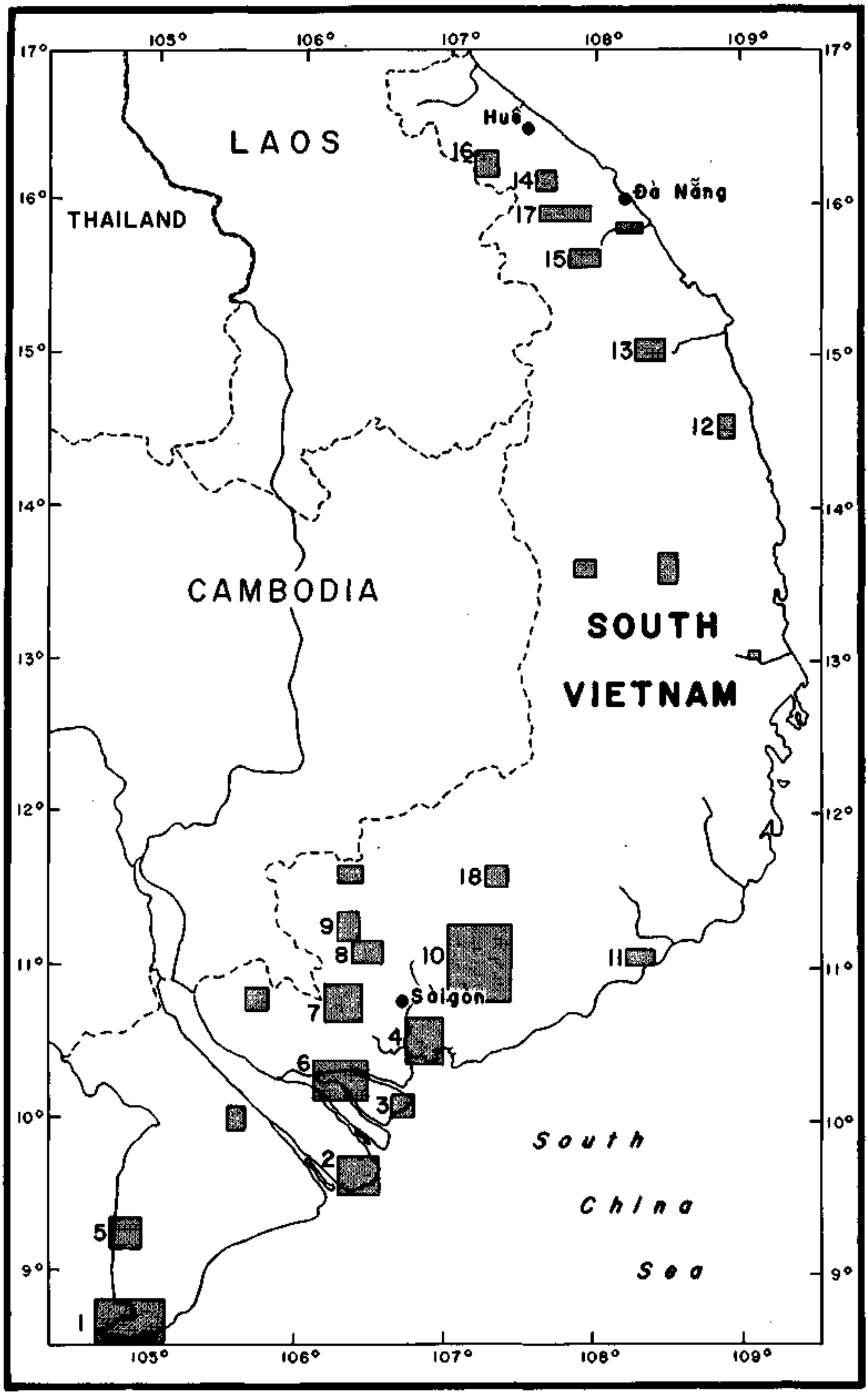

Fig. VII B-1. Location of the 25 areas selected for air photo interpretation study of the human aspects of the use of herbicides in South Vietnam. The seven unnumberered areas are those where air photo interpretation showed that the population had left the area prior to the beginning of herbicide operations. The seven areas were studied in detail, but the results are not included in this report.

Table VII B-1

The 18 Study Areas Subjected to Detailed Interpretation

of Aerial Photographs

Mangrove Settlements (wood-cutters, charcoal makers, fisher folk)

1. Tip of Ca-Mau Peninsula, An-Xuyen Province
2. Mouth of the Mekong Area, Vinh-Binh Province
3. Mouth of the Mekong Area, Kien-Hoa Province
4. Rung Sat Special Zone, Gia-Dinh and Bien-Hoa Provinces (see Sections IV C, VII A[3], VII B[1] and VII C)[a]

Delta Canal-Bank Settlements (irrigated rice--primarily commercial)

5. Coastal Area West of Quan-Long, An-Xuyen Province
6. Truc-Giang (Ben-Tre) Area, Kien-Hoa Province (see Section VII B-2)
7. Area North of Tan-An in Hau-Nghia, Long-An, and Kien-Tuong Provinces

Plantation Settlements (commercial crops for export)

8. Ben-Cat Area, Binh-Duong and Hau-Nghia Provinces (see Section VII B-2)
9. Tri-Tam Area, Tay-Ninh and Binh-Duong Provinces
10. Xuan-Loc Area, Long-Khanh Province (see Section VII B-2)

Lowland Valley Settlements (near coastal plain)

11. Coastal Hills, Binh-Thuan Province
12. An-Lao Area, Binh-Dinh Province
13. Hill Area West of Quang-Ngai City, Quang-Ngai Province
14. Lowland Valley, South of Hue, Thua-Thien Province

Upland Valley Settlements (irrigated rice--primarily subsistence)

15. Valley between Cai and Thu-Bon Rivers, Quang-Nam and Quang-Tin Provinces

Swidden Settlements (upland dry rice and other subsistence)

16. Central A-Shau Valley, Thua-Thien Province
17. Upland Valley, West of Da-Nang, Northern Quang-Nam Province
18. Headwaters Area of Dong-Nai River, Phuoc-Long and Long-Khanh Provinces

[a] The references indicate other sections of the Report containing results obtained at this study site.

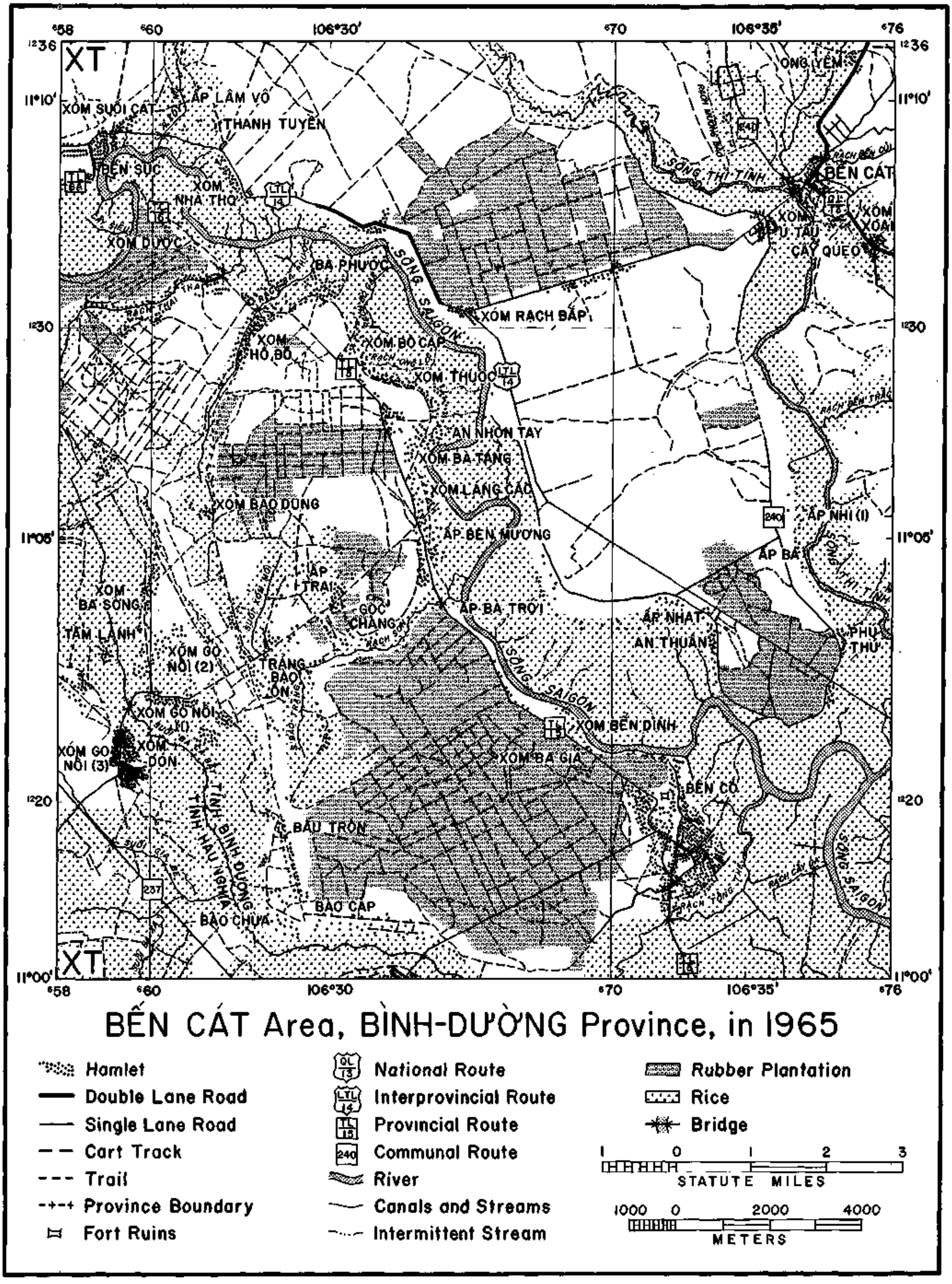

Fig. VII B-2. Sample of a Base Map for a Study Area, showing settlements in 1965, prior to reported herbicide operations. Here shown for Study Area 8, the Ben-Cat Area, Binh-Duong Province. The settlements in the upper left include the hamlets evacuated by the refugees who were resettled in the village of Binh-Hoa, north of Saigon (see Section VII B[2]).

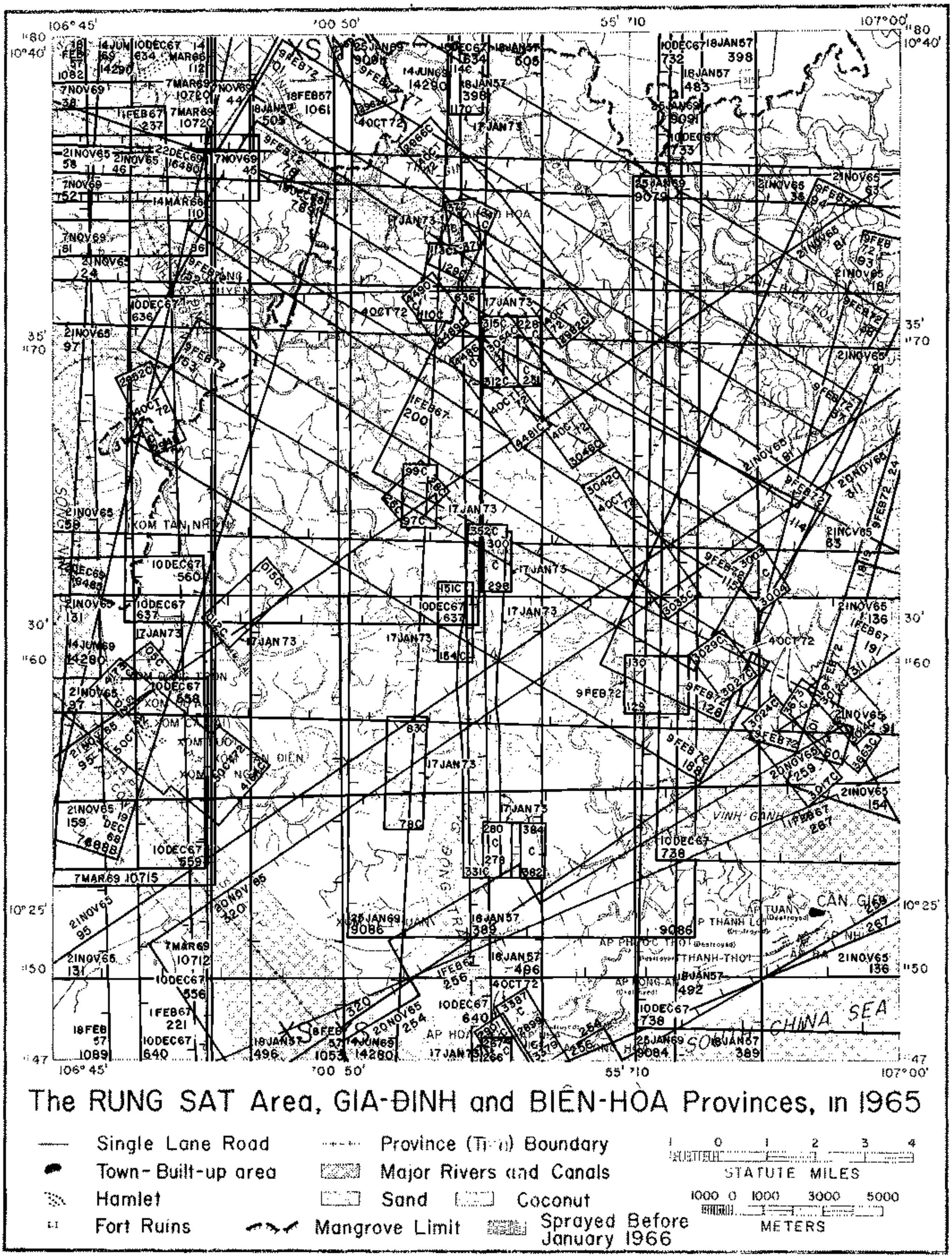

Fig. VII B-3. Sample of a Map of Aerial Photo Runs reported for a Study Area. Here shown for Study Area 4, the Rung Sat Special Zone. Aerial photography runs are identified by date taken, and first and last print numbers, placed within the lines outlining their location. Color transparencies are marked by the letter C.

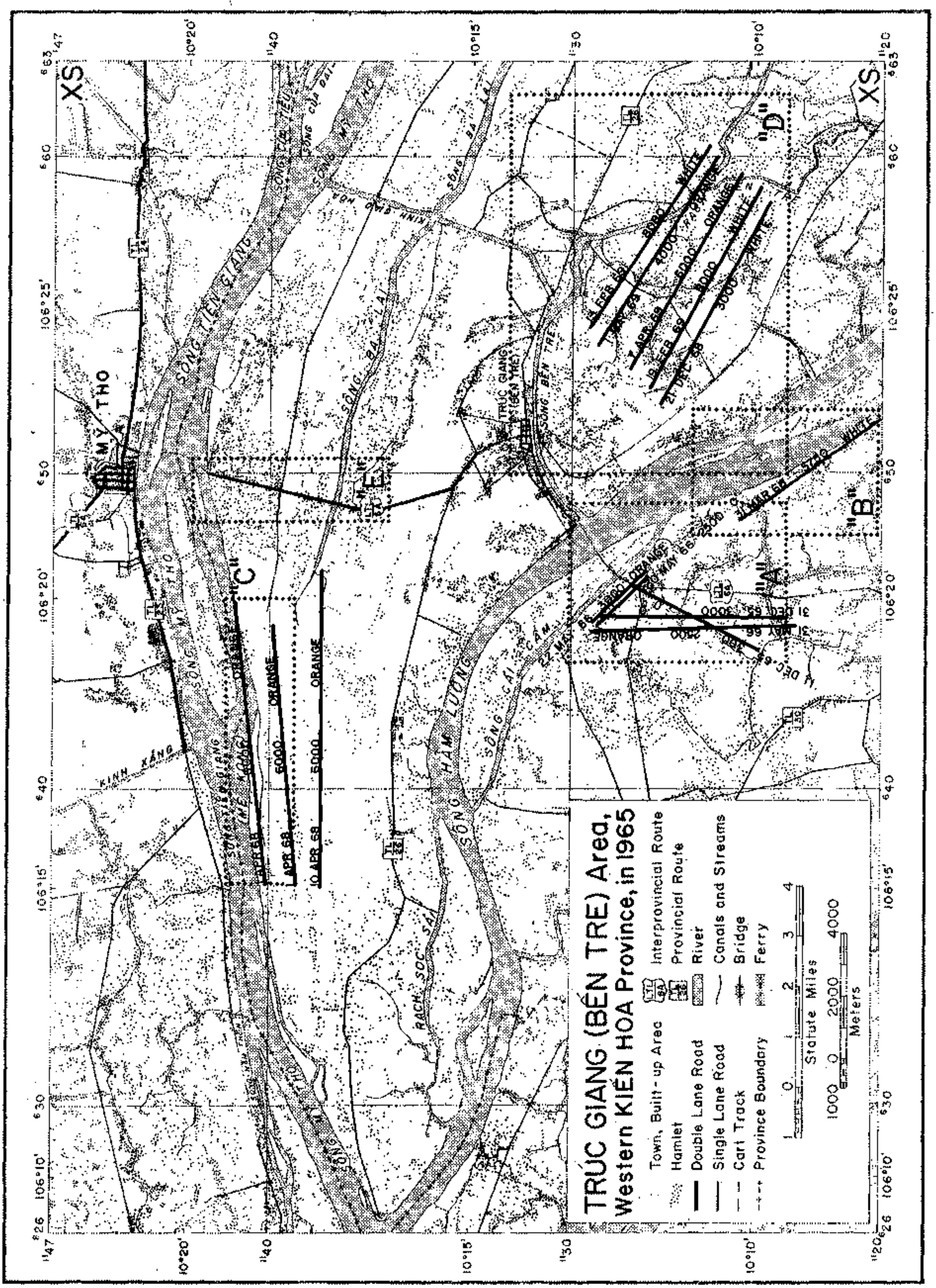

Fig. VII B-4. Sample of a Map of Herbicide Missions reported on the HERBS computer tape printout for the Provinces relevant to a particular Study Area. Here shown for Study Area 6, the Truc-Giang (Ben-Tre) Area, western Kien-Hoa Province. Strips are <u>centerlines</u> of reported herbicide missions (identified by date flown, number of gallons, and agent sprayed), and are <u>not</u> spray swaths with widths drawn to scale appropriate to the number of aircraft flying. The sub-areas "A"-"E" were investigated in detail. Fig. VII B-5 shows detail of sub-area "C".

scale (1:10,000 to 1:4,000) for easy interpretation of relevant features, (footpaths, animal pens, gardens, etc.). Color transparencies numbering 846 were taken in October 1972 and January 1973, well after the end of the period of spraying. All of these were at an appropriate scale and were useful in assessing land-use recovery. They provided very limited coverage, however, of only five study areas. Oblique photos and special emulsion or filter combinations (e.g., color infra-red) that would have been useful for interpretation of damage to vegetation were not taken or not released by DOD.

Population estimates were made by counting the number of occupied houses and multiplying by 7 as the average number of people per house.[a] Evidence of use, such as open trails, neatly arranged houseyards and gardens, crops growing in adjacent fields, were interpreted as indicating that houses were occupied. Partially or wholly destroyed or abandoned settlements were marked by abandoned houses, vegetation growing over paths and cart tracks, damaged or unrepaired houses, overgrown or untended fields and gardens, and dead or damaged vegetation (especially fruit trees).

(b) Sample of Findings from Selected Study Areas

The aerial photographs provided the evidence; their interpretation was conducted as objectively as possible. Each of the 18 study areas was unique in its population distribution, settlement patterns, and kinds and proportion of crops grown. The several illustrations which follow are representative of the findings about the effects of herbicide spraying.

Crop Damage and Destruction. A summary of the intention of the herbicide missions for the study areas is presented on Table VII B-2. Of the total of 1,659 reported herbicide missions, 82.8 percent were for defoliation, and only 10.6 percent for crop destruction and 6.6 percent for other military purposes. Agent Orange was used for 64.8 percent of all missions. Defoliation using Orange was the predominant purpose and agent in 14 of the 18 study areas; the exceptions were Study Areas 8 (Orange used for other purposes), 9 (defoliation using White), 12 (crop destruction using Orange), and 13 (crop destruction using Blue). Except for Study Areas 12 and 13, most damage or destruction of agricultural field and tree crops resulted from missions designated as defoliation rather than as crop destruction. Except for Study Area 13, more crop destruction occurred from the use of Agent Orange than by either Blue or White.

By virtue of its ubiquity in SVN, rice was the most important and most commonly sprayed crop. The damage or destruction of an irrigated rice

[a] The Demographic Survey of 14 Cities, 1969-1970 (Dieu-tra dan-so tai 14 thanh pho trong nam 1969-1970), published in Saigon by the National Institute of Statistics on December 2, 1971, gives a total estimated population for 14 cities as 1,536,170 living in 220,970 households, for an average household size of 6.95. Rural households usually are larger than urban ones.

