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THE EFFECTS OF HERBICIDES IN SOUTH VIETNAM
PART B. WORKING PAPERS: ECONOMIC STRESS AND
SETTLEMENT CHANGES

NATIONAL ACADEMY OF SCIENCES-NATIONAL RESEARCH COUNCIL

FEBRUARY 1974

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Economic Stress and Settlement Changes

WILLIAM L. THOMAS

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Economic Stress and Settlement Changes^a

WILLIAM L. THOMAS^b

The principal objective of this investigation was to ascertain some of the effects that the widespread spraying of herbicides in South Vietnam (SVN) had upon altering population distributions, patterns of settlement (isolated farmsteads, hamlets, villages), and agricultural and other economic activities surrounding the settlements, thus giving some idea of man's ability to continue to use the environment. Using the records of remote-sensing, 25 study areas representing six different socioeconomic types of settlements were studied (see Figure 1). Remote-sensing records are of particular value in a study of this type in that they provide supplementary evidence to such other types of data as human memories and/or ground effects still observable.^c

The organization of this report is as follows. First, the methods used and an explanation of why they were selected are given. Second, the problems met in obtaining and using the available materials are briefly discussed. Third, presentations are made of the six different socioeconomic

^aResearch for this report was conducted on Subcontract No. BA 23-73-37 with the Research Foundation, California State University, Hayward, California 94542.

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^cRemote sensors are mechanical devices that collect information, usually in storable form, about objects or scenes while at some distance from them. Cameras, radar, and x-ray machines are remote sensors, each of which use different forms (wave-lengths) of energy. Remote-sensing is a collective term for the process of data collection by remote sensors; aerial photography is but one familiar form of remote sensing. For other forms, see the brief description in the "Limitations" portion of this report, specifically the section on "Limitations in Materials."