Table VII B-2

Summary of Reported Herbicide Missions for the 18 Study Areas

by Intended Purpose and Agent Used

Study Area Number	Size (sq. mi.)	Reported Number Herbicide Missions	Intended Purpose and Agent: Defoliation			Crop Destruction			Other		
			Orange	White	Blue	Orange	White	Blue	Orange	White	Blue
Mangrove											
1	360	76	54	19	-	1	1	-	-	1	-
2	272	51	40	3	2	-	-	-	4	2	-
3	70	34	29	5	-	-	-	-	-	-	-
4	360	299	188	93	17	-	1	-	-	-	-
Delta											
5	196	43	23	17	3	-	-	-	-	-	-
6	375	13	9	4	-	-	-	-	-	-	-
7	308	64	34	19	3	2	-	-	6	-	-
Plantation											
8	139	97	14	22	2	3	1	4	42	1	8
9	196	56	19	22	1	2	2	3	7	-	-
10	1,147	313	165	127	9	8	-	-	1	1	2
Lowland Valley											
11	99	37	16	12	-	7	-	-	2	-	-
12	56	71	21	2	-	24	18	-	-	-	6
13	140	37	16	-	-	3	1	17	-	-	-
14	92	94	45	4	2	12	-	30	-	-	1
Upland Valley											
15	125	31	24	1	1	3	-	2	-	-	-
Swidden											
16	127	121	63	9	10	13	-	1	24	1	-
17	132	77	55	14	-	4	3	1	-	-	-
18	98	145	84	51	1	8	-	1	-	-	-
TOTALS	4,292	1,659	899	424	51	90	27	59	86	6	17
			Defoliation - 1,374			Crop = 176			Other = 109		

Total Missions Using: Agent Orange - 1075 (64.8%)
Agent White - 457 (27.5%)
Agent Blue - 127 (7.7%)

crop from spraying was ordinarily limited to a single season, unless the spray was repeated in the following season or the population abandoned the area. Destruction of crops and fruit trees in marginally-subsistence agricultural areas must have caused great economic hardships to the local inhabitants. This would have been especially true in the upland irrigated and swidden areas (Study Areas 15-18), particularly among the Montagnards who lacked economic alternatives. Further discussion of herbicide effects as perceived by Montagnards is contained in Section VII B(3) of this report.

The most important and persistent effects of herbicides on commercial crops observed in the aerial photographs were in the coconut groves of Kien-Hoa Province (Study Area 6), the major coconut-producing region of SVN, and formerly an important source of coconuts for export. Fig. VII B-5 provides an illustration of this evidence. Further discussion of the effects on coconut groves as seen from the ground is included in Section VII B(2).

Settlements Subjected to Spraying. For 17 of the 18 study areas (the exception being Study Area 10) there is plentiful evidence from the aerial photographs that inhabited isolated farmsteads, hamlets, and clustered settlements of villages and small towns were directly and repeatedly subjected to aerial spraying by all three agents (Orange, White, Blue). Table VII B-3 summarizes the findings, comparing the location of each settlement with the plotted location of the centerline of each herbicide mission reported on the printout from the HERBS tape. The high percentage of settlements sprayed evident in the table is in keeping with the fact that the study areas were selected for that criterion. It is to be noted, however, that of the 708 settlements exposed, 611 were sprayed more than once and 405 four or more times. Study Area 10, which is the exception, is shown in Fig. VII B-6, and on-the-ground studies conducted in a settlement in this area are described in Sections VII A(3) and VII C. The area is unique in this series in that it was not selected for the congruence of herbicide missions over human settlements but rather as an area where wind drift was believed to have covered wide distances.[a]

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[a]Damage by herbicide may be from drift as well as from a herbicide mission directly overhead. The count in Table VII B-3 includes all herbicide missions, the centerline of which passed one (1) kilometer from the center of a settlement. The HERBS locations were used because the air photo coverage was not frequent enough to verify the existence of each reported, or actual, herbicide mission. Further, swaths of spray damage overlap one another on the photographs and cannot be distinguished as having been made by several planes on one day, or by one plane on several different days. Finally, Vietnamese settlements are not always clustered; many are linear--along river or canal banks and roads (the units counted were hamlets or the centers of a group of dispersed farmsteads; in the upland valley and swidden areas the units are clusters of several newly-made forest clearings).

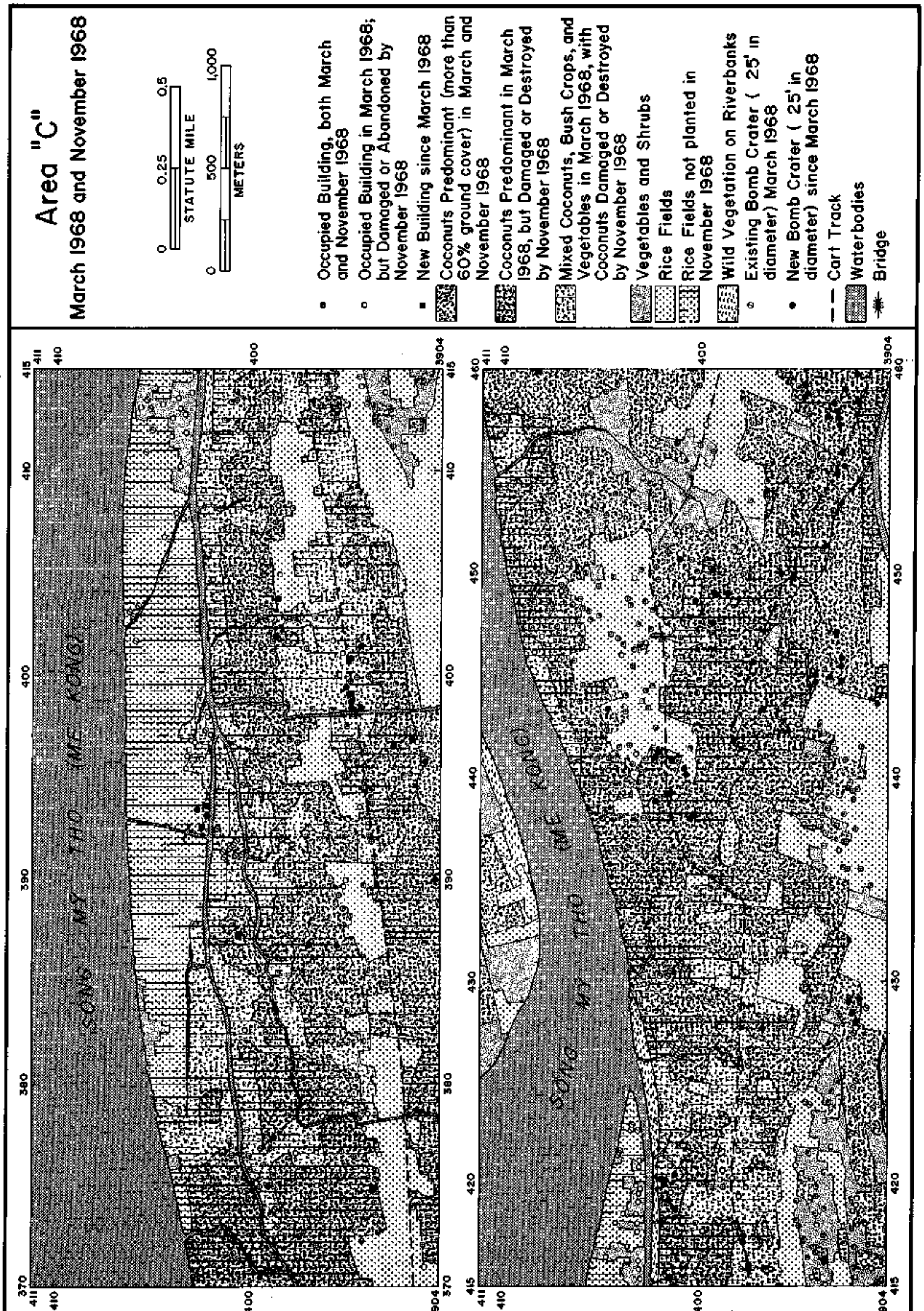


Fig. VII B-5. Detailed interpretation of aerial photographs for Kien-Hoa Province (Study Area 6), (for location of herbicide missions over this study area see Fig. VII B-4) shows a 77 percent reduction in coconut palm acreage and a decrease in occupied houses from 558 to 307 between March and November 1968.

Table VII B-3

Summary of Settlements in the 18 Study Areas that would have been Exposed to the Reported Herbicide Missions

Study Area Number	Total Number of Settlements in Study Area	Number of Settlements Arranged According to the Number of Times that the Centerline of a Reported Herbicide Mission Passed Within One Kilometer of their Centers: 0=not Sprayed	Sprayed 1 time	Sprayed 2 times	Sprayed 3 times	Sprayed 4 or more times	Settlements Sprayed as Percent of Total Settlements
Mangrove							
1	30	5	2	1	7	15	83.3
2	104	42	15	9	9	29	59.6
3	56	5	4	6	5	36	91.1
4	25	3	2	2	5	13	88.0
Delta							
5	67	34	8	6	1	18	49.3
6	119	57	12	21	20	9	52.1
7	102	26	12	19	10	35	74.5
Plantation							
8	62	6	5	5	12	34	90.3
9	32	18	4	4	2	4	43.8
10	140	122	10	4	2	2	12.9
Lowland Valley							
11	6	0	0	0	1	5	100
12	38	0	0	0	0	38	100
13	108	38	13	18	5	34	64.8
14	11	0	0	0	0	11	100
Upland Valley							
15	17	2	1	3	1	10	88.2
Swidden							
16	53	2	4	7	9	31	96.2
17	69	8	5	8	3	45	88.4
18	37	0	0	0	1	36	100
Total	1,076	368	97	113	93	405	

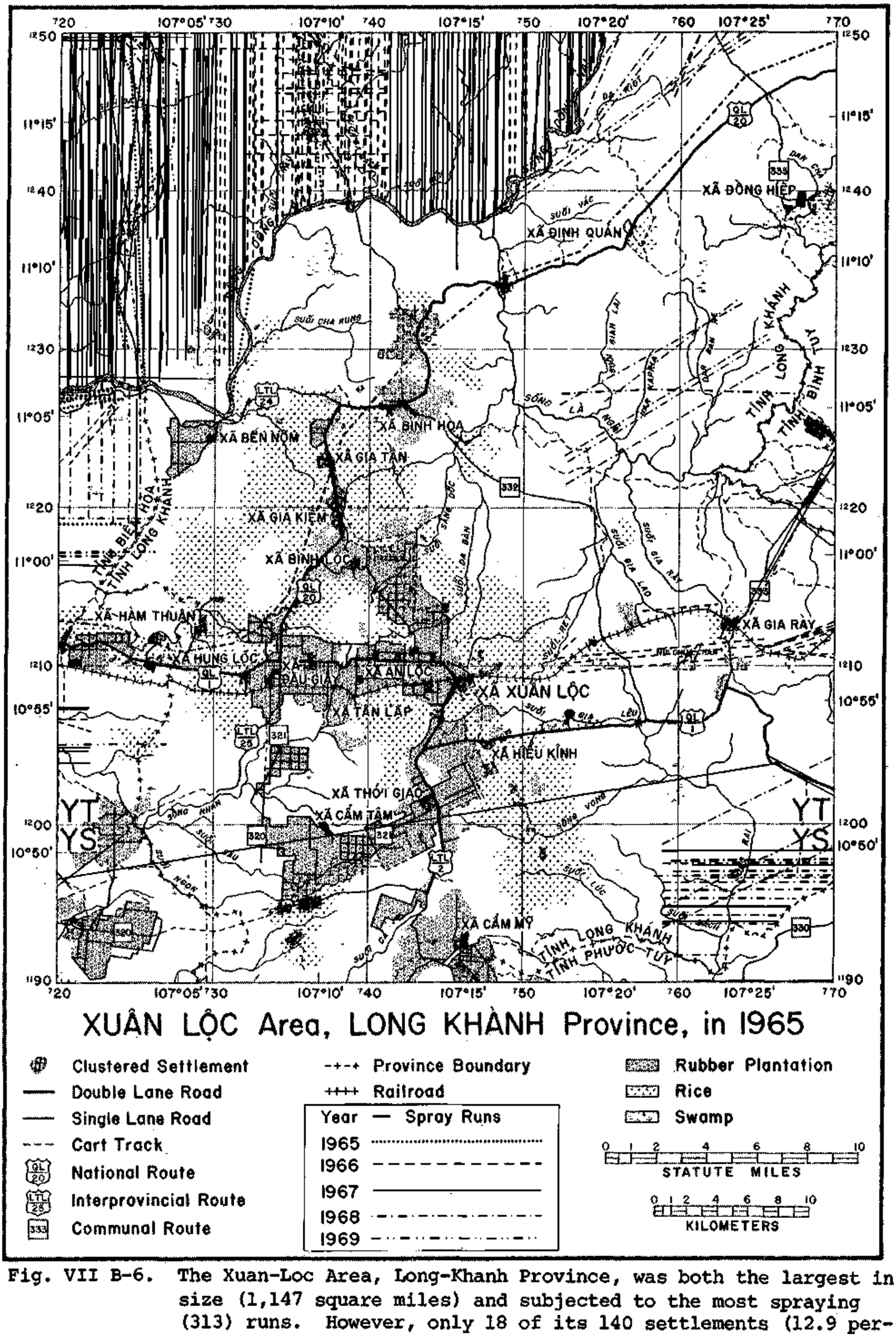


Fig. VII B-6. The Xuan-Loc Area, Long-Khanh Province, was both the largest in size (1,147 square miles) and subjected to the most spraying (313) runs. However, only 18 of its 140 settlements (12.9 percent) were exposed to spraying (see Table VII B-3). Owing to the congestion of herbicide missions and the small scale of the map, detailed data for each run (date, agent, gallons) are not indicated.

Population Displacement. In every one of the 18 study areas, without exception, there was aerial photographic evidence for the displacement of people from their homes following herbicide spraying. To be sure, herbicide missions may have been only one causal factor among many (insecurity, bombing, ground fighting, or other war-related events) that led people to decide to move. An example of massive evacuation of a population and herbicide destruction of crops, fruit trees, and houseyards is provided by Fig. VII B-7, showing the "before-and-after herbicide spraying" in a part of Study Area 12.

Another example is provided by Study Area 8 (see Fig. VII B-2), where the hamlets in the upper left included those evacuated by persons who were resettled in Binh-Hoa (see Section VII B(2), for results of interviews with some of these refugees).

Post-spray photographs were unavailable for most study areas. As far as the evidence permits us to say, only in the Rung Sat Special Zone (Study Area 4) has land use and settlement expanded after cessation of the herbicide operations (Fig. VII B-8). The Rung Sat had in 1972 a larger population than was present when herbicide spraying began.

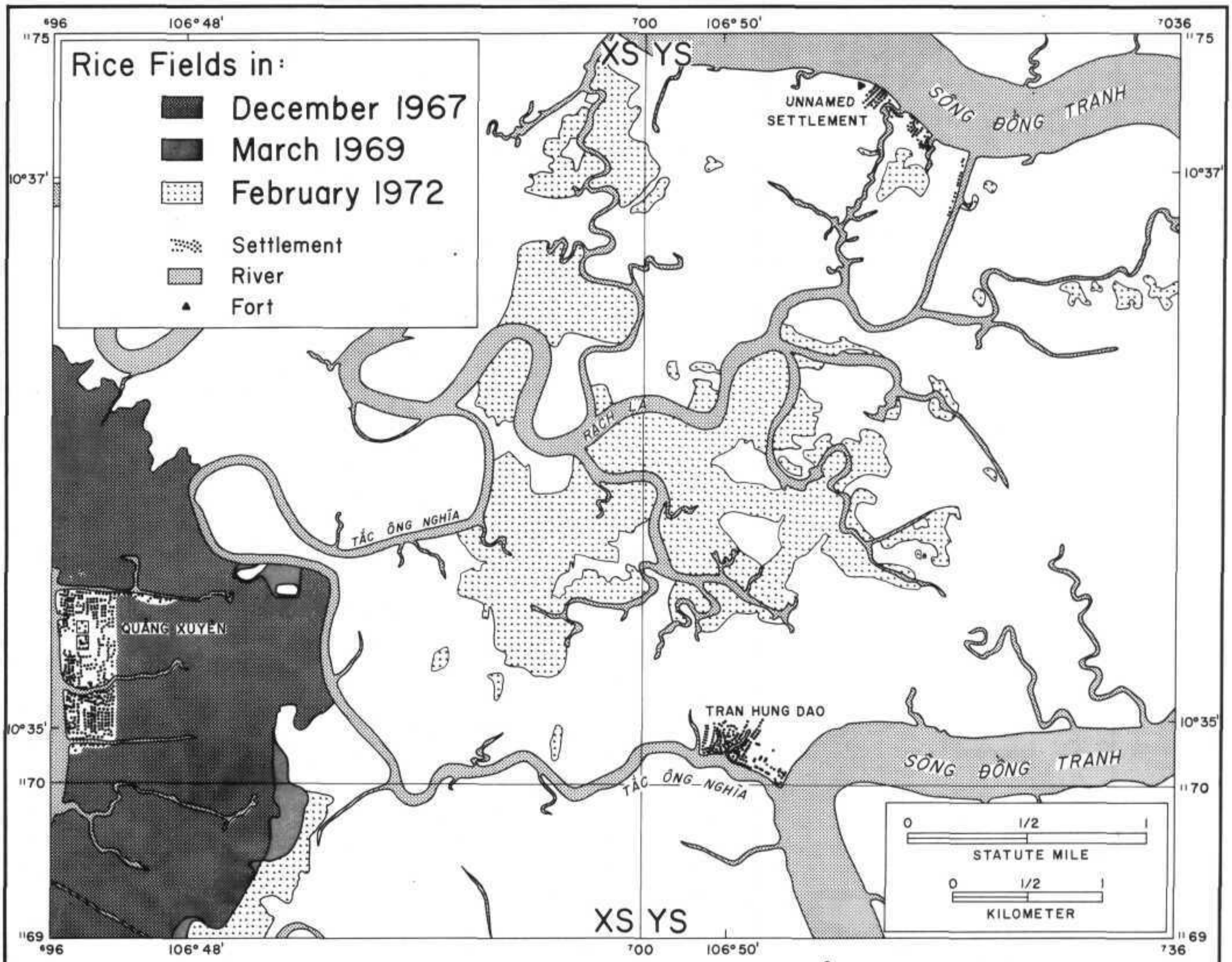
The cumulative effect of herbicide operations upon the rural countryside has been to displace people from their farmsteads and village homes, forcing their temporary or "permanent" relocation. Insofar as refugees have gone into camps, towns, and cities, the use of herbicides (together with all other war-related activities) has contributed to the massive urbanization of SVN which has occurred in the course of the war.

Land-Use Change in Sprayed Areas. The most heavily affected natural vegetation of those types extensively examined was the mangrove forest along the coast of the Mekong Delta (Study Areas 2 and 3), in the Rung Sat Special Zone (Study Area 4), and to a lesser extent in the Ca-Mau Peninsula (Study Area 1), in all of which, large areas were denuded of vegetation. To be noted here is the aerial photographic evidence that in the inland sector of the Rung Sat (on land farthest removed from tidal submergence) Vietnamese settlers have been removing the stumps and roots of killed mangrove trees, and planting new rice fields. Fig. VII B-8 shows the location and extent of this activity east of Quang-Xuyen and north of Tran-Hung-Dao.

(c) Summary and Conclusions

Since the study areas described here were chosen especially because they had been heavily sprayed, the results of this aerial photo-interpretation study cannot be extrapolated for unsprayed or lesser-sprayed areas, nor can they be used to obtain a nationwide quantitative estimate of total effects. Interpretation of photographic evidence on the effects of the herbicide operations on settlements of different types in the 18 selected study areas (Table VII B-3) leads to the following conclusions:

Fig. VII B-7. The densely settled and productively cultivated floor of the An-Lao River valley (Study Area 12) on 28 October 1965 (left), compared to the identical area on 24 June 1968 (right), indicates vast devastation and complete abandonment by at least 6,400 people (915 houses). Ten herbicide missions are reported over this area between 12 March 1967 and June 1968; another nine were flown in late 1968 and 1969, all for the purpose of crop destruction.



Expansion of Rice Plantings East of QUẢNG XUYÊN and North of TRAN HUNG DAO, 1967 to 1972

Fig. VII B-8. An example of land use change since the end of herbicide operations. Here shown is the inland sector of the Rung Sat Special Zone (Study Area 4), for which photographs of 9 February 1972 indicate a wholly new settlement since 1969 and an expansion of new rice fields totalling 900 acres (360 hectares) onto land where the mangrove forest cover had been killed by herbicide spraying.

(1) Many settlements as well as the cultivated tree, bush, and grain crops in fields surrounding the settlements were intensively sprayed. Except for one Study Area (10), many settlements were sprayed repeatedly. Rice, the most important crop, was most commonly sprayed. The most damaging effects of herbicides on commercial crops were in the coconut groves of Kien-Hoa Province (Study Area 6). Most damage or destruction to crops in the study areas resulted from spraying missions designated as defoliation (except for Study Areas 12 and 13 in which crop destruction missions predominated). Agent Orange was used in these areas almost twice as frequently as Agents White and Blue combined.

(2) People in all study areas were displaced from their homes following herbicide spraying. Only in the Rung Sat Special Zone (Study Area 4) have population and settlements increased over the pre-spray period. Elsewhere, the herbicide operations have contributed to the displacement of population of SVN.

(2) Beliefs, Attitudes, and Behavior of Lowland Vietnamese

The purpose of this part of the study is to describe the social, psychological, and economic effects of herbicides on people in several areas of lowland SVN. It includes sections on methods, effects on plants and animals, economic implications, compensation, refugee movement, health hazards, psychological strain, and lastly views on the use of herbicides. The goal is to present what people say they believe and to show the patterning of their feelings. Another concern is to put these beliefs in perspective by examining relevant facts when these are available.

(a) Procedures

This study is based on interviews and documentation which are described in a report of which these pages are a summary. Interviews were conducted with RVN officials at various administrative levels, as well as with farmers, fishermen, market women, etc. The documents consisted of newspapers, magazines, agricultural reports, hospital records, and the findings of a variety of studies carried out by Vietnamese and U.S. scientists. The procedures of the study can be described in three units: provincial studies, Binh Hoa community study, and newspaper analysis.