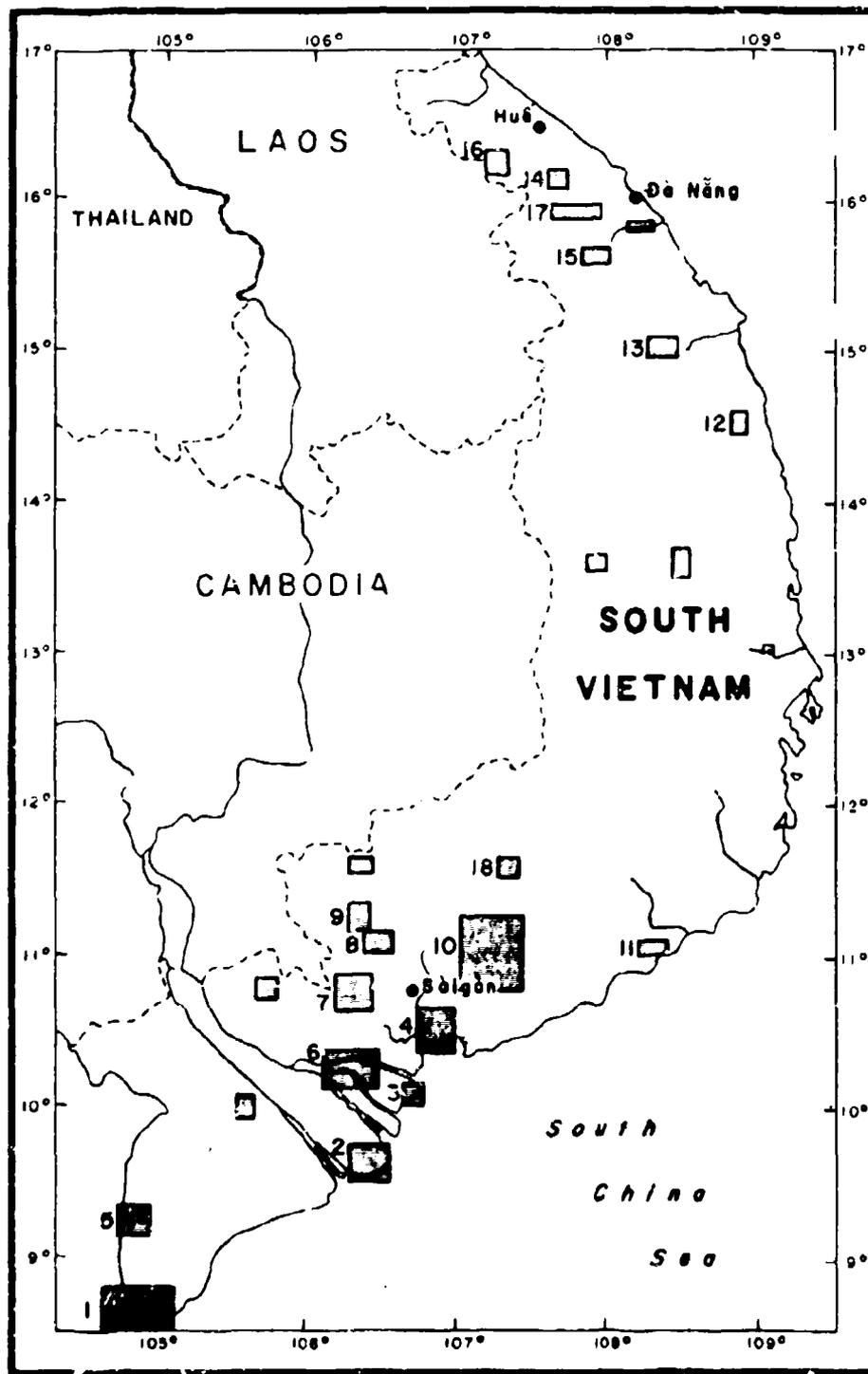


FIG. 1. Location of the 25 study areas selected for air-photo interpretation. The air-photo evidence revealed that the seven unnumbered areas were depopulated by other war-related activities before herbicide spraying began.

types of settlements. Fourth, conclusions of the investigation and recommendations for future studies are presented.

METHODOLOGY

Research began on aerial photo interpretation of selected community types in late June 1972. At that time there were available a map entitled "Southeast Asia Briefing Graphic" (Series L307, in two sheets, scale 1:1,000,000) and an overlay (No. 15, also in two sheets) showing a composite of the zones in SVN that had been subjected to herbicide spraying from the air. Because of the small scale (about 16 miles to the inch), locations of sprayed areas were only very approximate, and were not differentiated by date, agent, purpose, or amount of spray. However, the general locations where spraying had been done were evident. The next step was to compare the sprayed zones with the settlements (hamlets, villages, towns, cities) represented on the maps (Series 1501, scale 1:250,000) for the whole of SVN. From this map study and information based upon previous knowledge of socioeconomic conditions of Vietnamese and nonVietnamese peoples in SVN, some 24 different areas were selected, all of which appeared to contain settlements that had been subjected to herbicide spraying. These areas were then grouped into six socioeconomic types. In January 1973, one more study area (No. 10) was added (for a total of 25), to correlate with an on-the-ground field investigation under the direction of Drs. Alexander H. Leighton and Jane M. Murphy of the Harvard School of Public Health.^a After a detailed study of these

^aSee Murphy, J.M., G.D. Murfin, N.L. Jamieson, III, A.T. Rambo, J.A. Glenn, and A.H. Leighton. Beliefs, attitudes, and behavior of lowland Vietnamese, Part B of the Report on the Effects of Herbicides in South Vietnam. This lengthy report may be found in the office files of the NAS/NRC Committee on the Effects of Herbicides in Vietnam.

25 areas, seven were eliminated from consideration (see the unnumbered symbols on Figure 1), since it was determined that other war-related activities (bombing, ground action, fear for security) had depopulated each of these areas before herbicide spraying began. The 18 study sites given detailed air-photo interpretation are shown both in Table I and Figure 1.

It must be emphasized that these are areas selected for intensive case study because they were reported to be sprayed. Thus they are not a random sample of the entire countryside of SVN. They are representative of intensively sprayed areas, and care must be exercised in extrapolating from the conditions herein described to the whole of the country. Since these 18 areas are not the only settlements exposed to spraying (there are many other possible areas that could have been selected), they are representative of those portions of the country that were so exposed. The list as finally compiled (Table I) was designed to include several examples of each of the six settlement types; the total of 18 was determined by the limitations of resources and time.

The study areas are all rectangular in shape to simplify their identification by means of the map coordinates of their four corners. The coordinates were used in making requests for (1) all of the existing large-scale maps (Series L7014, 1:50,000; L8020, 1:25,000; and L8023, 1:25,000); and (2) all existing aerial photography that covered each study area. Computer printouts were made available for each study area listing all available unclassified aerial photographs. From these lists, an overlay was made at 1:50,000 scale for each study area, indicating the precise reported location of each run (sequence) of air photos (by date

Table I.

The 18 study sites given detailed interpretation of aerial photographs.

Mangrove Communities (woodcutters, 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

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
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
9. Tri-Tam Area, Tay-Ninh and Binh-Duong Provinces
10. Xuan-Loc Area, Long-Khanh Province

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

ani scale). From the plotted overlays, orders were placed for the aerial photos needed (selected for largest scale, for maximum extent of areal coverage, and to provide a time sequence of different seasons over as many years as possible).

For each province of SVN, a computer printout (from HERBS tape) was made available covering reported spraying missions from August 1965 to June 1971. (Other spray runs, 1962-65, prior to U.S. military control and record-keeping were not included.) From these lists, an overlay was made at 1:50,000 scale for each study area, indicating the precise recorded location of the centerlines of the runs of each spraying mission (by date, agent, and number of gallons). After the requested air photos had been received, their locations and dates were again checked for accuracy. Then the detailed interpretation could begin, comparing what could be seen on the air photographs (of known date) with the areas reported to have received herbicide spraying (at specific dates). Pocket and binocular stereoscopes were used to interpret photographs, most of which had sufficient (50% or more) overlap to produce a stereoscopic (3-dimensional) view.

Aerial photographs have been taken in large numbers for many years over the area of SVN. Interpretation of these photographs provided (1) estimates of population size (through counts of inhabited dwellings), (2) the kind and extent of agricultural and other economic activities (by examining fields in or out of cultivation), and (3) verification of the presence or absence of the effects of herbicide spraying (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 was possible to describe the changes in

population size, in settlement forms, in agricultural activities, and in the effects of other war-related activities (bombing--from craters present; spraying--from damage to or destruction of 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. Each of the 18 study areas was unique in its settlement pattern before spraying, in its spray history, in its air-photo coverage, and in the apparent consequences of spraying upon its settlements and agriculture.^a

^aA separate report of 18 chapters, containing the detailed analysis of the 18 study areas, is in the office files of the NAS/NRC Committee on the Effects of Herbicides in Vietnam, and is accessible to any interested person. Another copy is available on interlibrary loan from the University Library, California State University, Hayward, California 94542.

Each study area is described in a separate chapter, rendered comparable by each containing the following information:

Introduction

Fig. 1. Location map of the study area in SVN (a variant of Figure 1 in this report)

Description of the Area

Location and Size

Fig. 2. Base map for the study area, showing settlements in (year), prior to the reported herbicide spraying (for sample of a base map, see Figure 2 of this report)

Map Coverage and Coordinates

Table 1. List of maps (by series, scale, sheet number, name, edition, year of map information)

Air-Photo Coverage

Fig. 3. Map of aerial photo runs used (by date and print numbers) for each flight line as overprinted on base map--Figure 2; for sample of air-photo map, see Figure 3)

Table 2. List of air-photo coverage (by date, taking organization or project, sortie, scale, and print numbers)

Landforms and Drainage

Vegetation and Land Use

Settlements prior to Herbicide Spraying (by specified year)