Provincial Studies

Of the four physiographic regions in SVN, we chose the Mekong Delta Region and the Terrace Region since these encompass the majority of the country's population and its most productive resources. Within each of the ecological zones we focused on a single province as the unit of study: Kien Hoa Province in the Mekong Delta, and Long Khanh Province in the Terrace Region. Work in these provinces was done between July and October 1972. Semi-structured interviews with more than 300 individuals were conducted in 15 of the 19 villages in Long Khanh and 26 of the 115 villages in Kien Hoa.

Data were collected by one Vietnamese and four American social scientists, as well as 17 Vietnamese research assistants. We endeavored to maximize validity by utilizing diverse sources of information, through analysis aimed at detecting inconsistencies, through the participation of Vietnamese with appropriate experience and training, and through the proficiency in the Vietnamese language of some of the American team members.

Attributes of the two provinces are compared in Table VII B-4. A smaller quantity of herbicide was applied in Kien Hoa where there appears to have been direct exposure to people and crops, especially in NLF areas. According to the HERBS information on spraying in Long Khanh, most missions were flown over essentially uninhabited forests located away from populated and cultivated areas. In this province, the people attributed exposure to wind drift from spraying conducted over the forest areas.

Table VII B-4. Characteristics of Provincial Study Sites

Study Unit	Kien Hoa Province	Long Khanh Province
Ecological setting	Mekong Delta	Terrace Region
Vegetation	Rice paddies, coconut groves, mangroves	Upland forest, rubber plantation, cultivated fields
Surface area	2,155 km^2	4,460 km^2
Population (1971)	618,870	166,539
Population density	287 persons/km^2	37 persons/km^2
Ethnic composition	Lowland Vietnamese	Lowland Vietnamese, and a few Montagnards
Settlement pattern	Lineal hamlets and dispersed homesteads	Nucleated, with most of forest areas uninhabited
Economic orientation	Small holder rice, fruit and vegetable farms, coconut groves, fishing	Timber, rubber plantations, small holder fruit, vegetable and rice farms
Population under NLF Control (1968)	Approximately 50% of population	Approximately 10% of population
Quantity of herbicides 1965-1970 (gals.)	276,935	1,639,350
Agent	78% Orange, 22% White	60% Orange, 39% White, 1% Blue
Spray Locales	Chiefly mangroves, coconut groves, and waterways	Principally heavily forested areas
Exposure of people and crops	Direct spraying over inhabited areas, especially those under NLF control	Apparent long-range wind drift from spray runs over forest areas

Table VII B-5

Herbicide Missions in Relationship to Location of Hamlets in Kien Hoa Villages Where Data were Collected [Using a 1 km (0.6 mi) Range]

Village	Hamlet	UTM Coordinates of Village/Hamlet	Date of Mission	Agent	Quantity (gal.)
Phu-Tuc	Phu-Xuan	XS 388398/	1 Apr 1968	Orange	2000
		XS 370395		Orange	2000
Tuong-Da	An-Loc	XS 425385	10 Apr 1968	Orange	6000
	An-Dinh	XS 442375	1 Apr 1968	Orange	6000
Thanh-Trieu*	Phuoc-Thanh	XS 400380	10 Apr 1968	Orange	6000
Thanh-Phong	Thanh-Loi	XR 835940	24 June 1966	Orange	2000
	Thanh-Loc	760863	6 June 1966	Orange	2000
	Thanh-Phuoc	770880	"		
	Giong-Dai	787904	"		
	Dai-Nhon	790917	"		
	Thanh-Loc	760863	27 May 1966	Orange	4900
	Thanh-Hoa	760866	"		
Giao-Thanh*	Giao-Thanh	XR 767949	2 June 1966	Orange	4000
	Giao-Hoa Cho	762934	"		
	Giao-Thoi	XR 817937	23 May 1966	Orange	3700
	Giao-Thanh	767949	"		
	Giao-Binh	797958	"		
	Giao-Tan	XR 753855	27 May 1966	Orange	4900
	Giao-Hoa B	768913	"		
	Giao-Loi	790958	"		
	Giao-Hoa B	XR 768913	6 June 1966	Orange	2000
	Giao-Binh	797958	"		
	Giao-Thanh	XR 767949	22 June 1967	Orange	2790
My-Thanh	Cho-Hanh-Sao	XS 593300	1 May 1969	Orange	4000
An-Nhon*	An-Binh A	XR 735941	22 June 1967	Orange	2790
	An-Dinh	744923	"		
	An-Hoa	741934	"		
	An-Binh B	XR 767050	12 June 1967	White	2400
Chau-Hoa	Phu-An/P.-Thuan	XS 634302	25 Apr 1966	Orange	3000
	Phu-Hoa/P.-Tri	XS 640294	"		
	Thoi-Hoa/T.-Tri	650286	"		
	Phu-An/P.-Thuan	XS 634302	13 Nov 1967	White	2000
	Phu-Hoa/P.-Tri	640294	"		
	Phu-An/P.-Thuan	XS 634302	16 June 1967	Orange	6250
	Phu-Hoa/P.-Tri	640294	"		
	Thoi-Hoa/T.-Tri	650286	"		
	Thoi-Thuan	658273	"		

Map coordinates are for each hamlet.

*Villages for which HERBS tape, aerial photos, ground photos and data collection on the ground are coordinated.

For Kien Hoa it was possible to compare the HERBS tape data with the locations of people who were interviewed. The purpose of this was to estimate the extent to which first-hand observation could have been the basis for the information reported to us. Table VII B-5 shows the HERBS information on missions flown within one km (0.6 mi) of hamlets in villages where interviews were conducted. A hamlet is a smaller administrative unit than a village, and in a densely populated area such as Kien Hoa it is reasonable to assume that what occurs in one hamlet is known to most villagers. Thus, it can be seen that in 8 of the 26 villages studied there is evidence of close proximity to flight paths. Nine other villages studied were in a 3 km (1.8 mi) range. Thus in about two-thirds of the areas where interviewing was conducted it was likely that people had first-hand knowledge. In four of these villages the interview data is supplemented by aerial and ground photographs.

The Binh Hoa Community Study.

Binh Hoa is located in the province of Binh Duong and is inhabited mostly by refugees from the Iron Triangle area in War Zone D who were resettled as part of a U.S. military operation (Cedar Falls) in 1967. Prior to their evacuation and destruction, the native hamlets of the Binh Hoa refugees had been subjected to heavy military activity, including the use of herbicides (see Section VII B-1).

In the study of this group, a systematic sample totalling 92 people was interviewed according to a structured questionnaire format.

Newspaper analysis and literature survey.

Content analysis was done of two newspapers, one pro-establishment and the other anti-government, together with a review of other types of Vietnamese literature. The aim was to gain more understanding of urban middle-sector opinion regarding the use of herbicides.

(b) Beliefs About Effects on Plants and Animals

In all areas studied, people believed that herbicides have damaged or destroyed a variety of crops ranging from manioc and fruit trees to rice. They made no distinction between types of agents and thought of herbicides as a single entity.

By and large, ideas about plant sensitivity parallel what is known from experimental and other sources. Thus, damage to fruit trees was the most commonly reported and the topic about which there was greatest agreement. There was general belief that papaya was exceedingly sensitive and that jack-fruit, coconut, and bananas were also highly susceptible. Among field crops, beans were believed to be very sensitive, and manioc and sweet potatoes were also thought to be easily damaged. A sizeable number of people thought rice could be badly damaged during the pollen formation stage, but there was much less agreement about its susceptibility at other stages.

People in Long Khanh believed that rubber and timber had been affected by herbicides, but reports tended to be inconsistent with regard to the extent of damage sustained.

There seemed to be a general belief that herbicides did no lasting harm to soil. On the other hand, people held that poultry are susceptible after consuming feed or water contaminated by herbicide. Reports on pigs were similar. Illness and death were mentioned, but resistance to herbicide was thought to be related to the physical condition and age of the animals. There was general agreement that cattle and water buffalo were seldom affected.

(c) Economic Implications for Agriculture

As background for estimating the impact of herbicides on the lives of individual Vietnamese, we made two studies of economic implications. One focuses on Long Khanh Province where it was possible to draw certain conclusions from official records. The other concerns Kien Hoa and is based on interviews with coconut growers (see also Section VII B-1).

Official herbicide records show Long Khanh to have been among the most heavily sprayed provinces in the country, with 1967 as the peak year. The Provincial Agriculture Report for the year indicates a drop of about one-third from normal crop yields per hectare. Three reasons for the drop were given: herbicides, Rome plowing, and the take-over of land by RVN and Allied/ U.S. forces. Villagers and local officials also expressed the belief that herbicides had been a major causal factor. It is not possible to factor out the role of herbicides from that of other causes, but the combined effects can be examined.

Did people in Long Khanh have enough to eat in 1967? Rice consumption declined but on the average remained above general Asian standards. On the whole, severe physical deprivation did not result, thanks to alternative sources of income in the war-inflated economy. The "average," of course, conceals a great deal. Data limitations preclude systematic study of the question of how many people lost how much. Instead, we assumed an average yield decline for various crops and calculated illustrative economic consequences for two types of farmers--the owner-operator and the sharecropper. For this purpose it was necessary to translate the provincial information into terms which have meaning for an individual farmer. The concept of "disposable income" is utilized as the market value of agricultural output after purchased inputs such as seeds and fertilizer have been deducted. Thus, when it is indicated that an owner-operator farmer has an expected disposable annual income of 21,400 piasters for one hectare of rice, it means that the crop has that monetary value whether the farmer uses it for family consumption or sells it. From such calculations, it is possible to offer "order of magnitude" estimates of loss as shown in Table VII B-6.

Table VII B-6. Estimated Household Disposable Income in 1967 for Prototype Farm Units (In Piasters)[a]

	One-Hectare (2.5 acres) Plot		Three-hectare (7.5 acres) Plot		Loss of Disposable Income (%)
	Expected	Achieved	Expected	Achieved	
Owner-Operators					
Sweet potatoes	67,800	10,000	203,400	30,000	85
Manioc	48,700	5,900	146,100	17,700	88
Mung beans	41,100	6,600	123,300	19,800	84
Peanuts	31,700	5,100	95,100	15,300	84
Soybeans	27,500	7,400	82,500	22,200	73
Rice	21,400	7,300	64,200	21,900	66
Sharecroppers					
Sweet potatoes	52,400	6,600	157,200	19,800	87
Manioc	36,700	3,000	110,100	9,000	92
Mung beans	30,300	3,900	90,900	11,700	87
Peanuts	24,000	2,500	72,000	7,500	90
Soybeans	19,500	4,000	58,500	12,000	79
Rice	16,100	5,100	48,300	15,300	68

[a] The values shown here are derived from the Long Khanh Agricultural Report of 1967. The numerous steps of calculation which lie behind this summary are detailed in Part B of the Committee's report.

In interpreting these piaster results, dollar conversions are virtually meaningless. Instead, we have used various existing economic studies to calculate an indigenous welfare indicator (compare Sampson, 1970; and Stanford Research Institute, 1968). On this scale, an annual income of 20,000 piasters indicates "subsistence," an income of 65,000 piasters is "comfortable," and anything over 100,000 piasters qualifies as "rich" by provincial Vietnamese standards. Table VII B-6 suggests that for the small owner-operator the loss of disposable income would have ranged from 66 to 88 percent depending on the crop. A three-hectare rice farmer moved from a comfortable level of income to the boundary of subsistence. A one-hectare rice farmer moved from "subsistence" to "very poor." At this level, starvation would be unavoidable without alternate employment, borrowing, assistance from the extended family, or government relief. For sharecropping tenants, the story is similar. The losses would have ranged from 68 to 92 percent. Since tenants are closer to subsistence to begin with, the welfare implications are greater.

For growers of perennial crops such as coconuts, a different sort of analysis is required. We studied this problem in Kien Hoa Province where many growers were said to have suffered total loss. Others apparently sustained drift damage, but were not severely harmed in terms of current income since the price of coconuts tended to rise. All owners, whether directly affected or not, experienced a decline in wealth due to a drop in the value of their land, as shown in district records in Kien Hoa. Thus coconuts became an increasingly risky crop--not only because of the herbicides, but also because of war activity in general. Unlike the annual crops, significant long-term damage occurred because the loss of trees meant no production for at least 5-7 years and, more importantly, the war precluded replanting and upkeep.

(d) Compensation

It was the stated intent of the RVN to reduce the unfavorable impact of herbicide damage by providing compensation for destroyed crops. This intention does not, however, appear to have been uniformly translated into action.

In Kien Hoa we were able to examine documents and consult officials to ascertain how the compensation program was organized. Two channels were available for seeking compensation; one for claims under 100,000 piasters and another for claims over that amount. The apparatus was obviously unwieldy and it is not surprising that eight months or more were often required to complete a claim.

The proportion of compensation in relation to actual loss was very low. A Kien Hoa coconut grower, for example, with a one-hectare (2.5 acres) plot of 250 trees totally destroyed by herbicides could claim a maximum compensation of 25,000 piasters. Yet, if we take 1968 prices, such a plot would have yielded an annual income of 97,800 piasters. If a grower had sought compensation in 1969 he would still have received 25,000 piasters. With inflation, his trees would have yielded him a crop worth 138,000 piasters by that time.

In Long Khanh we were unable to determine the exact nature of the provincial administrative machinery used to process claims. The villagers in this province were, however, much more resentful than in Kien Hoa. People were dissatisfied with the amount of payments, but in addition, they believed that only a few favored individuals received compensation due to corruption, the complexity of the claim filing process, and the cost involved in processing the paper work. However, the fact that high officials believed wind drift could only occur over short distances and thus would not consider many claims appears to have been a principal obstacle to a just and effective compensation program.

(e) Refugee Movement

The relocation of people has been one of the most pronounced human effects of the Vietnam war. While it is likely that the part played by herbicides varied in different sections of the country, in Long Khanh and Kien Hoa only a few respondents cited herbicides as an explanation for refugee movement. Indeed, some respondents stated that it would be pointless to try escaping herbicides by shifting location because no matter where they went they would still risk the possibility of herbicide exposure. These findings are in agreement with the major refugee studies that have been done in SVN.

(f) Health Hazards

The problem of birth anomalies has been dealt with earlier in this report (see Section VII A-1). While working in the two provinces, we investigated the possibility of using hospital records to address this question. Records were non-existent except for the most recent two years and even then they lacked information on total number of births from which the proportion of birth defects could be estimated. Our interviews with doctors, nurses and lay people on the topic indicated that many persons had heard rumors that deformed babies may be caused by herbicides, but no one held this as a firm conviction based on what to him would be acceptable evidence. While this information does not refute the possibility of fetal damage, it does indicate that the sources which could be consulted by our methods did not offer any positive indication of such a consequence.

On the other hand, a variety of immediately painful and disagreeable symptoms associated with herbicides were described by many people. These can be grouped in five categories: (1) respiratory symptoms (coughing, shortness of breath, soreness of throat, inability to breathe, coughing blood, bleeding from the nose, etc.); (2) central nervous system symptoms (headaches and dizziness); (3) gastro-intestinal symptoms (diarrhea, nausea, and stomach ache); (4) dermatic and ocular symptoms (skin sores, rash, and eye irritation); and (5) generalized symptoms (pain, fever, fatigue, trembling, perspiring, palpitations, and general soreness).

In the systematic survey of refugees at the Binh Hoa settlement in Binh Duong Province, each person was asked, "Have you ever been made ill by herbicides?" "If so, how?" Forty-eight subjects (i.e., 52 percent) responded by giving one or more of the symptoms listed above. Respiratory, central nervous system, and generalized symptoms were the most common while disturbances of the gastro-intestinal tract, skin and eyes were less frequently reported.

In Long Khanh and Kien Hoa both direct exposure and drift were seen as noxious, and all of the symptoms except respiratory and dermatic-ocular responses were also thought to be possible consequences of eating food or drinking water which had been contaminated. It is generally believed that most people will recover from the physical disabilities caused by herbicides, yet a large number of interviewees indicated that some people were especially vulnerable while others were resistant. Many individuals believed that the old, the sick, and especially children were likely to experience illness.

(g) Psychological Strain

Psychological strain is one type of effect which results from threats to human well-being or survival. Strain may sometimes become a long-lasting pattern of anxiety, depression, apathy, anger or other emotional state which then often prevents successful adaptation. Among the Binh Hoa refugees we administered a questionnaire, technically referred to as the Health Opinion Survey (HOS), which indicates levels of psychological strain. Within the last 15 years this questionnaire has been applied to over 2500 people in North America and West Africa. The Binh Hoa refugees have a significantly higher score on the average than any other randomly selected sample with which we were able to compare them. None of the other samples, however, had undergone such a high degree of stress as the Binh Hoa people who were subjected to bombing, ground maneuvers, herbicide spraying, evacuation and resettlement, as well as numerous other effects of war.

Using a widely employed social-psychological technique called the Self-Anchoring Scale, we endeavored to place the Binh Hoa refugees' assessment of their conditions of life in relation to other Vietnamese groups. On a scale of 10 (with 10 representing the best possible circumstances and 1 representing the worst) Binh Hoa people on the average rate themselves at 2. Residents of two other Vietnamese villages which had not experienced such an intense level of war stress rate themselves at 4. A sample of U.S. citizens rate themselves as 6. Thus, the Binh Hoa people see themselves in a position of greater disadvantage than the other groups, and we interpret these ratings as confirming that the Binh Hoa refugees have experienced extraordinarily high levels of stress. It seems probable that their high HOS scores are at least partly the psychological outcome of these experiences.

If this interpretation is correct those individuals in Binh Hoa who have borne the largest number of the hard knocks of war should be the ones exhibiting the highest HOS levels of strain. If exposure to herbicides can be isolated as a separate and specific hard knock, we can perhaps weigh the relative influence of herbicide stresses and other war stresses. To this end we developed a Herbicide Stress Scale which concerns adverse health and economic effects attributed to herbicides, and a War Stress Scale which refers to death of relatives, having relatives in military service or prison, etc. The relationships between psychological strain and the different kinds and degrees of stress are shown in Table VII B-7.

Table VII B-7
Mean HOS Scores with Type and Degree of Stress

Type and Degree of Stress	Sample Size	Mean HOS Scores
Low Herbicide-Low War	27	30.6
Low Herbicide-High War	22	33.0
High Herbicide-Low War	20	32.7
High Herbicide-High War	23	34.8
Total	92	32.7

Those people who reported no ill effects from herbicides and who experienced little war stress compared to the others at Binh Hoa have a score of 30.6. Those who perceived themselves as having suffered from herbicide spraying and who also experienced a high degree of war stress have a score of 34.8. From the statistical point of view, the probability of this difference occurring by chance is one time out of a hundred, and we conclude that herbicide operations have played a discernible role among the correlates of psychological scars.

(h) Views on the Use of Herbicides

Our findings indicate that there is a major dichotomy between the views of the rural population and those of the urban middle-sector regarding the use of herbicides in SVN. Contrary to what might be expected, the herbicide missions are a much less emotional issue among the peasants, who bore the brunt of the effects, than it is among urban intellectuals for whom it has become a symbol.

Peasants

Studies of the Vietnamese peasant suggest that he, like many other peasants around the world, is a pragmatist concerned with physical and economic security for himself and his family. In keeping with this, our findings indicate the people in areas not exposed to herbicides operations have relatively few attitudes about them, and those they do have are of low intensity.

On the other hand, the rural population living in or quite close to sprayed areas have concrete and detailed beliefs about herbicides. They consider the main consequences to have been economic loss to farmers and fruit growers. Very few thought of damage as permanent in an ecological sense. Villagers were both angered and saddened by the loss of their crops, but such feelings resulted from the loss and were not specifically because herbicide was the damaging agent. Although most people did not express value judgments about herbicides, they believed that the Americans were responsible for the spraying. For the most part spraying was accepted as a fact of life, one part of a larger situation which was deplorable and defied comprehension.

Despite extensive propaganda and counter-propaganda campaigns waged by the RVN and the NLF, peasant views regarding herbicide effects seem to be based upon their own experience. The RVN stressed that herbicides were used as a military measure to deprive the guerrillas of their hiding places, that the herbicides might damage crops but could also have beneficial effects, and that people and livestock would not be adversely affected by spraying. NLF statements emphasized the dangerous nature of herbicides. They claimed that the chemicals caused the death of people as well as livestock and crops, resulted in increased numbers of miscarriages and stillbirths, and caused numerous diseases, especially leprosy and conjunctivitis. Further it was said that the U.S. had deliberately introduced "chemical bacteria" into the spray which could penetrate people's bodies and cause disease. The fact that the villagers did not appear to subscribe blindly to the propaganda claims of either side does not mean that they lacked political opinions nor that they were uninfluenced by information derived through the mass media. Rather it seems to mean that their opinions on this issue came mainly from their own observations.

Urban Middle Sector

In contrast to the peasants, an important segment of the urban middle sector has come to believe that as the direct result of the herbicide operations, lasting and widespread ecological damage has been done, the health of the rural people has suffered (including instances of death, paralysis, birth defects, miscarriages, and a variety of strange diseases), many refugees have been created, and the national economy has suffered severe, long-term impairment.

The above conclusion is based on an analysis of the content of newspapers and magazines that are inferred to reflect the attitudes and beliefs of the urban middle sector as a whole. Numerous formal and informal interviews with educated Vietnamese in Saigon support this inference.

The media analysis may be described in the following terms. A sample of daily editions of two principal papers (one pro-establishment, and one anti-government) was selected for the period 1965-1972, and categories representing 39 war-related topics of concern (including herbicides) were constructed for coding purposes. The sample was then examined to determine the number of lines devoted to each topic. A second approach attempted to determine the frequency of articles on herbicides usage and the attitudinal content of such articles. Every available issue of the pro-establishment paper from April 1964 to July 1972 and of the anti-government paper from June 1967 to July 1972 was scanned for articles discussing herbicide usage.

In terms of the number of lines printed over the years analyzed, news reporting of herbicide in the pro-establishment paper ranked 29th of the 39 news topics coded, and in the anti-government papers, herbicide renked 23rd. Editorially, herbicide ranked 26th in the pro-establishment paper and 29th in the anti-government papers. Table VII B-8 presents a composite view of the quantitative saliency of the topic of herbicides, compared with several of the other news topics which were examined. It can be seen that regarding space devoted to reporting, herbicides rank low in comparison to topics such as ground combat and military casualties.

In regard to content, reporting was objective and non-evaluative, prior to 1969. This occurred despite the fact that 1967 and 1968 account for a very high proportion of the total amount of herbicides used in the Vietnam war. Beginning in the spring of 1969, however, many more articles about herbicides began to appear, and the greatest increase took place in the opposition press. Not only did the number of articles increase, but quite suddenly attitudes appeared which were exceedingly critical, and there was a spurt of reporting of alleged adverse effects. As seen in Table VII B-9 this trend continued through 1970 and 1971 after large-scale military use of herbicides had been discontinued.

The shift in content and tone was marked by a series of articles in Tin Sang (anti-government) claiming that Vietnamese women were giving birth to "eggs." More articles followed linking birth defects, miscarriages, and other health problems to herbicides. As for belief in the effects upon animals, Tin Sang moved from reporting that herbicides were not harmful (January 27, 1969) to the following statement: "In the defoliated areas of South Vietnam most farm animals are dead. Pigs, chickens, ducks, bees, frogs, fish, and snakes--all have disappeared. Those that are still alive are weak and unable to reproduce." (February 2, 1969).

Herbicides were also mentioned as contributing to the generation of refugees and by mid-1970 concern was being shown for the more general ecological effects. At the conclusion of a long and objective article on herbicide use in SVN, Chinh Luan (pro-establishment) (August 25, 1970) said:

> "A large area of land has been sprayed with defoliants and the long-term effects have not been definitely assessed. Nevertheless, the excessive spreading of a number of strange chemical substances into the botanical environment will certainly affect the ecology, and chain reaction could cause a depletion of the nation's natural resources."

Table VII B-8

News Reporting: A Comparison of Herbicide and Some Other Selected Topics

Topic	1965	1966	1967	1968	1969	1970	1971
Herbicides	0.03	0.01	0.19	0.07	0.78	0.38	0.43
Military Casualties	11.80	10.20	11.30	12.30	10.70	9.00	9.30
Ground Fighting (RVN)	16.80	13.70	15.10	19.60	15.20	9.40	9.80
Terrorist Action	8.60	10.10	7.80	6.40	6.30	3.10	2.10
Loss of Weapons	0.17	0.09	0.23	0.09	0.06	0.03	0.02
U.S. Build-Up	1.10	0.54	0.90	0.12	0.37	0.01	0.06
Vietnamization	0.00	0.00	0.00	0.08	0.57	0.36	0.71
Population Movement	0.62	0.36	0.77	1.50	0.24	0.61	0.06
Anti-U.S. Sentiment	0.23	0.83	0.16	0.02	0.00	0.97	2.58
Cost of Living	0.23	0.66	1.10	0.49	1.10	0.88	1.90
Blackmarket	0.53	2.70	0.29	0.77	0.59	0.56	0.36
Peace Moves	5.60	6.10	8.30	5.80	4.50	3.10	3.10
TOTAL LINES CODED	17389	19588	16407	41544	38819	28185	28674

The numerical value is the percentage for a given topic of the total lines coded for a given year. Thus, herbicides account for about 3/4ths of one percent (.78) of the total output of coded news lines in 1969. The columns for 1965-1967 refer to the pro-establishment press only. The anti-government paper was coded for only a portion of 1967 and is not included for that year. The columns for 1968-1971 combine data from both presses. Since only a portion of the 1972 papers from both pro-establishment and anti-government was analyzed, that year is also not included in this tabulation. The percentages for the 27 other topics not selected for this table appear in Part B of the Committee's report.

Table VII B-9

Selected Attitudes About Herbicides
in the Pro-Establishment and Anti-Government Press

	1968	1969	1970	1971
Objective reporting of statements about herbicides without editorial comment	50% / 17%	50% / 17%	33% / 4%	25% / 18%
Doubting the advantages of herbicides as compared to disadvantages, etc.	0% / 17%	0% / 7%	42% / 16%	37% / 13%
Critical of RVN because of herbicides, failures of compensation program, etc.	0% / 67%	0% / 56%	0% / 20%	0% / 24%
Critical of U.S. because of harmful effects of herbicides on crops, humans, environment, etc.	0% / 17%	0% / 28%	0% / 92%	12% / 69%
Total number of articles	6 / 6	6 / 43	12 / 25	8 / 45

The percentage of articles from the pro-establishment press which display a given attitude appears in the upper left hand corner of each cell: 50%

The anti-government percentages are in the lower right: 17%

The pro-establishment articles in 1965, 1966, and 1967 were similar to what is shown for 1968. The anti-government articles reviewed for half of the year 1967 were similar in number and attitudes to 1968. Table VII B-9 is limited to the four years for which we were able to make a year-long review of both papers.

The four attitudes shown here are a selection from the 14 categories used for coding purposes. The remainder are shown in Part B of the Committee's Report.

There was belief by some writers that the soil may have been permanently affected and the vegetation destroyed or irremediably altered in certain areas. Floods were blamed on herbicides and eventually it was alleged that herbicides change the climate.

The extent and significance of the change in view is demonstrated by an article which appeared in Chinh Luan just before the 1971 elections. Raising what they termed "the people issue," Chinh Luan in effect demanded that Thieu and Huong demonstrate their willingness and ability to stand up to the Americans and exert more control over American actions in SVN. Chinh Luan's editors' beliefs regarding the use and effects of herbicides in SVN were an explicit and major factor in a more general disenchantment with the U.S. performance in the country:

> "The U.S. Armed Forces have a low regard for the lives and property of the people of this country. As a result much indiscriminate bombing has taken place, and careless herbicide spraying has been conducted, a spraying that is beyond the real and reasonable tactical needs... Indiscriminate defoliation activities of the U.S. Armed Forces have inflicted great damage upon trees and crops which are a source of life to the people."
>
> (Chinh Luan, September 29, 1970)

Such a statement in this prestigious, normally pro-American newspaper is a striking demonstration of the extent to which attitudes and opinions had changed on this issue.

In April 1972, a journal whose editorial board includes numerous non-Communist scholars and intellectuals, Trinh Bay, published a special issue on "The American Destruction of Indochina." This presentation was prefaced by an introduction which informed the readers that they were being given reports of research on herbicides which were:

> "... actually carried out by American specialists and scientists and publicized in the United States, which are relevant to the present American war policy in Vietnam--a policy which we wholeheartedly oppose because of its cruel and senseless nature, and because it is contradictory to the very goals which the Americans themselves loudly proclaim: the defense of the Vietnamese people, defending by exterminating the very people one wishes to protect! Especially when we note the aspect of the long-term destructiveness of that policy upon our land."

Our conclusion is that among the urban middle sector herbicides had become a symbol through which fear, anger, and resentment toward the U.S. are both expressed and stirred. The importance and weight of this symbol is most evident in the content and emotional tone of the articles rather than in their frequency, although this too had increased. The point had been reached where a poet or writer seeking to express complex emotions about the impact of the Americans in Vietnam, or perhaps of the war in general, would often select herbicides as a symbol.

(i) Summary and Conclusions

To summarize this material on beliefs, attitudes, and behavior among the Lowland Vietnamese, it would seem that herbicides induced a number of harmful effects. These related not only to the fact that people perceived damage done to crops and animals but also that for some people there appears to have been ill effects upon their economic status as well as physical and emotional health.

We believe the contrast between the views of the peasants and the city dwellers is one of our most important findings. Those people in the countryside who had experience with herbicides hold the pragmatic belief that herbicides are a bad thing among the many bad things that have occurred as a result of war. In the urban centers strongly held feelings developed in which herbicides came to be an emotionally charged symbol that stands for many apprehensions and distresses, but especially those for which Americans are blamed.

We attach importance to this because the urban middle sector is politically influential. Further, it is our interpretation that in the long run their views will influence the peasants rather than vice versa. It is not so much that the peasant will change his mind about herbicide effects but rather he may begin to share the symbolic meaning. The fact that herbicides have become a symbol does of course not mean that they are the cause of the rise of negative attitudes thereby represented--nor even the most important factor among a complex of factors. It does, however, mean that the power of this symbol to mobilize and articulate feelings is one aspect of the herbicide impact on SVN.

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(3) Perceived Effects of Herbicides in the Highlands

The purpose of the research on the Highlands was to assess the perceptions of Montagnards concerning the effects of herbicides. Due to the timing of this study and problems of security, it was not possible to check the views of these people by observations on plants and animals or by medical examination of people.

The techniques used in this study were intensive interviews with over 30 key Montagnard informants from twelve villages who had been relocated in five refugee centers in Kontum, Pleiku and Darlac provinces. Location at the time of interview, original location, ethnic background, and characteristics of the interview subjects are listed in Table VII B-10. These people had been relocated as a result of the Spring 1972 offensive. The people interviewed represented several ethnolinguistic groups: Halang, Jarai Arap, Jarai To-Buan, Rengao, and Sedang. A Hroy Highlander, who had been trained in Hanoi as an agricultural engineer and had served as an agricultural advisor with NLF forces in the border area before defecting to the RVN side, was also intensively interviewed. Interviews were conducted by an American anthropologist with over a decade of experience in Vietnam. He used the advice and assistance of interpreters all of whom were employed by the U.S. Government at the time of the research. They spoke the various dialects involved, and translated into English or French. At times the anthropologist talked directly in Vietnamese with interview respondents.

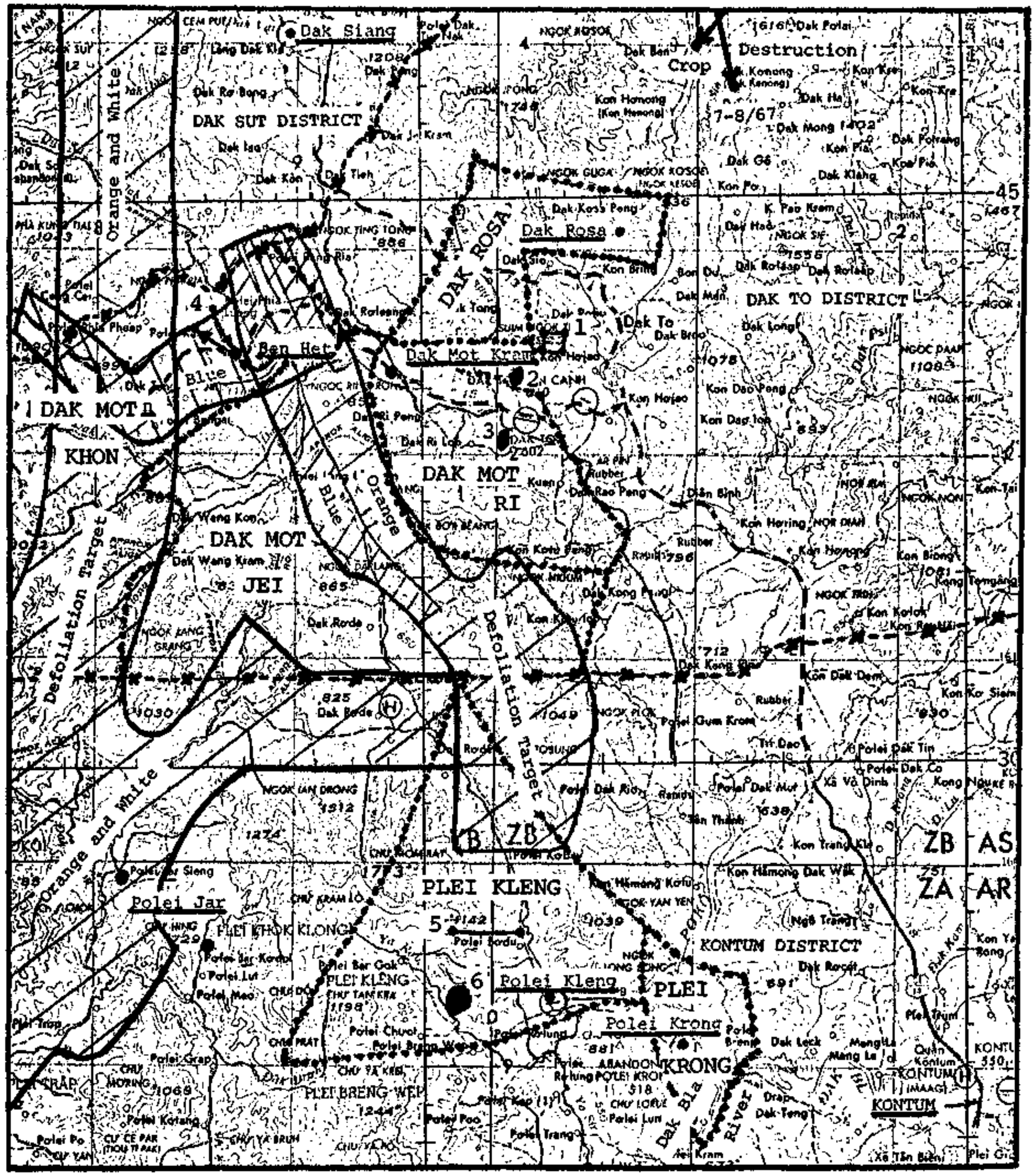
The interpreters were briefed prior to the interviews to clarify terminology and references to various kinds of herbicide sprays and effects. Interview subjects were sought from locations believed to have been sprayed on the basis of recorded herbicide mission data. An attempt was made to locate as precisely as possible both the settlements and swiddens of the respondents and the herbicide missions to which they were exposed. A comparison of herbicide mission data from HERBS tape printouts with areas inhabited by the respondents suggests that they were living in close proximity to targets for defoliation and/or crop destruction missions. The greatest distance any group of settlements appear to have been from target coordinates is about 15 km or 9 mi (see Figs. VII B-9, B-10, and B-11).

Respondents were asked about settlement patterns, locations of farming areas, types of crops grown, and other economic activities. They were then asked about their perceptions of spraying: whether or not they had seen the aircraft, and their perceived effects of the spray. Interviews were repeated with respondents in the Dam San Refugee Center, and with the group at Plei Don in Kontum Province (I and III in Table VII B-10). The subjects were very responsive, their general opinions regarding herbicide effects appeared clear, though their quantitative information was sometimes vague. The respondents were in general agreement that there had been many herbicide operations on or near their settlements and swiddens since 1967. This was confirmed by herbicide mission records which show that the major spraying effort near the respondents began in

Table VII B-10

Characteristics of Persons Interviewed in the Highlands

Location of Interviews	Original Village of Respondents	Ethnic Group	Characteristics of Principal Interview Subjects, Principal Respondents
I. Dam San Refugee Center, Darlac Prov.	1. Long Djon, near Dak To Distr. Hq., Kontum Prov.	Sedang	Two young men, one older woman
	2. Dak Rosa, near Dak To, Kontum Prov.	Sedang	Older man
	3. Dak Tang Plun, near Tan-Canh, Dak-To Distr., Kontum Prov.	Halang	Several older men, several women, two younger men
	4. Plei Ro-O near Polei Kleng, 30 km west of Kontum City	Jarai Arap	Young man (NLF defector) Several women
II. Mary Lou (Ngok Long) Refugee Center, Kontum Prov.	1. Dak Mot-Khon, west of Tan Canh, Dak To District, Kontum Prov.	Sedang	Village chief
	2. Dak Mot-Tri, west of Tan-Canh, Dak To District, Kontum Prov.	Sedang	Hamlet chief
	3. Dak Siang Ranger Camp Dependent's Settlement, northwest of Dak To Distr. Hq., Kontum Prov.	Halang	Young woman, her father, older man, older woman
III. Plei Don Refugee Group	1. Polei Krong cluster of villages, west of Kontum City	Jarai Arap Halang Rengao	Man Man Man
	2. Polei Krong, cluster of villages, west of Kontum City	Rengao Jarai Arap	Older men Older men
IV. Prisoner of War Refugee Center, Pleiku Prov.	1. Polei Kleng, west of Kontum City	Jarai Arap	Young hamlet chief Older woman Older man
	2. Plei Jar Tum, west of Kontum City	Jarai Arap	2 men 3 women
V. Camp Enari Refugee Center, Pleiku Province	1. Plei Ea Tung Hamlet, Plei Ngol-Drong Village near Edap Enang Resettlement Center, Rte. 19	Jarai To-Buan	2 men
VI. Highlander	Phu-Bon and Phu-Yen	Hroy	Man, follower of Viet Minh, moved to North in 1954, trained as Agricultural Engineer in Hanoi University, returned to highlands area astride Phu-Yen/Phu-Bon border in 1969, organized food production for NLF, had "rallied" to GVN at time of interview.



Boundary:
District
Village

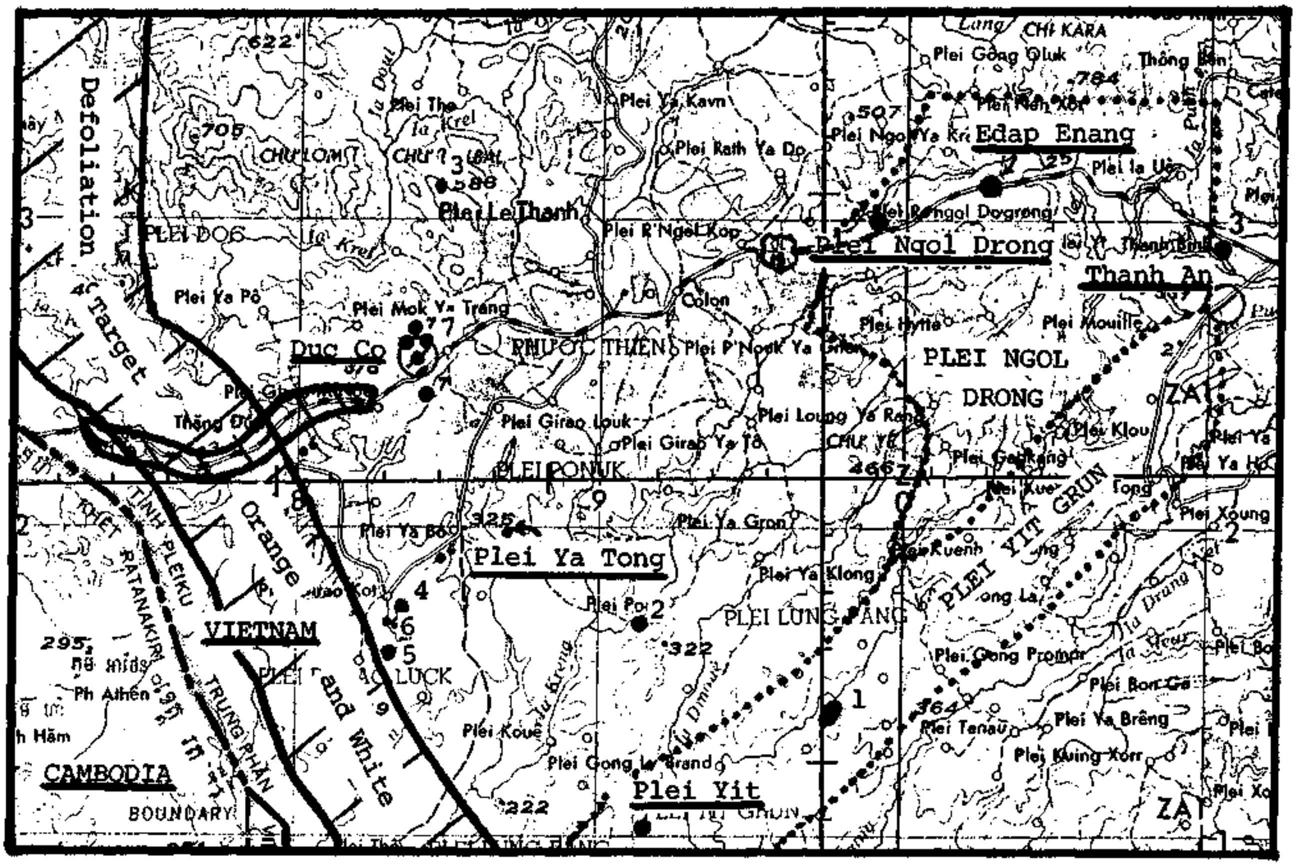
0 5 10
Kilometers

Scale: 1:250,000

Key to Special Targets

1. Aug 68 - 800 gallons White - NLF cache site
2. Aug 68 - 100 gallons White - Military perimeter
3. Aug 68 - 100 gallons White - Military perimeter
4. Aug 67 -1100 Gallons Blue - Crop destruction
5. Nov 68 - 200 gallons White - Military perimeter
6. May 69 - 770 gallons White - Military perimeter

Fig. VII B-9. Informant Settlement Areas and Herbicide Missions in Kontum Province



0 5 10
Kilometers

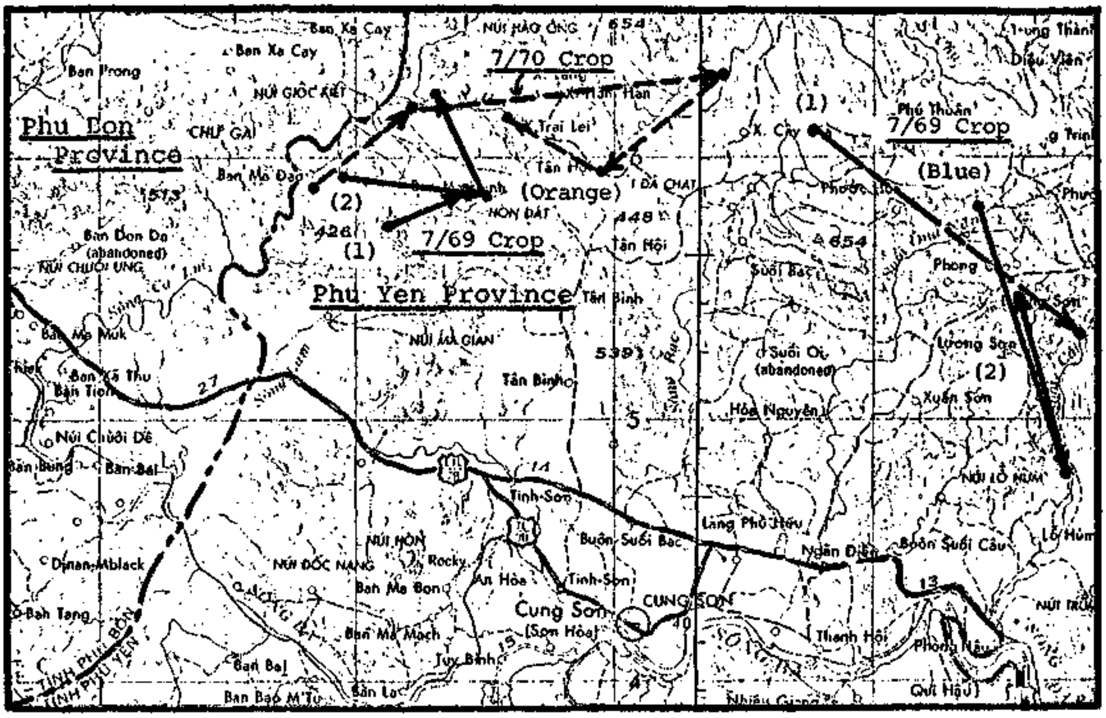
Scale: 1:250,000
Boundary:
Village ....