Human Aspects of the Use of Herbicides

Record of Herbicide Spraying

Table 3. List of reported herbicide spraying runs (by date,

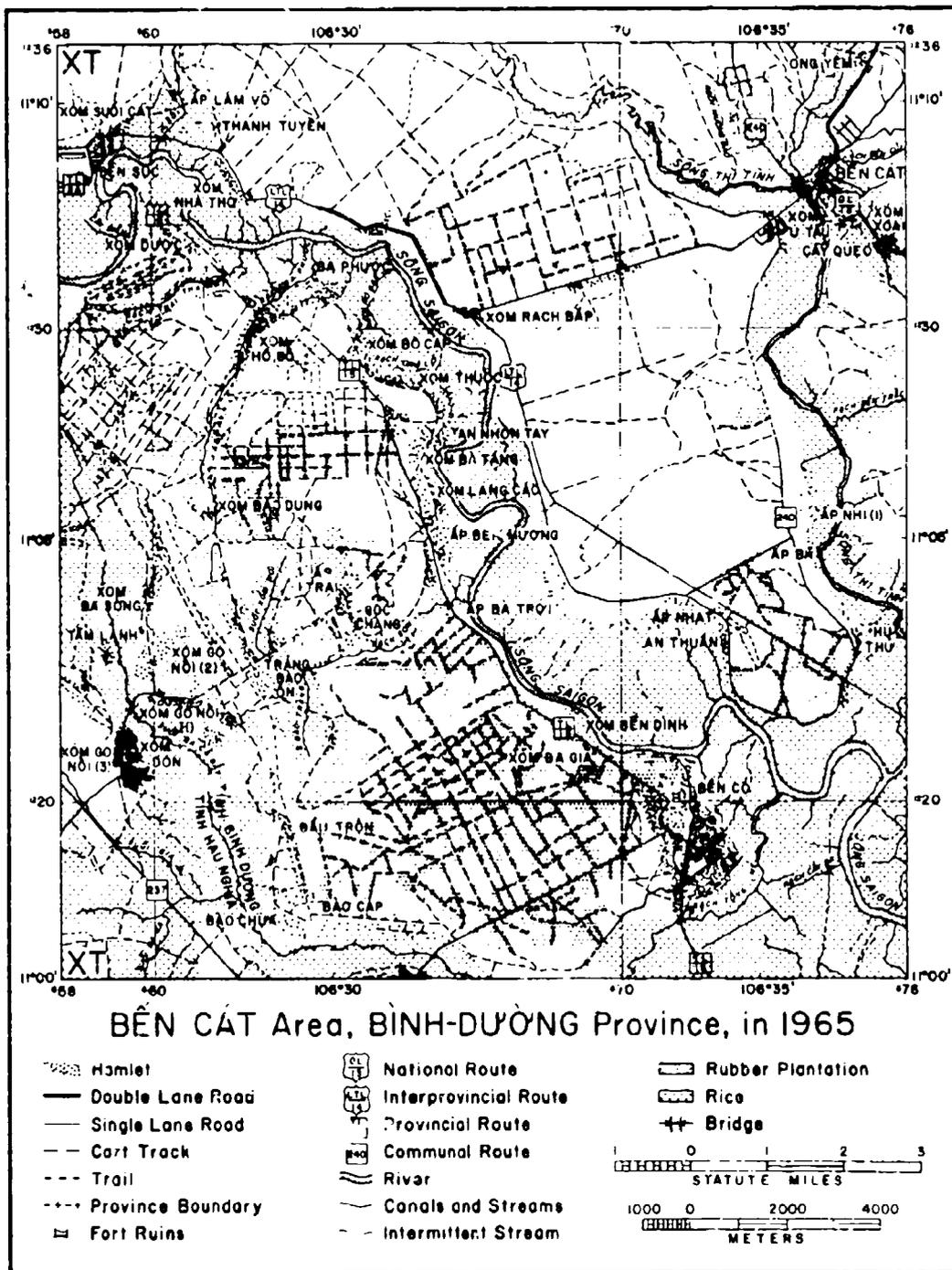
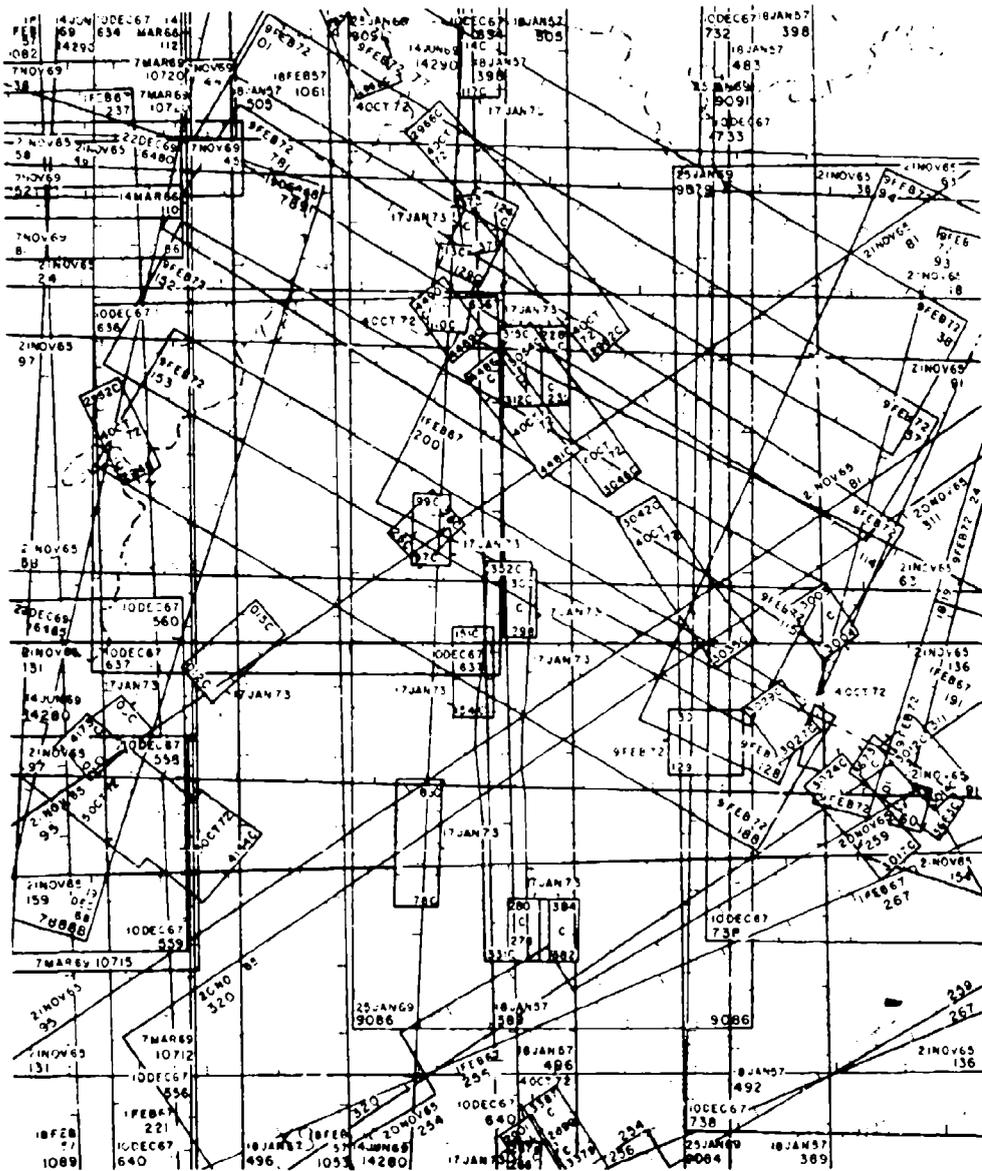