Key to Special Targets:

Agent White	Objective
1. 27 Sept 68 - 550 gallons	- Enemy cache site
2. 24 Oct 68 - 100 gallons	- Crop destruction
3. 28 Oct 68 - 100 gallons	- Military perimeter
4. 29 Oct 68 - 100 gallons	- Military perimeter
5. 1 Nov 68 - 100 gallons	- Military perimeter
6. 10 June 69 - 220 gallons	- Military perimeter
Agent Orange	
7. 6-30 Nov 65 - 5800 gallons	-Defoliation near Highway 19*

*Only one target coordinate given for each of the five missions.

Fig. VII B-10. Informant Settlement Areas and Herbicide Missions in Pleiku Province.



0 5 10

Kilometers

Scale: 1:250,000

Fig. VII B-11. The NLF Food Production Area Phu Yen/Phu Bon Border Region.

1967 and ended in 1970. Information on general agricultural patterns of the groups represented had been gathered in previous ethnographic field work since 1965.

(a) Agricultural Practices

Among the Highland people of SVN, a wide variety of agricultural practices is found, ranging from wet-rice paddy farming such as is found among the Vietnamese, to swidden farming. All of the villagers interviewed in this study rely on the swidden technique, and this also was the method employed in NLF food production in Phu-Yen Province as described by the Hroy respondent.

Although the swidden farming techniques vary from group to group, there are some common basic characteristics, particularly among the groups in Pleiku and Kontum. Essentially, swidden farming in Highland SVN is a system of rotating agriculture wherein a given field is cleared, the cut wood burned, and the land afterward farmed for a duration of years that depends on the adjudged fertility of the soil. The field then is left to fallow, until a new growth of trees appears, and eventually it is farmed again.

Among the Jarai, Halang, Rengao, Sedang, and Hroy, the work of preparing the fields for farming usually begins in January or February. Men perform the heavier tasks such as felling trees (large trees normally are left standing) while women and children cut the brush. When the wood has dried, it is gathered together and burned. The larger logs are set ablaze, and the fires are controlled as much as possible. When the rains begin, normally in mid-April or early May, the crops are planted; the men make holes in the ground with dibble sticks while the women follow up to plant the seeds.

The staple crop is upland dry rice, and several varieties with varying maturity periods (usually three to six months) are planted by all of the groups. Also, maize is cultivated in the swiddens as are a number of secondary crops. These include manioc (a major crop in the Phu-Yen Province NLF food production area), sugarcane, bananas, pineapples, eggplant, onions, yams, cabbage, chili peppers, and various kinds of tuber plants. Papaya trees are planted around the edge of the swidden. Many of these same crops are grown in kitchen gardens located in the villages, and the gardens may also contain tobacco, green leafy vegetables, and lemon grass. In some villages, coconut and mango trees are grown. Small huts are constructed near the swiddens so the young men can guard the fields against marauding animals during the growing season.

(b) Results of Interviews

Most informants report having seen the herbicide spraying and give accurate descriptions of the aircraft. From the interviews it appeared the forest or sometimes the swiddens, not the villages, were the targets although spray sometimes drifted into the villages.

A difficult area of inquiry concerned possible deaths due to the herbicides. Sickness and death are common occurrences in Highland villages, and infant mortality is particularly high. In addition, NLF/DRVN propaganda about the harmful effects of the sprayed chemicals, which began in 1962, stressed the fact that human beings--especially children--might fall ill and die if exposed; and both the RVN and NLF/DRVN charged that water and food supplies were being poisoned by the opposing side in order to kill the inhabitants.

The interview subjects consistently reported that illness occurred among people who lived in or near the sprayed areas. The most common symptoms reported were abdominal pains and diarrhea, with vomiting, respiratory symptoms and rashes also frequently reported (Table VII B-11). Some respondents said that there were unusually high numbers of deaths, particularly among children following the spraying.

Most respondents reported widespread deaths among their domestic animals following the spraying, particularly chickens and pigs. Some respondents reported villagers found dead wild animals, particularly wild boars, in the forest after spraying. Responses concerning effects on aquatic life were more variable than those on humans or other animals. Dead fish seen floating in the stream near Long Djon (Location I.1) may have been due to herbicides or they may have been killed by the many soldiers in the area who frequently threw grenades in the streams to kill fish. The Plei Ro-O respondent also reported a great many dead fish in streams following spraying. The fish appeared swollen, and villagers who ate them got diarrhea. Plei Ngol Drong (Location V.1) and Polei Krong respondents (Locations III.1 and III.2) reported similar effects in dead fish following spraying. The latter also noted the gills of some of the dead fish were blackened or reddish in color.

The respondents were consistent in reporting effects of herbicide on plants: over a period of weeks following the spray, plants wilted and died. Where the spray fell on swiddens, the crops died; where it drifted into gardens, the crops wilted. Rice which was not killed outright produced no grain. Fruit trees died, or failed to produce edible fruit. Some villagers reported eating parts of affected plants, after which they got diarrhea. Others decided not to eat any of the sprayed plants. The spraying was reported to have resulted in serious food shortages for the villagers and also for the NLF in some areas. Some villagers reported that big trees survived after losing all their leaves, others reported the big trees had died, and many had been cut for firewood.

Responses of the villagers concerning long-range effects in sprayed areas varied. The Hanoi-trained agricultural engineer reported he believed effects on people and on plants would be only temporary. He believed that one of the types of herbicides being used broke down in the soil and actually increased soil fertility. Some villagers felt they could plant again in the affected areas, but most apparently decided to relocate their fields into unsprayed areas. Some reported persistent effects they believed to be due to herbicides more than a year after the spraying.

Table VII B-11. Illness Perceived by Highlanders Following Herbicide Spraying

Location	Symptoms	People Affected, Deaths
I.1 Long Djon	Abdominal pains, diarrhea, nasal irritation, coughs lasting more than a month	More children than adults were affected "many children died"
I.2 Dak Rosa	Abdominal pains, diarrhea, skin rashes looking like insect bites following contact with sprayed vegetation	Several children died; "unusual number" of still-births among exposed mothers
I.3 Dak Tang	Diarrhea, cramps, skin rashes, fevers	Many children became ill, an estimated 30 died
I.4 Plei Ro-O	Diarrhea, cramps, rashes, fever, coughing blood	Thirty-eight children reported to have died as a result of eating sprayed crops
II.3 Dak Siang	Diarrhea and abdominal pains after drinking water from stream in sprayed area, dizzyness and vomiting after eating bamboo shoots from sprayed area	Some children died after drinking water from sprayed area
II.1,2 Polei Krong	Diarrhea, cramps, fever, rash looking like burns with small blisters over red areas	Higher than usual number of children died after spraying
IV.1 Plei Kleng	Diarrhea, vomiting, fever within one day of spraying	About 40 adults and children died with these symptoms
IV.2 Plei Jar Tum	Diarrhea, vomiting, fever	Four children and one adult died
V.1 Plei Ngol-Drong	Abdominal pain, diarrhea, vomiting, skin rash	Some people died two days after spraying; rash resembled chicken pox
VI. Kontum-Phu Yen Border	Abdominal pain, diarrhea after eating manioc harvested after spray, with inadequate cleaning	Illness only among those not following instructions given to agricultural engineer in Hanoi; no deaths

(c) Summary and Conclusions

The reports of serious deleterious consequences of herbicide spraying on humans, animals, and plants are internally consistent. At a minimum, they indicate an association in the minds of the Highlanders between the use of herbicides and harmful effects to themselves, their animals and plants, and their environment. Reports of human illness following spraying are so striking it is difficult to dismiss them as simply the effects of propaganda, high normal death rates, or faulty understanding of cause and effect.

C. Study of a Mangrove Forest Community in Relation to Herbicide Effects

The Committee wanted to study the direct and indirect effects of herbicides as they affected human communities. An ideal research design would be a coordinated interdisciplinary study *in situ* of a sample of communities representing major land-use types, in order to describe the impact of herbicide spraying on both the natural environment and the human population. We were able to make a partial study combining observations on medical-ecological, botanical, soil, fisheries and socioeconomic aspects of human communities only in one settlement in the Rung Sat mangrove area, Tran-Hung-Dao Hamlet in the north central portion of the Rung Sat Special Zone. The location of this settlement is shown in Fig. IV C-5 (Site No. 6).

Of all the ecosystems affected by herbicides, the mangrove forest had the most extensive and persistent damage (see Section IV C). Large blocks have been virtually denuded of mangrove trees. Under these circumstances of undeniable major environmental impact it was appropriate to study effects on human communities of massive use of herbicides, even though the mangrove forest comprises only about 1.7 percent of the total land area of SVN. Recent data on the population of the Gia-Dinh Province portion of the Rung Sat and of Tran-Hung-Dao Hamlet are given in Table VII C-1.

Table VII C-1. Population of the Gia-Dinh Province Portion of the Rung Sat, 31 December 1972

District	Total	Permanent	Temporary
Quang Xuyen	17,097	15,301	1,796
Can Gio	10,350	10,350	0
Rung Sat Total	27,447	25,651	1,796
Tran-Hung-Dao Hamlet (Quang Xuyen District, An Thoi Dong Village)	1,573	1,242	331

Source: HES/70 VILLAGE/HAMLET GAZETTEER as of 31 Dec 72, Report Number R7223.00.0, Hamlet Evaluation System, Run Date 21 Jan 73, MACV-CORDS, Operations and Analysis Division, Village Sequence, pp. 398-399.

Research techniques included an examination of records of herbicide spray missions, and comparison of a series of aerial photos taken from 1957 in the pre-defoliation period to 1973, over two years after defoliation was stopped, to reconstruct patterns of environmental change associated with herbicides. A medical-ecological study was undertaken to determine the existence of malaria and the probable insect vectors responsible for its transmission (Section VII A[3]). About 25 residents were interviewed, some through an interpreter and others in English, to determine community history and economic patterns, and to solicit their recollections of the impact of herbicides on community residents and environment. A small number of samples of water, soil, vegetation, firewood, fish, rice, crustacean and sugarcane specimens were collected for analysis of herbicide residues (see below). The estuarian study reported in Section IV C-6 included collections in the immediate vicinity of Tran-Hung-Dao.

Herbicide operations in the Rung Sat apparently began in 1964 with missions along major channels. Similar missions were carried out in 1965. In 1966 and thereafter spraying included inland portions of the Rung Sat as well, so that a large proportion of the entire mangrove forest area had been sprayed when fixed-wing aerial defoliation was concluded in 1970 (see Figs. IV C-6 and IV C-7). There were three recorded spray projects in 1964 and 1965, and from 1966 through 1969 there were approximately 29 missions (18 of Agent Orange, 10 Agent White, and one Agent Blue) with centerlines passing within one kilometer of the center of the community.

Some time prior to 1957 a fort had been built on the confluence of the Tac Ong Nghia and the main shipping channel to Saigon. The area was one of sparse, impermanent human population. It was a dense mangrove forest, apparently managed for sustained cutting of firewood, and probably also used for fishing. Aside from the military camp there was no permanent settlement nearer than Quang Xuyen, on the Nha Be River, about 5 km to the west.

By 1965 the fort had been abandoned, and there was a strip of killed vegetation along the main shipping channel and other major water routes. By 1967, a new, larger fort had been built, extensive herbicide operations were being carried out, inland as well as along the water courses, and civilian settlement was gathering around the fort. The civilians came primarily from Long An and Kien Hoa provinces, both "pushed" by the urgings of military and civilian officials and "pulled" by the availability of resources and the relative security available at Tran-Hung-Dao. At first they gathered wood and fished. As the dead wood readily available within safe and easy commuting distance of the fort was exhausted, more and more of the people turned to fishing, and to farming which began in 1969. Defoliated areas inland and to the north of the settlement were cleared of debris, watered by the flood of the river during the rainy season, and planted to rice.

The community in February 1973 was composed of about 2,000 Vietnamese civilian residents in the main part of the settlement, a military camp with 65 families of dependents, and about 30 Nung refugees living about 1 km from the main settlement. Hamlet Evaluation System population figures for 31 December 1972 were 1,242 permanent and 331 temporary residents (Table III C-1).

The present economy of the hamlet is best described as marginal, dependent on an insecure and in some aspects vanishing resource base. By February 1973 about 60 percent of the civilian households supported themselves primarily by fishing, 10 percent by farming, and 30 percent by wood gathering. The hamlet is not self-sufficient in rice production, and rice and other food products, as well as drinking water, must be brought in. Firewood and surplus shrimp and fish are sold primarily to the Saigon market; the Nung refugees are farmers and diggers of "Peanut worms" (Sipunculids) which they eat and sell in Cholon.

The firewood is not regenerating nearly fast enough to replace the amount collected. The woodcutters have been reduced to digging up stumps in areas where all the above ground wood has already been cut. Thick regrowth of mangrove trees is found here only on some river banks, not in the interior, which is largely covered with Paspalum grass and scattered shrubby vegetation. The cost of gathering wood (in terms of time and fuel for transport, and also risk of attack) is increasing.

Fish yields are reported to be declining rapidly. Some of the residents attribute it to the great increase in numbers of fishermen within the area, including temporary residents who come regularly for periods of two weeks or more from Kien Hoa or Long An provinces. At this point it is probably impossible to determine whether the herbicides had any direct effect on killing the fish or reducing their ability to breed or to feed themselves. The increase of fishing pressure is undeniable, and the evidence of decline in the fish population (from measures of catch per unit effort and from fish seining studies) seem consistent (Section IV C-6 and Table IV C-4).

Farming is being done by primitive techniques in an area of high salinity and "alum," with an unsure fresh water supply. The development of farmland has been slow because undecayed stumps remaining in the soil must be dug out. The farmers cannot afford draft animals or tractors for plowing. To date they have left the soil untilled, or have hoed their rice fields by hand. They lack the capital or technical knowledge to improve their tillage techniques or substitute other, more suitable crops. Farmers are consistent in reporting declining yields. Some attribute this to inadequate fertilizer; some to inadequate tillage or hardening of the soil; others believe they lost a very large proportion of their crops to rats which they report are present in increasing numbers in the debris of dead and decaying mangrove trees and the grasses which have grown up in the past few years.

Examination of the area in 1973 showed that except for some river banks almost all trees had been replaced by grassy or brushy vegetation, and some areas had been cleared for rice fields. There are fowl and swine in the village, but no fruit trees, and only a few kitchen gardens or chili peppers growing in pots, at least during the dry season when the hamlet was observed. Numerous rats were observed in the hamlet, but because of security considerations it was impossible to trap for rats in the fields (Section VII A-3).

Observations described in Section VII A[3] support the hypothesis that defoliation has produced an environment favorable to the reproduction of malaria-bearing mosquitoes, and that these mosquitoes are now transmitting malaria in an area where it was probably previously absent.

Despite their economic hardships, the lack of water (which they must either buy or receive from the weekly visit of the RVN Navy waterboat), and the apparent limits on their economic future, many of those interviewed indicated they wanted to stay in the community, which at least gives them free access to claim land if they clear and develop it themselves. Many have no land to return to, or fear to return to their homes which they believe to be unsafe.

Those interviewed had a range of opinions regarding the effects of the herbicides on humans, on domestic livestock, and on the fish and crustaceans. Some indicated they had been directly exposed, had suffered nausea or skin irritation or had their hair fall out. Some believed that children had died as a result of herbicide exposure; others said they had suffered no ill effects, and though they recognized that children had died, they believed the deaths (which took place several months after the spray runs passed over the hamlet) were due to malaria or some other cause. Some believed that all fowl exposed to the chemicals became sick and died, and that pigs (sheltered in their pens from direct exposure) became ill but did not die; others believed that no chickens had died as a result of the spray. Some said they had seen the water white with dead fish after the spray and that the fish and shrimp catch had declined ever since, others said they believed the chemicals had no effect on fish or shrimp. Many believe defoliation has made it possible for them to live in the mangrove forest, both by making the area untenable for the NLF forces, and by clearing vegetation from fields which can now be used for growing rice.

Picloram at 0.01 to 0.05 ppm was found in some soil samples from Tran-Hung-Dao. This is in agreement with similar findings in other defoliated areas of the Rung Sat (see Section V A). No 2,4,5-T was found in soil at the sensitivity limit of the method used (<0.02 to <0.0068 ppm). Neither picloram, nor 2,4,5-T and 2,4-D could be detected in rice grain, vegetation (grass, mangrove branches, rice straw), shellfish and fish, and a peanut worm (Sipunculid). Arsenic levels in rice grain, fish and shellfish, the peanut worm, water from a rice field and surface water from the river were well within known arsenic ranges for plants, marine organisms and water. On the basis of the small number of samples we have, there is no evidence that the people of Tran-Hung-Dao ingest herbicides in any substantial quantities, nor arsenic at levels higher than generally found in food and water.[a]

Summary and Conclusions

Tran Hung Dao is a community in an area which was probably sprayed as heavily as any part of SVN. The natural environment (mangrove forest) is representative of only 1.7 percent of the total land area of the country. Tran Hung Dao hamlet is different from some other mangrove forest communities because it has a large number of resettled inhabitants and a sizeable

[a] Analyses for TCDD in fish and shellfish samples from this site have not been completed.

military post with family dependents, but in neither of these respects is it unique in the Rung Sat, and conditions found in Tran Hung Dao appear to represent changes which will be found in other heavily defoliated mangrove areas.

Human settlement and use of resources has become more concentrated and more permanent in places where physical security has been increased by a combination of herbicide applications and military presence. Associated with the wartime changes in settlement patterns to which the herbicides have contributed, there have been a series of technological and economical changes, including use of motorized boats which have made possible a more intensive and extensive exploitation of the forest, fish, and shellfish. Land clearing, assisted in part by defoliation, and the gathering of dead mangrove trees for fuel has in some places been followed by the introduction of wet rice farming. With the present levels of population density and technological and capital investment, returns of all these activities are declining.

Defoliation in the Rung Sat continues to have profound effects on relationships between man and the environment. In the absence of evidence regarding the allegations concerning toxicity and teratogenicity, the major conclusions are: (1) Chemical analyses, as well as the growing of rice, suggest the soil of this area does not contain herbicide residues nor to have undergone other changes which would inhibit plant growth. The slow regrowth of mangrove forest species may be due to lack of sufficient seed sources or changed micro-environment following destruction of most vegetation (compare Sections IV C and V A); (2) ecological changes are in general such as to increase economic instability; (3) the changes in the environment are such as to increase the probability of important harmful diseases. These changes are liable to persist either until there are major alterations in the patterns of human occupation and use of the area, or until the mangrove vegetation is restored.

STATEMENTS OF EXCEPTION

Translated from the French.

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Departement de Botanique

Prof. Pham-hoang Ho

Saigon, December 3, 1973

Professor Anton Lang
Director, MSU/AEC Plant Research Laboratory
Michigan State University
East Lansing, Michigan 48824

Dear Professor Anton Lang,

I would like to apologize for my being late at the last (November 1973) meeting in Washington. The long formalities necessary to leave the country are responsible.

However, I do not think the results would have been much different, even if I had been on time. It is a pity that the committee lost four to five months more to restudy the problem of the damages in forests; as for myself, I have regretted waiting this length of time to confirm what I wrote to you on 6/21/73, and that at your request I gave my approval not to distribute to the members of the committee. The results of the new (?) study appear to be identical to the ones proposed in June; because they are now better written, in more refined shades, more toned down, more skillful, does not mean that I have to accept them.

I do not speak of the figures concerning the extent of the defoliated areas. We estimate that the non-recorded represent defoliated areas about 15 percent of the total area.

What I would like to speak to you about here concerns the methodology used to calculate the amount of the damages, or more precisely, the material and the methods used.

Material Used

1. The report draft has specified that the committee has chosen a certain number of sites necessary for a good sampling of defoliated forests. But for reasons of security and convenience we have had to adopt other itineraries (p. 30).

We have used a base-line material that we have accepted but not chosen.

2. In addition, the quality of the transparencies, or at least those which I was able to study in Seattle, leave much to be desired - whether because of insufficient sharpness, or because the exposure (time of exposure at the time of shooting or processing?) is not correct (in most instances overexposure), for example, the roll S29 going through the region of Tâyninh, Thiềnngôn. The excellent photographs as the roll N16, B8-4 do not represent the majority.

On overexposed transparencies it is already very difficult to count the dead trees because of the absence of contrast: the background becomes lighter than the trunk of the dead trees. It would be impossible to count the poles. In effect, these photographs represent the forest at 1:5,000; a tree trunk of 45 cm or 450 mm diameter is represented thereon by a line 0.09 mm wide, visible if the photograph is sufficiently contrasted. But if the tree is represented by a covered pole it would be represented by a point of 0.09 mm diameter; this point has to be very bright to be easily recognized.

In addition, if the region has been subjected to brush fires, the trunk of a tree may be more or less charred, more difficult to see on the photo; the poles would in this case become practically indiscernible even in stereocopy. The same holds true for the kines, the surviving epiphytes.

3. I have read in the report that the Committee has chosen Tâyninh as study site (XT and YT quadrangles).

I do not know if the study was made with roll N14. As I had occasion to remark in Seattle this roll is not a good sample for several reasons:

- it passes through a region where there are many recent rays (swidden agriculture). It is in no way representative of the forest.

- in the counting, quadrats were not discarded in which there are rivers. Apart from the fact that there are no trees on the rivers, there are along the banks often thickets of bamboo with very few or no trees.

- the roll passes through areas (068) where there are blockhouses (abandoned); around the blockhouses there is a large bare area. Do we consider these areas as a primary prairie or a zone where there are no dead trees?

Methodology

1. Coincidence of the co-ordinates of defoliation operations with those of the damaged forests.

The problem of knowing whether a defoliation swath reported by the pilot and recorded, exactly matches with the one where the defoliants really come into contact with the forest. This problem does not exist when we deal with the overall estimation of the damages. But it exists when one wants to study the influence of the number of operations on the extent of the damages. Often these strips are close together, criss-crossed.

Allow me to believe that in the detail the coordinates given by the HERBS tape do not always correspond to reality. One can admit navigation errors by the pilot; a deviation of a few hundred meters for a large plane is--I think--normal. In addition, there is the drift of the droplets of the herbicide due to wind. The damages to the Hevea plantations, to the teak plantation at Dinhquán, to fruit tree plantations were often due to these causes. In addition, one can also see it on the photographs. For example:

Photo 037 (N16): I counted outside of the swath of defoliation indicated, quadrats (1.5 ha) where there are 7 to 16 dead trees.

Photo 090 (N16): In places where the HERBS tape shows one operation, I counted per quadrat of 1.5 ha 18, 8 to 9 dead trees, when nearby, where 3 operations are indicated, I counted only 8 dead trees.

Photo 0135: In the stretch where the forest is totally decimated, one operation is indicated.

Photo 0143: In the quadrats 134, 133, I counted respectively 11 and 10 dead trees; these quadrats are outside of the swath of defoliation recorded.

The same comments for photographs 0753, 1552....

With all this, allow me not to believe the assertion on p. 34: "The cleared strips coincide geographically with areas where four herbicide missions were flown...." Either the co-ordinates of the HERBS tape are not always the biological co-ordinates, or many times 2 sprays are sufficent to kill all the trees.

All the more reason, it is impossible for me to believe that we can write (p. 35): "the forest was essentially intact after the first three herbicide exposures."

2. I think that for the study of each quadrat, one should not base himself only on the vegetation map of Rollet, but also obligatorily on photographs taken before the defoliation, for example the aerial coverage of 1948.

This makes it possible to not classify a forest which is actually totally destroyed in the category "savanna". I remember that you yourself--like the majority of the members of the Committee--have never believed in the existence of of the areas where the defoliation has destroyed all the trees. At the time of the July meeting, nobody believed me when I spoke of the strips where the forest is totally destroyed by the defoliation. I even showed photographs (unfortunately, in black and white). In the report draft presented in July, it was never mentioned.

In this way, we have eliminated the areas most seriously damaged. Yet these stretches are easily visible from satellites (see infra-red photograph of ERTS I, for example).

When I have been at Seattle, and particularly at the Geographic Department in Washington, for each photograph, I had to look for each photo exactly what was there before the defoliation. It takes longer, but it is more accurate.

3. In Seattle, I brought up the problem of the poles. In my letter of June 21, 1973 I explained it again to you.

Many dead trees appear in 1973--even in 1972, if I remember properly--in the form of trunks without branches (crowns) which we have called by the term poles. Even in the Mangrove, if you remember well, in the maritime region of

Rùng-sát where we were in December 1972, were many poles, too. Along the Route Nationale from Saigon to Phantiết, it is the same.

A great majority of the errors committed in the estimation of the damages derive from these poles:

a. In the first study, these poles were not counted. Dean Bethel himself recognized this fact when I was in Seattle.

Now, these poles are difficult to count, and even if one succeeds, it is with a great margin of error:

- photographed vertically from above, they are represented by a whitish dot of 0.09 mm diameter (for a tree of commercial value with a diameter of 0.45 m). One can identify them with certainty only with a special stereoscope for these large photographs. I did not find one in Seattle. In Seattle, there is a small stereoscope; one can examine these photographs with this small stereoscope provided that the photographs are cut to bring them closer. How many have been cut?

- how to distinguish a dot of 0.09 mm that is counted, from a dot of 0.08 mm that is not counted; corresponding to trees without commercial value, and this with the rolls of photographs without contrast, without sufficient sharpness, or overexposed?

- when the photographs are taken in the morning, with the sun at an angle casting long shadows, the poles are easier to detect if the ground is even, constituted of a savanna for example. This is the case in the strip where the forest is totally destroyed.

But where there still is a shrubby or arborescent layer, the shadows are difficult if not impossible to detect. The photographs 766, 767, 768, and 769 are particularly instructive: one can see projected on the rivers shadows of poles which are themselves invisible!

My observations in the Corypha forest (Nationale Highway from Saigon to Phanthiết) and in the Mangrove lead me to believe that there are now as many if not more poles than dead trees retaining their branches. The study of the photographs in Washington and Seattle confirmed this for me.

Here are some figures taken at random from my notes (per quadrat of 1.5 ha):

Photograph	With Branches	Poles
730	10	7
760	0	40
706	1	3
	6	6
		1
		1
		8
1537		16-18
1553	5	20-25

In many areas where the forest is totally destroyed, there are only poles and no trees with branches. For example, on roll B7.

b. These bare areas bring up other particularly important remarks.

The examination of the photos taken before the defoliation shows that the region was covered by a beautiful forest. On the areas now bare, or more precisely covered by a savanna, I counted for example (photographs 1552-3-4) 10 to 41 poles per quadrat of 1.5 ha.

This does not mean that the primitive forest had only from 10 to 41 trees per 1.5 ha. In other words, even counting the poles correctly--which I doubt--the estimation was made strongly--very strongly--with a lack of judgment.

This therefore makes it already possible to refute the assertion (bottom of page 14) "complete destruction by fire or decay--although such complete disappearance of merchantable size trees in the period in question is unlikely". That complete destruction of the trunks of dead trees happens only in bare areas is highly unlikely!

These bare areas alternate with ones where the forest persists but is strongly damaged. In counting the number of trees alive and dead, one can still get an idea of the trees which disappeared because the number obtained is too small for the normal number of trees of the forest, even secondary.

X

X X

Could I be impassioned or do I have a prejudice in this question? I hope that you know me enough after more than one year of collaboration to not believe it. As of now, I have not written or published anything on the defoliation in Vietnam. As a Vietnamese, I am wrong. But as a scientist, I have liked to have more observations, more studies, to have a more exact idea, free from preconceived ideas on the problem. I thank the Committee for having permitted me to do this.

But conversely, could one say that the portion of this report draft concerning the damages in the forest is impartial? I doubt it strongly. And it seems to me from the beginning, the Committee took--for this portion--an incomprehensible attitude of taking a view opposite to the ideas of some persons.

You said in the introductory part that political conclusions must be avoided. But would it be an apolitical attitude which consists of doing exactly the opposite of what others, whom you judge to be extremists, did?

When reading this part of the Report one cannot help but think of two things. First, the tone used is more one of justifying oneself than that of a scientific work. Next, the effort to minimize the facts is apparent. It is never in my ideas, nor those of Vietnam, to ask for compensation for defoliated forests. The damages--as far as commercial value--belong to the past. But the report is too polarized by this aspect and thus neglects what concerns the biologists, naturalists, environmentalists--namely to understand the biological damages.

In the citations concerning the value of the forests of South Vietnam, only the portions of Rollet's work which suggest a forest of little value are cited. Maurand (1965) who, after all, spent all of his life in Vietnam as a forester and Director of Waters and Forests, has not been cited; nor Barry et al. (1960) who give an idea of the richness of the dense forests in 1960. Not taken into account were the similarities between the forests of South Vietnam and Cambodia, similarities such that Rollet used the same terms to describe them; yet in Cambodia, Rollet gives an average of 200 m^3/ha for the dense forests and 230 m^3/ha for the semi-dense forests; the forests of South Vietnam could be a little richer, being more humid.

This effort resulted in curious numbers that I really do not understand. As on page 30:

volume in cubic meters of all inland forests of SVN:

753.533

If that is the total volume "of merchantable timber", I dare not discuss it further. If that is the estimated volume destroyed by the defoliation, I cannot believe it any more.

Let us take for example just the forests totally destroyed. The committee estimated their area at 53.598 ha.

Using Rollet's figure one obtains

$$200\ m^3 \times 53,598 = 10,719,600\ m^3 \text{ destroyed}$$

There are reasons to think that these forests were very rich and dense forests, to deserve to be treated so many times.

The forests defoliated 3 times represent twice as large a surface area. If half of the trees are destroyed, one obtains an analogous number.

So, just for these two types of damaged forests, there is more than $21 \cdot 10^6\ m^3$!

As for the forests defoliated one time? In the report draft I have read, I do not have the figure informing on the number of dead trees per hectare for this category. But, judging by the figures concerning the volume of wood of commercial value destroyed (2 to 4% of the figures of Flamm and Westing, i.e., from 10^6 to $2 \cdot 10^6\ m^3$) this does not differ much from the ones given in the previous report draft ($1.74\ m^3 \times 301,385$, i.e., $0.51 \cdot 10^6\ m^3$). I conclude from this that the number of dead trees per hectare has not varied much.

The study of the influence of the number of sprays is difficult when the swaths are close, as in the majority of the cases. One cannot eliminate the drift of the droplets of herbicide.

But some photos (roll N16, very good photographs) permit us to have an idea. These photos are of a region of beautiful forests.

On photograph 090, there are very distinct strips "one spray". On it I counted per square of 1.56 ha:

Quadrat	Number of dead trees
116	17
100	6
140	5-6
139	7-8
139	2

(This is a forest with bamboos, therefore containing less trees).

On photograph 0114:

Quadrat	Number of dead trees
31	12
30	15

Do these dead trees have a diameter DBH greater than 0.45 m? I do not know, but since they belong to the upper story of the forest, I allow myself to believe it.

With such numbers of trees of the upper story dead, the number presented by the committee appears ridiculously low.

In conclusion, as a scientist who--I think--knows Vietnam and who is familiar with the aspects of the defoliation, it appears impossible for me to associate myself with the conclusions of the Committee.

I ask you therefore to kindly present this letter to the Report Review Panel, along with the report draft or, if it is too late, to withdraw my name from the Committee.* If ever this report is translated into Vietnamese, I ask you also to insert the translation of this letter in its entirety.

In more than one year of collaboration, I have admired your kindness and your comprehension, valued the very high competency of the members of the Committee, and enormously benefitted from their knowledge. It was for me one of the greatest honors to work with you. I therefore regret even more not being able to associate my name because of this small part of the work.

Please, dear Professor Anton Lang, believe in my best memories.

/s/ Phạm-hoàng Hộ

Phạm-hoàng Hộ

cc: Professor Richards
Professor Thói

* Since receipt of this letter, Professor Ho has withdrawn his resignation from the Committee, but not his exceptions concerning Section IV B.

NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY OF SCIENCES NATIONAL ACADEMY OF ENGINEERING

2101 CONSTITUTION AVENUE WASHINGTON, D.C. 20418

DIVISION OF BIOLOGY AND AGRICULTURE
COMMITTEE ON THE EFFECTS
OF HERBICIDES IN VIETNAM

TELEPHONE: (202) 961-1761

February 4, 1974

Professor Phạm-Hoàng Hộ
Department of Botany
Faculty of Science
227 Công-hòa Street
B.P. A-2
Saigon, Vietnam

Dear Professor Hộ:

This is written in reponse to your letter of 3 December 1973. I have to apologize that this reponse has taken such a long time. I was very busy with various other aspects of finishing the Committee Report and had also to consult a couple of times with Dr. Bethel and Dr. Turnbull concerning certain points in your letter. Permit me also to reiterate in this letter some points which I already made in that of 21 December so that all comments which I would like to make are assembled in one document.

To begin with a number of general points.

I cannot accept your statement that for this part of the study the Committee has taken from the start a partial attitude, namely the opposite view to that of some other persons whom we consider as extremists. In this as in all other parts of the study we have tried to be as unprejudiced as humanly possible, and to use available methods which could be utilized under the circumstances to arrive at objective conclusions. In the estimation of the loss of merchantable timber--chosen because this was the kind of loss where a reasonably reliable quantitative estimate could be made--we used methods which have been used before in non-tropical as well as tropical forests and which have proven to provide results reliable within ca. 10 percent. Because of the problems of this particular study we realize that the reliability is less and use in the latest draft of the report a range, 500,000 to 2,000,000 m^3 which implies a larger error. But we consider it quite impossible that the error is anything like 20 to 100 fold. As to the other authors, our intent was at first not to enter into any discussion of their data. However, the first time our figures were shown to the Report Review Panel we were blamed for disregarding this earlier evidence, and had no choice but to explain why we consider those data entirely wrong. We do not claim to be infallible and may have made mistakes, but this was not because of partiality. If you consider one section of the report as partial this means the whole report is partial. I fully expect that accusations of partiality will be made; I regret profoundly that you are joining in this.

I also regret that you feel the new study consists only in better writing, in softer terms. In fact, this new study involves recounting for merchantable dead trees on more than 33,000 quadrats. The object was to obtain more complete information--whether it changed the preliminary figures or not. Also, much time and effort was spent on 10,000 photos covering the period 1965-70, and on providing specific clarifications to satisfy questions by members of our Committee, primarily your own, and of the Report Review Panel.

Turning now to individual items in your letter:

> -"I do not speak of the figures concerning the extent of the defoliated areas. We estimate that the non-recorded defoliated areas represent about 15 percent of the total area."

We are not clear on this statement. It could mean (i) 15 percent of the area already considered as sprayed, i.e., the actual area is 115 percent of what the Committee used as sprayed area; or (ii) it could mean 15 percent of the whole country, i.e., the Committee's figure of 10 percent for the whole country should be 25 percent.

If (i) is the meaning that it agrees closely with the Committee's estimate that herbicide operations not accounted for in the HERBS records amount to 15 to 17 percent (15 percent of the quantities used, 17 percent of the cumulative area sprayed) of those recorded.

That this amount of sprays is missing is said repeatedly (Section IIIC; Section IVB-3, p. 86) and is discussed in relation to the forest damage study on p. IV-71. It is explained at the latter place that increase in "total country sprayed" and increase in "area sprayed within sample" would both happen as a consequence of over-all increase in area sprayed. Unless there is evidence that the unrecorded spraying was outside MR III or completely missed by the sample, it is fair to assert that the increases in numerator and denominator of the ratio page IV-61, equation (1) would tend to cancel, leaving the ratio unchanged. The limited information concerning pre-August 1965 spraying locates much of it in MR III.

If (ii) is what is meant, this suggests an error of 150 percent. There is nothing in the data available to us to support such an assertion. It seems unlikely that this is the meaning intended; if it were so, I would regret very much that we were not alerted to this conclusion before.

"Material Used"

> #1. "The project report has specified that the Committee has chosen a certain number of sites necessary for a good sampling of defoliated forests. But for reasons of security and convenience, we have had to adopt quite different itineraries.--We have used a base-line material which we have accepted but not chosen."

It is true that the sample areas selected had to be reselected. The main points of importance are:

i) The request from the Department of Defense was to arrange the sample points so that they could be flown as a small number of longer lines rather than a large number (over 30) of short flight lines. The reselection was made by the Committee, by making minor shifts in sample location so that sets of points occurred now on the same straight line. These shifts, ranging from 0 to 10 km, were made without regard to the intensity of spraying or degree of effect (the latter unknown to the Committee until the photo flights were made.) The sample areas originally selected and still included in the reselected sample were 23 out of a total of 31, or 74 percent.

ii) The areas selected initially would have resulted in a total sample area of about 40 x 10 kilometers of flight path, or 400 km^2. The reselected areas and lines gave about 7 x 150 or 1050 km^2 or 2.5 times the photo coverage requested originally.

iii) An effect of shifting sample areas could be to increase or decrease the degree of damage or the fraction of any given type of forest included in the sample. An argument against the samples could be made if it were shown that the degree of damage in relation to number of spray applications (based on the HERBS records) was high or low in the sample compared with the spray effect as a whole. No basis for such an assertion has been presented. In fact, the estimates of damage for 2 and more applications, for example, were based on samples that deliberately included some of the most heavily damaged areas.

Altogether, we did not accept samples we had not chosen. The modifications which we made in the original sampling plan were small and are counterbalanced by a larger size of the sample. The sample would be considered entirely satisfactory in forest inventory practice.

> #2. "In addition, the quality of the transparencies, or at least those which I was able to study at Seattle, leaves much to be desired (etc.)"

True. For this reason a careful selection of films was made to give as extensive a sampling as possible and with satisfactory quality. Copies of film seriously lacking in quality (S29) were copied in black and white from the original so that good quality (S59) was obtained. The latter were used in the final sampling.

> -"On overexposed transparencies it is already very difficult to count dead trees because of the absence of contrast; the background becomes lighter than the trunk of the dead trees. It would be impossible to count poles. In effect, these photos represent the forest at 1:5,000; a tree trunk of 45 cm or 450 mm diameter is represented thereon by a line of 0.09 mm wide, visible if the photo has adequate contrast. But if the tree is represented by a covered pole, it is represented by a point of 0.09 mm in diameter; this point has to be very bright to be recognized."

i) The Committee had certainly as much desire to have good data as do yourself.

ii) It is true that in the small portion of film representing area in direct line with the center of the camera field, and vertically below, a pole would appear as a point. But most of the area is not exactly on center; most of the trees are seen with some degree of obliqueness.

iii) Trees (and parts of trees) of a diameter much smaller than 45 cm (e.g., tree branches of a diameter of 10 cm) are clearly visible on film of good quality as selected for the final sample.

iv) Possible errors in dead tree counts, including error in judgement of size are discussed on page IV-67 which should be studied carefully. An important fact is that counting trees too small to be 45 cm in diameter can increase the count (number) of merchantable trees considerably but, since those trees are small, this has only quite a small effect on the volume of merchantable tree. The reverse is true for undercounting merchantable trees.

Reference should also be made to the new non-merchantable inventory (page IV-73) et seq.) and the assessment of damage to non-merchantable volume. As indicated there, the number of trees of 30-45 cm diameter killed by herbicide would be 20-30/ha in some locations. You may question whether these trees are non-merchantable. That they were killed is not being argued. We believe that when you counted dead tree numbers in the range of 20-40 cm many of these were below merchantable size--the only number which we tried to determine at that time.

> -"Moreover if the region had been subjected to brush fires the trunk of a tree may be more or less charred, more difficult to see, and the poles would in this case become practially invisible, even with the aid of a stereoscope. The same holds true for surviving vines and epiphytes."

i) No indication is given as to the extent of such burning. Did it occur often enough to cause a serious error? Generally where brush is extensive, the number of merchantable size trees is small (see Table IVB-4) since most are scattered over areas that had been cleared for agriculture.

ii) As indicated in the discussion of factors that may have affected the estimates of damage (p. IV-63) there is no doubt that dead merchantable trees were included in the count that were not killed by herbicide--compensating to some degree for trees that were killed and then covered or blackened. Again, however, no indication of the amount of the latter has been provided.

#3. -"I have read in the Report that the Committee has chosen Tayninh as a study site (XT and YT quadrangles).--I do not know if the study was made with roll N14. As I had occasion to remark at Seattle this roll is not a good sample for several reasons:

-"it passes through areas where there are many recent rays (swidden agriculture). It is in no way representative of the forest."

Our samples were chosen to represent all the areas sprayed within the general category "inland forest". The one million hectares so designated include recent swidden that was sprayed - therefore it is sampled. In other samples the amount of such areas is less; the total samples reflect the various vegetation types found within "inland forest" in a manner which would again be considered satisfactory in forest inventory practice.

-"in counting quadrats were not discarded in which there are rivers. Apart from that fact there are no trees along the banks there is often a thicket of bamboos where also few trees are present.

-"the roll passes through areas (068) where there are blockhouses (abandoned); around the blockhouses there is a large bare zone. Are these zones considered as primary prairies or as a zone where there are no dead trees?"