FIG. 2. Sample of a base map for a study area. Here shown are the settlements of Study Area 8, the Ben-Cat area, Binh-Duong Province, in 1965, prior to the reported herbicide spraying. The hamlets in the upper left (e.g., from An Nhon Tay to Thanh Tuyen) were evacuated, with some of their refugee population being resettled in the village of Binh-Hoa, north of Saigon.



The RUNG SAT Area, GIA DINH and BIEN HOA Provinces, Viet Nam

- Provincial Boundary
- Major River and Canal
- Town Boundary
- Major Road
- Market
- Village
- Fort Ruins
- Water
- Light
- Spot Height

FIG. 3. Sample of a map of aerial photo runs used in the detailed interpretation of a study area. Here shown for Study Area 4, the Rung-Sat Special Zone. Aerial photography runs are identified by date taken and by first and last print numbers placed within the lines outlining their location. Color transparencies are marked by the letter C.

This report can only summarize the results of a lengthy research program. Population estimates were made by counting the number of occupied houses and multiplying by seven, the average number of people per house.^a Occupied houses were determined from evidence of use: open trails leading to them, nearly arranged houseyards and associated vegetation, crops growing in immediately adjacent fields. Settlements partially or wholly destroyed were marked by abandoned houses: spontaneous vegetation growing over paths and cart tracks, houses damaged or in disrepair or gone (only foundation platforms marking the sites of the former houses), overgrown

gallons sprayed, acres covered, purpose, agent, and coordinates of ends of flight lines, for each spray run)

Fig. 4. Map of reported herbicide spraying runs (by date, number of gallons, and agent for each flight-line of each spraying run, as overprinted on the face of the base map, Figure 2). On each such map the strips are centerlines of recorded spray paths, not spray swaths with widths drawn to scale appropriate to the number of aircraft flying. (For sample of a plot map of spray run, see Figure 4 of this report)

Interpretation and Evidence of Population Displacement, Settlement Changes, and Economic Impact

Fig. 5. Settlements in (year), following completion of herbicide spraying, showing changes since (year) in settlements that have disappeared, those that have declined, and those that have grown. (For sample of a settlement change map, see Figure 5 of this report)

Assorted figures of maps and photographs, including comparisons of the same places before and after spraying, to illustrate changes in settlements, in location and extent of cultivated areas, and evidence of herbicide spraying damage and destruction.

Conclusions

^aThe 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 of 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.