Our non-forest types 6, 7 and 8 are identified in the sample (see page IV-39) and in the results (Table IVB-4) to separate these from forested areas. Rivers are for example in our micro-type No. 7. As expected these areas have very few trees, dead or alive (see also Table IV-60). But they are part of inland forest and therefore cannot be simply disregarded.

"Methodology"

1. Coincidence of the coordinates of defoliation operations with those of the affected forests.

-"Allow me to believe that in the detail the coordinates given by the HERBS tape do not always correspond to reality. One can admit navigation errors by the pilot; a deviation of some hundreds of meters for a large airplane is--I think--normal. In addition, there is the drift of droplets of herbicide due to wind. The damage to Hevea plantations, to the teak plantation at Dinhquán, to tree fruit plantations were often due to these causes."

Agreed; see page IV-71/72 of Report. But herbicide may have also been applied because of these reasons to areas bare of vegetation. Intentional and accidental spraying of crop lands is discussed in several sections of the Report (IIIB, VIIB [1], [2]). Where this occurred in the inland forests (mainly active swidden) that amount should be subtracted from "inland forest area" and added to "cultivated area". But the reverse accident could happen and has happened, i.e., spraying designed for crop destruction has impinged on inland forests (see also Section III B-6).

-"With all this, allow me not to believe the assertion on p. 34: The cleared strips coincide geographically with areas where four herbicide missions were flown."

A study of that whole area established too strong a similarity in pattern of "four spray" applications and pattern of "conspicuous damage" to be dismissed. It is true that some of the severely damaged areas had been both bombed and sprayed.

> -"All the more reason, it is impossible for me to believe that we can write (p. 35) 'the forest was essentially intact after the first three herbicide applications'."

In the 1968-69 (1:50,000) photographs the area is undistinguishable from many sprayed areas as visible on black and white photography, namely, it appears as a grey-white swath--within this the trees are visible. In 1972-73 (1:5,000) color photographs the dramatic damage in certain strips is clearly visible. According to spray records, three applications occurred prior to the 1968-69 photographs and one after they were taken. In some parts bomb craters are visible within the dramatically damaged strips.

2. "I think that for the study of each quadrat, one should not base himself only the vegetation map of Rollet but also obligatorily on photographs taken before the defoliation, for example the 1948 aerial photo coverage"

See report. We do not know of 1948 photography. 1958 1:50,000 photographs and some 10,000 prints for the period 1965-70 were used. The prespraying vegetation maps given in the report are derived from the former photographs which are excellent.

3. The problem of poles. Part of this is covered under item #2 of "Methods Used", above. In addition, the following remarks should be made:

i) CEHV counts were made by a combination of monoscopic and stereoscopic observation following a pattern of photo interpretation that is commonly used and that has proved to be accurate in a great many similar studies in the past. This was the subject of a special inquiry when three specialists reviewed our procedures at President Handler's request. We were advised that the team found our procedures to be reasonable and to yield accurate and reproducible results. The procedures consisted essentially of using monoscopic observations when it was found, by checks with stereoscopic observations, that the counts were consistent between the two. This was the case for the large scale counting and typing. For special studies and in doubtful cases stereoscopic observations were used throughout.

ii) Comparison of different observers with the same criterion on the same material was a common quality control procedure used throughout the study. When counts of an observer were consistently higher or lower than of the others they were discarded.

iii) Altogether, we are compelled to say that counting poles, "snags", "climber towers" is a question of photo interpreting skill and we believe that we have coverd this problem in our data gathering, in the range of assessment values presented, and in the narrative in the report.

In the last part of your letter, speaking of the total damage estimate, you say that if this volume is the total for 'merchantable timber' you do not wish to discuss further ("je n'ose plus discuter"); if it is the estimate for the total destruction by defoliation you do not believe in it even more.

Let me emphasize that in the version of the chapter to which your letter refers we were always and explicitly speaking of loss of merchantable timber only. This leads me to say that, in my opinion, the important sources of disagreement are, and have been all the time, two. First, while we were speaking of merchantable timber--this being the type of timber which we felt could be estimated with a reasonable degree of accuracy--yourself and some others had in mind the total standing timber. These are obviously two quite different categories which cannot be interchanged. This problem is discussed on p. IV-49 of the Report. When the difference between these categories is observed, the large volumes you cite for example for Cambodia become much smaller; Rollet considers 15 m^3/ha as a high current merchantable yield. Second, we have followed Rollet's classification of vegetation types in South Vietnam; it seems to me that when you speak of forests you think of undisturbed or little disturbed dense forests. We are aware of the publications of Maurand and of Barry et al., and certainly do not deny that such high quality forests exist in South Vietnam and that they have suffered from herbicide operations. But Rollet's is the only available classification for the entire country, and our objective was to assess the damage in the entire inland forests, not in selected areas of one type or another. The only alternative would be to re-define the term "forest", excluding swidden, bamboo thickets, and some other degraded secondary forests which Rollet in his map includes under "forests." But this would almost mean preparing a forest inventory of South Vietnam, a task beyond the possibilities of this Committee even under much more favorable conditions. As long as the Rollet classification is accepted, however, it is clear that all its "forest types", including bamboo etc., have to be considered. It is, as I am sure you will agree incompatible with the scientific approach to arbitrarily disregard some sample areas or to exclude results we consider well documented by quantitative data, even if these may disagree with qualitative impressions of the forests of South Vietnam. However, I believe that our procedure, accepting Rollet's classification as the only basis available, was the correct one as it covers total damage, in both the good and the poor parts of the forests, and this needs to be known if a comprehensive and efficient rehabilitation program is to be developed. As a matter of fact, we believe, and say so in the Report, that while loss of merchantable timber in the more degraded forest areas is relatively slight, other damage is very serious and calls for rapid action if circumstances should permit it.

Reading the present, final version of the Report you will, I hope, note that we have introduced further modifications, designed to clarify the issues about which you have expressed concern. In particular, we have added estimates of losses of non-merchantable timber--again, please note for the total inland forest area, including all forest types from genuine dense forests to highly degraded secondary ones--even though we have ourselves considerably less confidence in these estimates than those of merchantable timber losses.

Let me conclude by saying that whatever your decision concerning this report, I will always remember with profound respect and gratitude your help and cooperation, given

I am afraid often at detriment to your regular, demanding responsibilities, and I am sure the entire Committee shares this feeling. We know that without your generous assistance we would have accomplished very little.

With best personal regards,

Sincerely yours,

(Signed) Anton Lang

Anton Lang
Chairman

cc Professor P. W. Richards
Professor Le-Van-Thoi

SCHOOL OF PLANT BIOLOGY
UNIVERSITY COLLEGE OF NORTH WALES
MEMORIAL BUILDINGS
BANGOR, CAERNARVONSHIRE

STATEMENT

Though I am in general agreement with the rest of the Report, I wish to express a personal reservation with regard to the section on 'Quantitative Assessment of Herbicide Damage to the Inland Forest'. Earlier estimates of herbicide damage may have been too high, but I am not convinced that the loss of 'merchantable timber' (itself only a small fraction of the total damage to the forest) was not considerably greater than is suggested here. I have been led to this conclusion by my general knowledge of forests in many parts of the tropics, my (admittedly very limited) field experience in SVN, and by such studies as I have been able to make of the air photographs. In my opinion there are two important reasons for the low figures: (1) that the methods used led to a serious underestimate of the number of dead trees in the 1972-73 photography, much of which was of indifferent quality, (2) there was an inadequate appreciation of the post-mortem changes to which trees are subject in humid tropical climates. Because of these changes counts of dead trees and estimates of crown and tree diameters in air photographs taken long after the death of the trees may be very unreliable.

(Signed) Paul W. Richards

Received in the Committee Office, February 4, 1974.

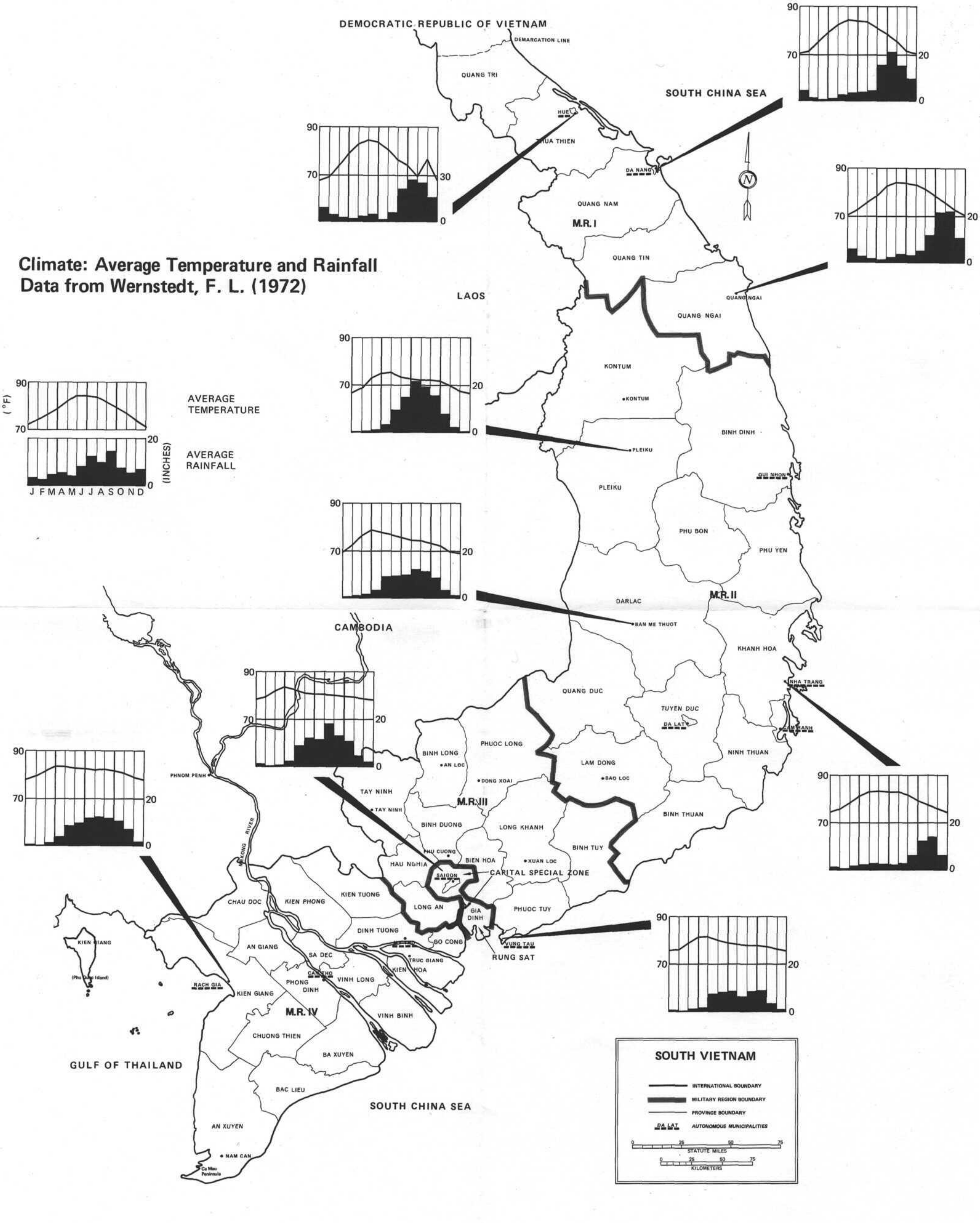
Western Union MAILGRAM

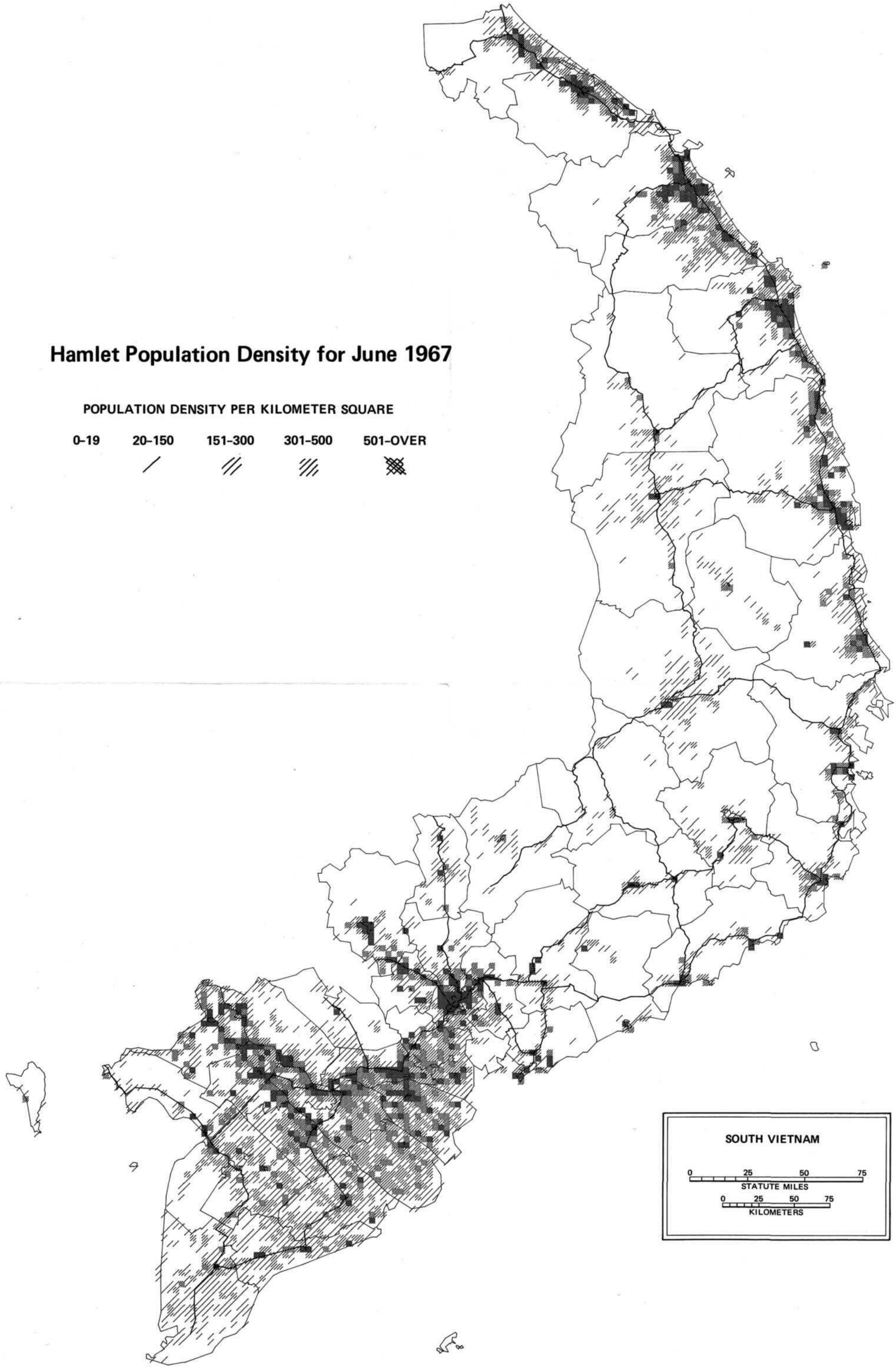
February 8, 1974

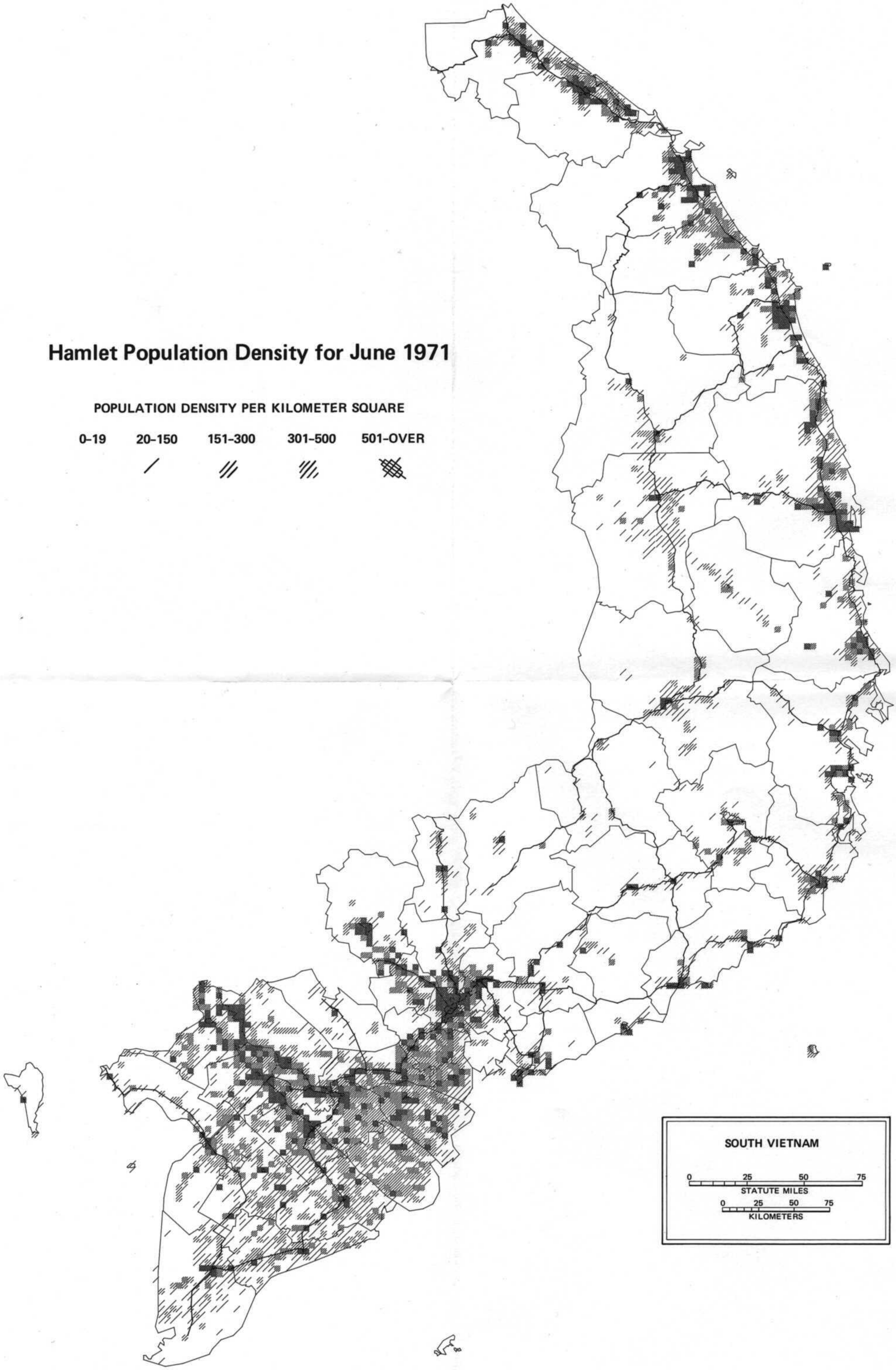
Philip Handler, National Academy of Sciences
2101 Constitution Ave
Washington DC 20418

Ordinarily in a joint scientific endeavor that involves several disciplines, each member expects to accept within limits contributions from disciplines not his own without necessarily understanding all the technical procedures and the precise nature of the evidence. When, however, the task is as complex and difficult as the work of our committee and when there is as much controversy as there has been among scientists in given subject matter areas regarding conclusions, then the matter of approving the report as a whole becomes extremely difficult. I have in mind particularly the section on the inland forests and think it not appropriate that I should appear as either approving or disapproving it.

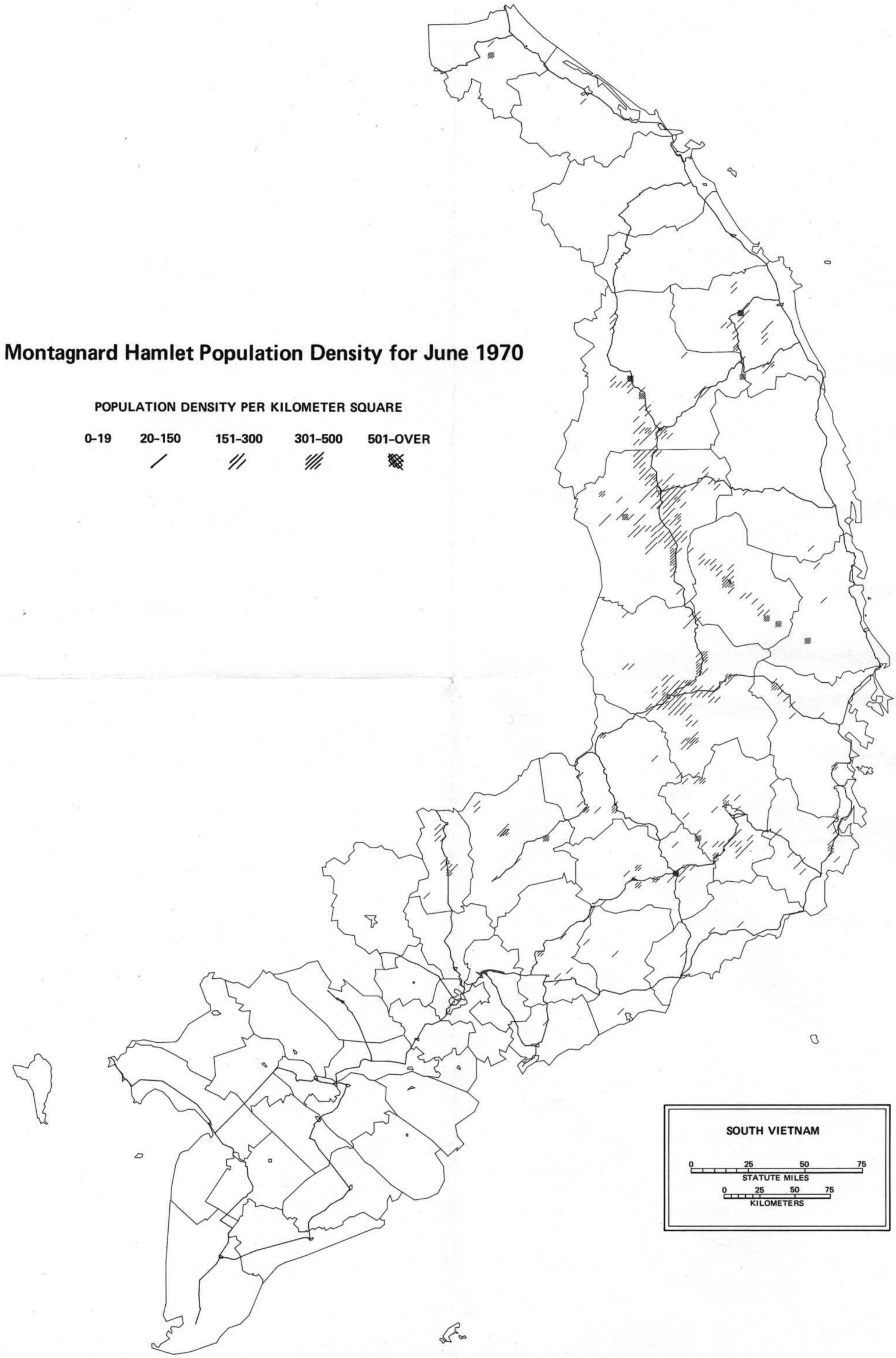
Alexander H. Leighton, M.D.

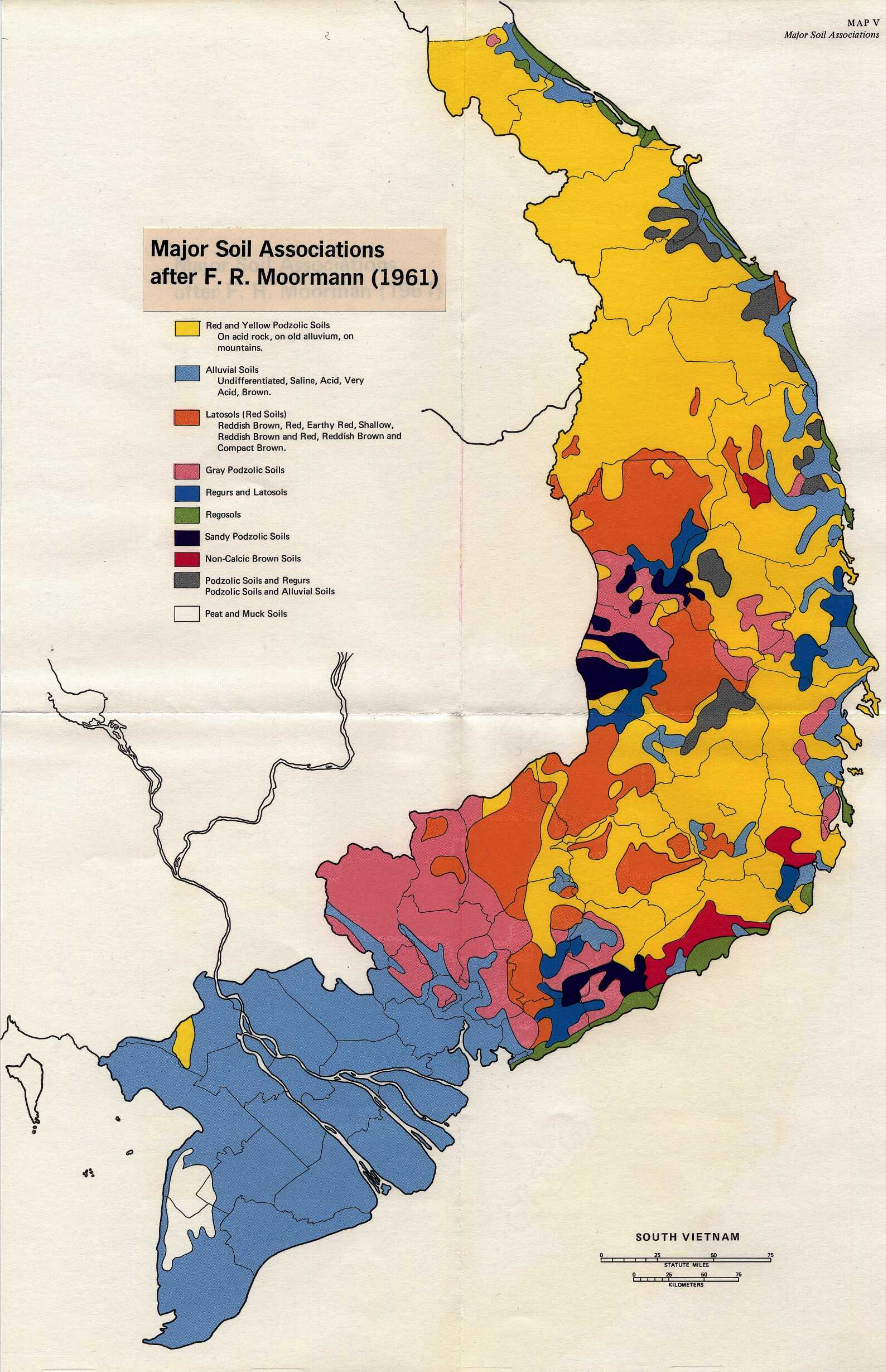

Climate: Average Temperature and Rainfall
Data from Wernstedt, F. L. (1972)
AVERAGE TEMPERATURE
AVERAGE RAINFALL
(°F)
(INCHES)
J F M A M J J A S O N D
DEMOCRATIC REPUBLIC OF VIETNAM
DEMARCATION LINE
SOUTH CHINA SEA
LAOS
CAMBODIA
GULF OF THAILAND
SOUTH CHINA SEA
QUANG TRI
HUE
THUA THIEN
DA NANG
QUANG NAM
M.R. I
QUANG TIN
QUANG NGAI
KONTUM
BINH DINH
QUI NHON
PLEIKU
PHU BON
PHU YEN
DARLAC
M.R. II
BAN ME THUOT
KHANH HOA
NHA TRANG
CAM RANH
QUANG DUC
TUYEN DUC
DA LAT
LAM DONG
BAO LOC
NINH THUAN
BINH THUAN
BINH TUY
PHUOC LONG
BINH LONG
AN LOC
DONG XOAI
TAY NINH
M.R. III
BINH DUONG
LONG KHANH
PHU CUONG
BIEN HOA
XUAN LOC
HAU NGHIA
SAIGON
CAPITAL SPECIAL ZONE
LONG AN
GIA DINH
PHUOC TUY
VUNG TAU
RUNG SAT
PHNOM PENH
MEKONG RIVER
CHAU DOC
KIEN PHONG
KIEN TUONG
DINH TUONG
GO CONG
AN GIANG
SA DEC
TRUC GIANG
KIEN HOA
CAN THO
VINH LONG
PHONG DINH
KIEN GIANG
RACH GIA
(Phu Quoc Island)
M.R. IV
VINH BINH
CHUONG THIEN
BA XUYEN
BAC LIEU
AN XUYEN
NAM CAN
Ca Mau Peninsula
SOUTH VIETNAM
INTERNATIONAL BOUNDARY
MILITARY REGION BOUNDARY
PROVINCE BOUNDARY
DA LAT AUTONOMOUS MUNICIPALITIES
STATUTE MILES
KILOMETERS

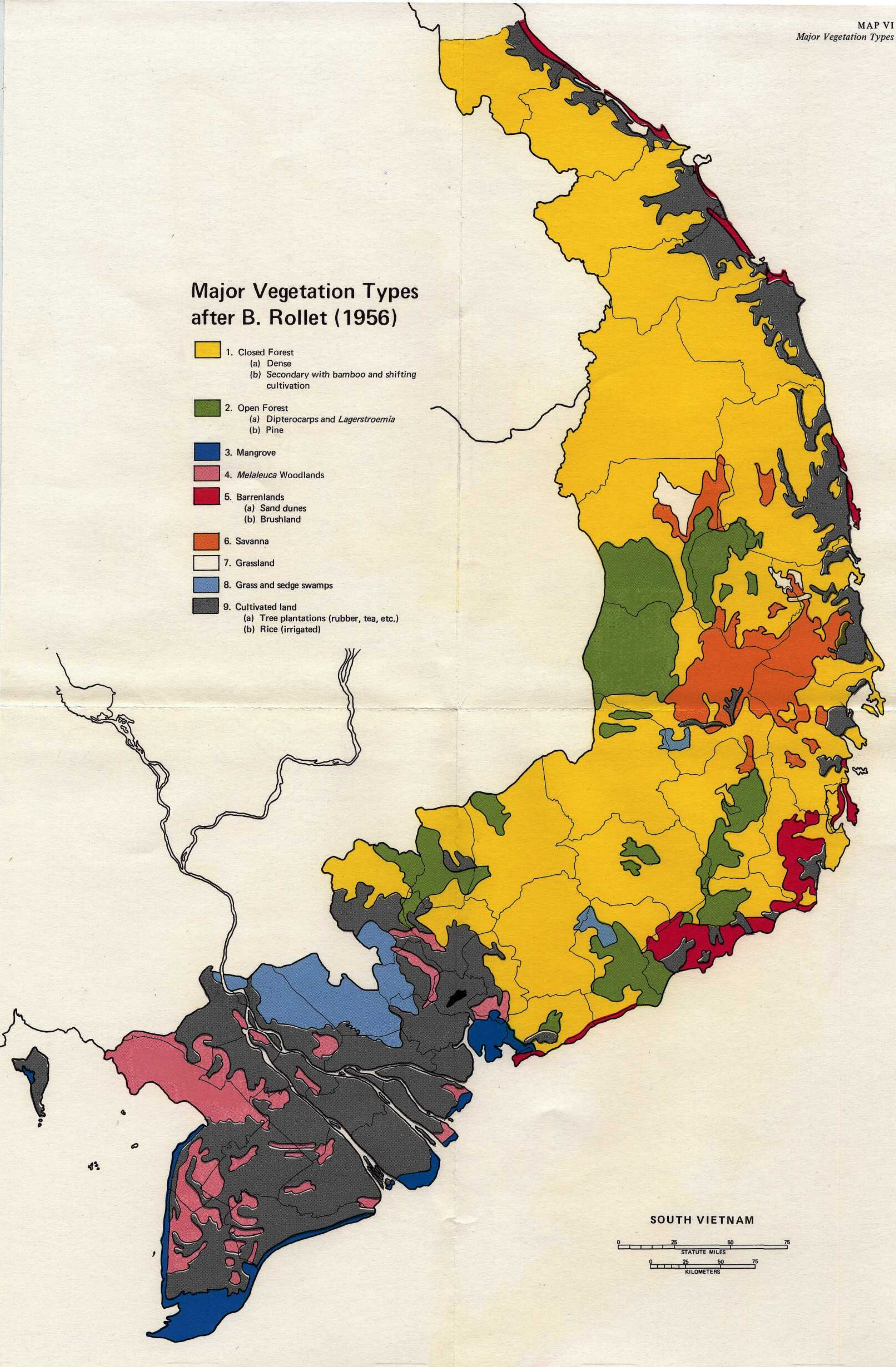

Hamlet Population Density for June 1967
POPULATION DENSITY PER KILOMETER SQUARE
0-19
20-150
151-300
301-500
501-OVER
SOUTH VIETNAM
0 25 50 75
STATUTE MILES
0 25 50 75
KILOMETERS

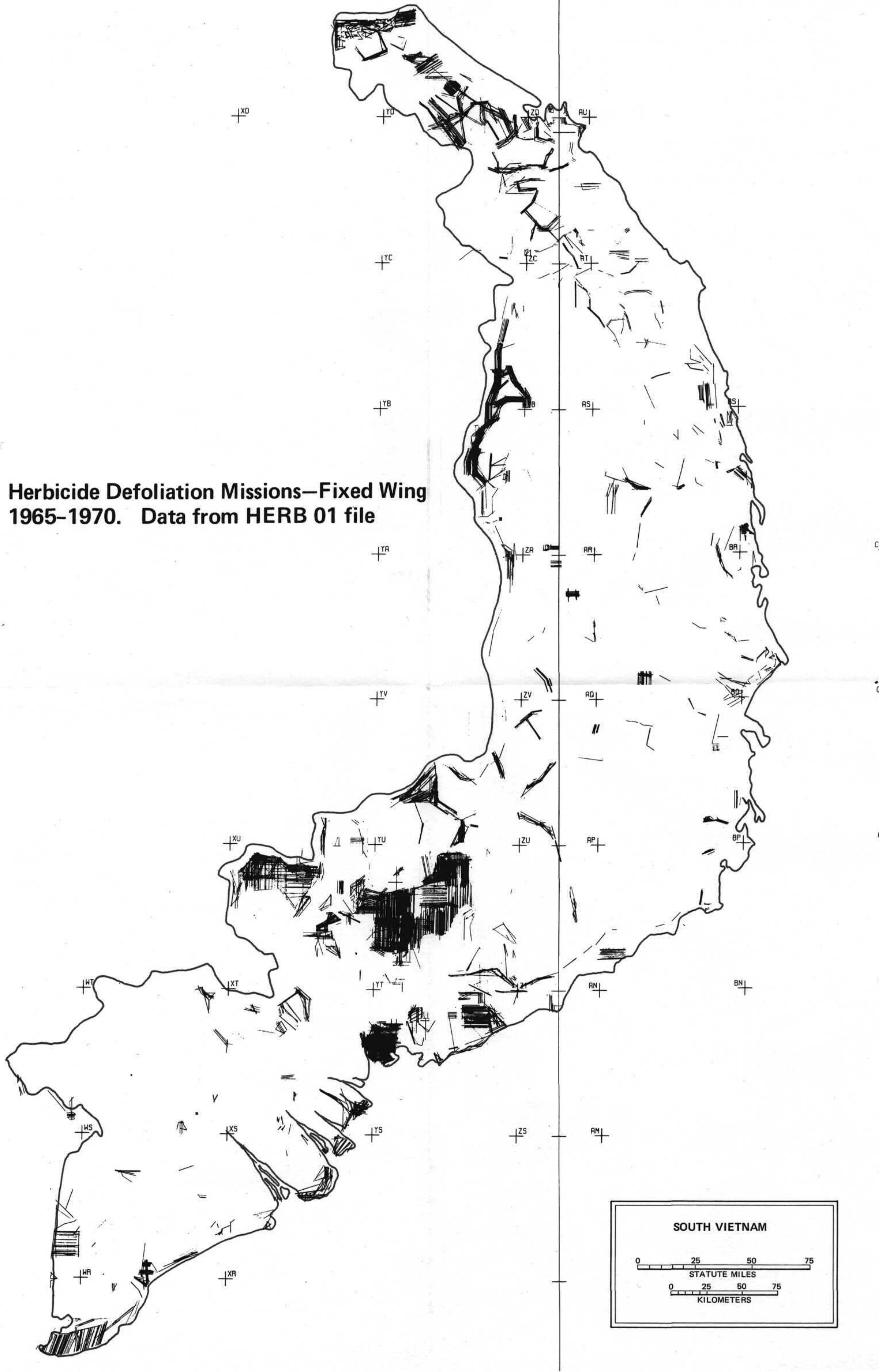

Hamlet Population Density for June 1971
POPULATION DENSITY PER KILOMETER SQUARE
0-19
20-150
151-300
301-500
501-OVER
SOUTH VIETNAM
0 25 50 75
STATUTE MILES
0 25 50 75
KILOMETERS

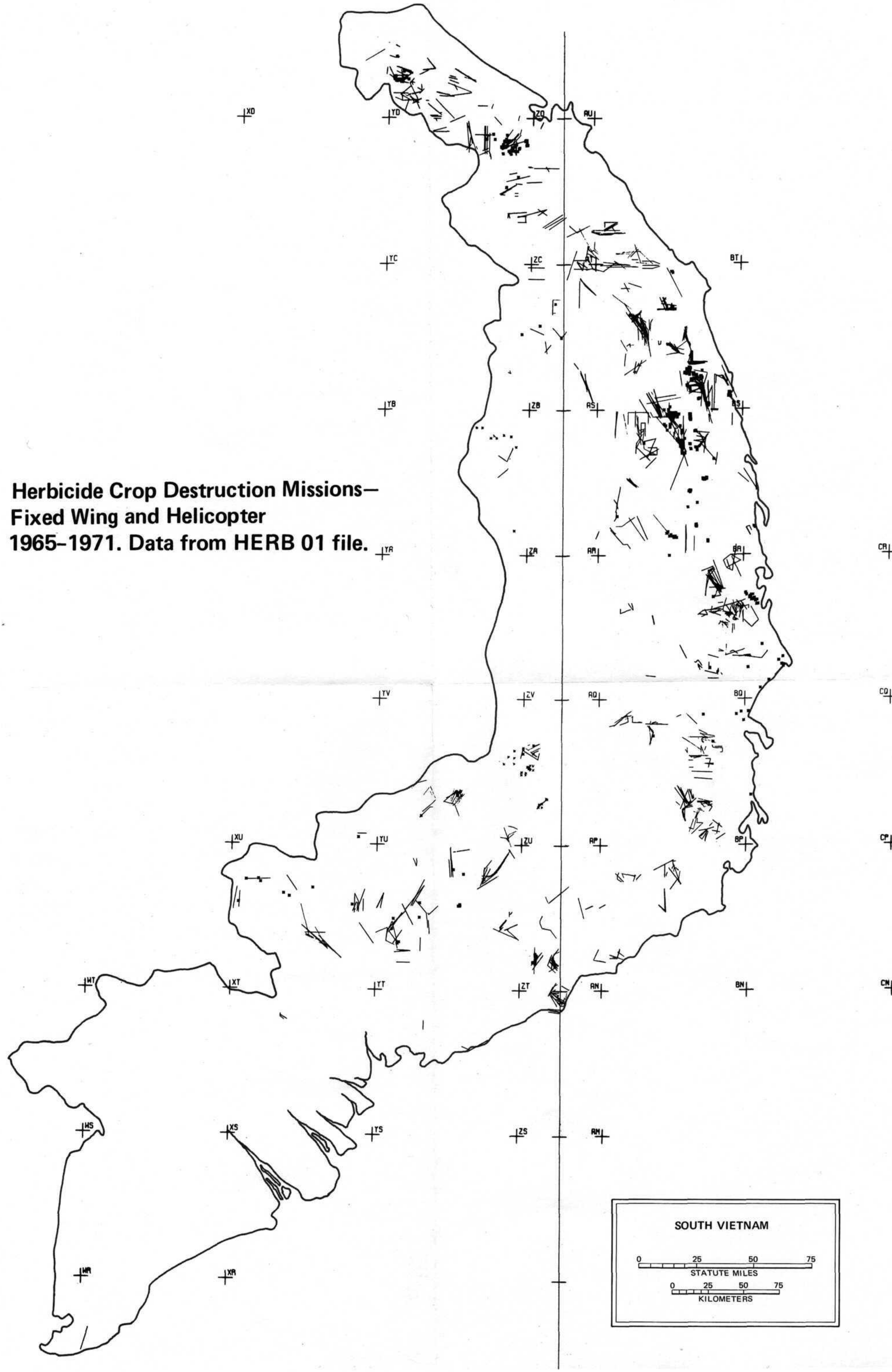
MAP IV
Montagnard Hamlet Population Density for June 1970




Major Soil Associations
after F. R. Moormann (1961)
Red and Yellow Podzolic Soils
On acid rock, on old alluvium, on mountains.
Alluvial Soils
Undifferentiated, Saline, Acid, Very Acid, Brown.
Latosols (Red Soils)
Reddish Brown, Red, Earthy Red, Shallow, Reddish Brown and Red, Reddish Brown and Compact Brown.
Gray Podzolic Soils
Regurs and Latosols
Regosols
Sandy Podzolic Soils
Non-Calcic Brown Soils
Podzolic Soils and Regurs
Podzolic Soils and Alluvial Soils
Peat and Muck Soils
SOUTH VIETNAM
0 25 50 75
STATUTE MILES
0 25 50 75
KILOMETERS


Major Vegetation Types
after B. Rollet (1956)
1. Closed Forest
(a) Dense
(b) Secondary with bamboo and shifting cultivation
2. Open Forest
(a) Dipterocarps and Lagerstroemia
(b) Pine
3. Mangrove
4. Melaleuca Woodlands
5. Barrenlands
(a) Sand dunes
(b) Brushland
6. Savanna
7. Grassland
8. Grass and sedge swamps
9. Cultivated land
(a) Tree plantations (rubber, tea, etc.)
(b) Rice (irrigated)
SOUTH VIETNAM
0
25
50
75
STATUTE MILES
0
25
50
75
KILOMETERS


Herbicide Defoliation Missions—Fixed Wing
1965–1970. Data from HERB 01 file
XD
YD
ZD
AU
YC
ZC
AT
YB
AS
BS
YA
ZA
AR
BR
CR
YV
ZV
AQ
BQ
CQ
XU
YU
ZU
AP
BP
CP
WT
XT
YT
ZT
AN
BN
CN
WS
XS
YS
ZS
AM
WR
XR
SOUTH VIETNAM
0 25 50 75
STATUTE MILES
0 25 50 75
KILOMETERS



**Herbicide Crop Destruction Missions—
Fixed Wing and Helicopter
1965–1971. Data from HERB 01 file.**