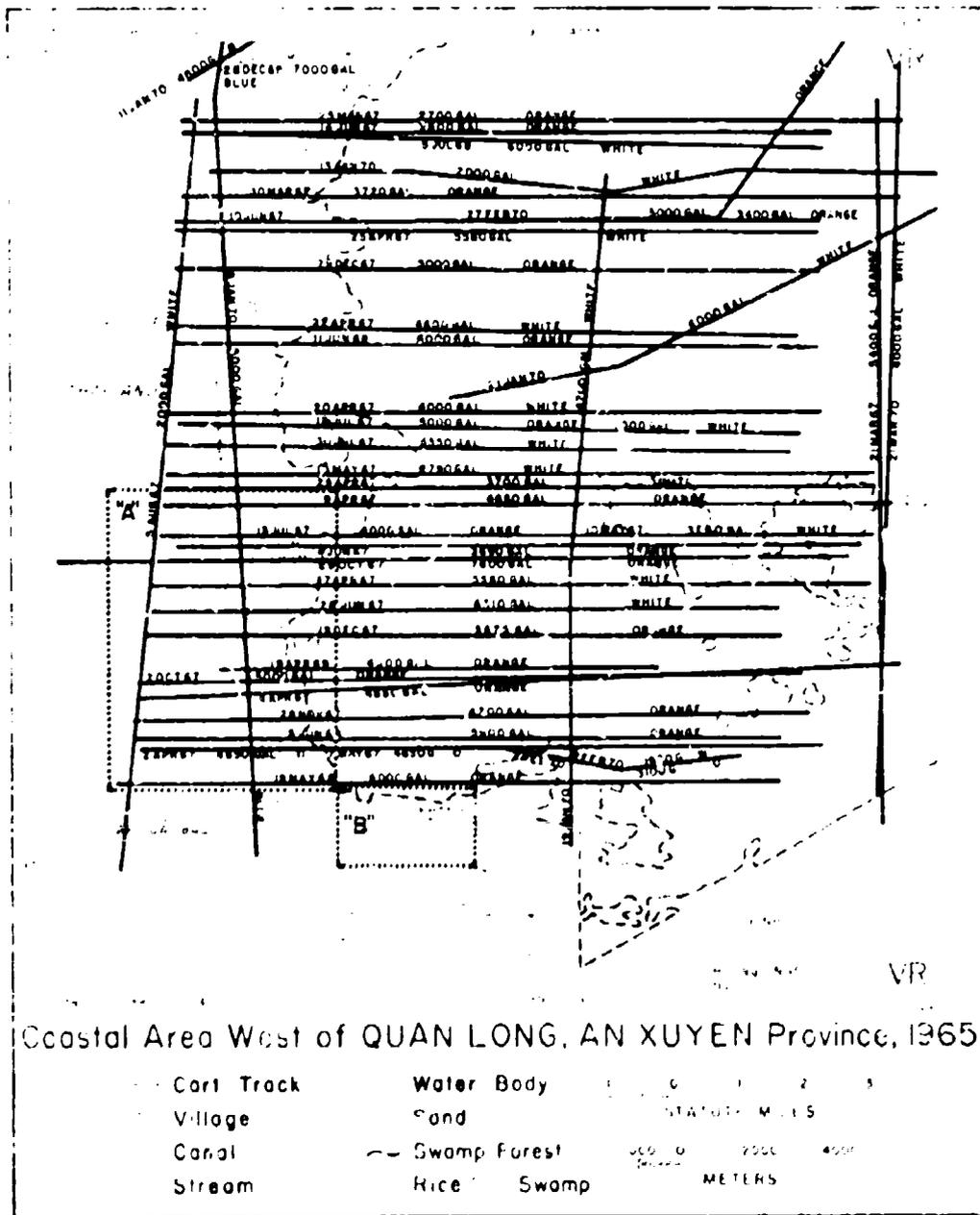


FIG. 1. Sample of a map of reported herbicide spraying runs. Here shown for Study Area 5, the coastal area west of Quan-Long, An-Xuyen Province. Strips are centerlines of reported spray paths (identified by date flown, number of gallons, and agent sprayed) and are not spray swaths with widths drawn to scale appropriate to the number of aircraft flying.

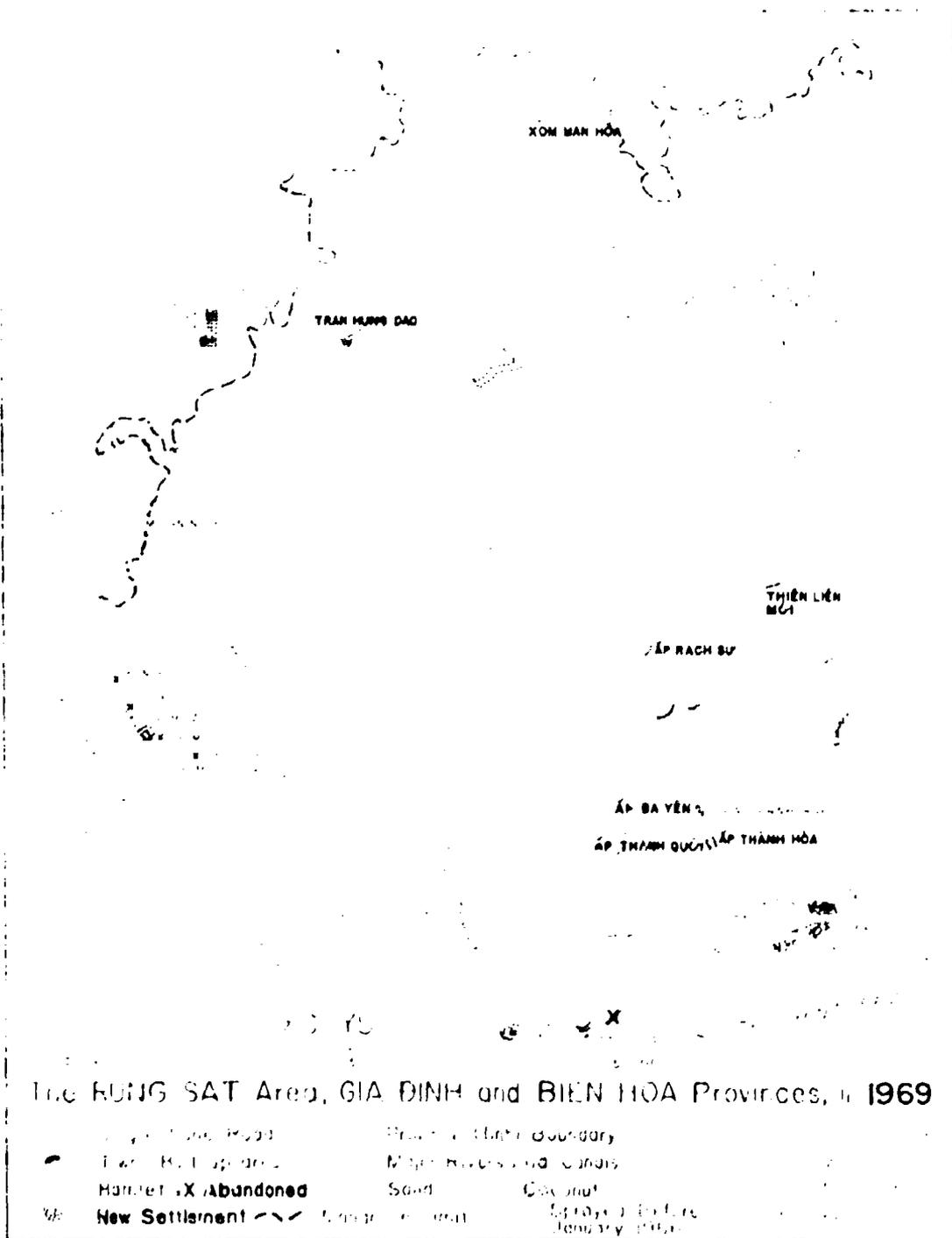


FIG. 5. Sample of a map of settlement changes after herbicide spraying. Here shown for Study Area 4, the Rung-Sat Special Zone, in 1969. New and expanded settlements since 1965 are indicated by the black overprint.

houseyards and/or dead vegetation (especially fruit trees), no crops growing in immediately adjacent fields. Complete abandonment of settlements is rare but does occur, as noted. In the pages that follow, there are included, as illustrations (see Figure 6 et seq.), several reproductions of selected air photos to indicate conditions before and after herbicide spraying.

STUDY LIMITATIONS

A research project that must use the evidence obtained and the records compiled by countless other persons under conditions of war over a time span of 9 years and a distance of thousands of miles is subject to numerous limitations: time, materials, and human error.

Limitations in Time

Time is the most intractable of all limitations in a retrospective project in air-photo interpretation.^a One must work with the available photos that were taken of particular places at particular times in the past; for example, there is no way that additional photo reconnaissance missions can be flown in 1973 to provide more evidence on conditions of settlement and cultivation in 1965 or 1967.

^aA further time limitation existed for this project. Of the time available for its completion, fully one-half had elapsed before the majority of the necessary materials could be assembled and made ready for interpretation. For example, the process of photo acquisition involved securing computer printouts, plotting of locations of photo runs, the ordering of desired photos, and then their retrieval and printing from the archives of DOD. Thus, only 8 months were available for the interpretation, writing, and drafting process. The last photographs were received in May 1973.

A related limitation was lack of coordination between the time and coverage of existing photography and the time and place of herbicide spraying. Good photographs of pre-spray conditions might exist for areas not sprayed, whereas photographs of study areas might be poor (e.g., cloud covered) or too old (e.g., the only available photography might have been taken 2 or 3 years prior to the beginning of herbicide spraying), and thus constitute doubtful evidence of actual conditions at or just prior to the time of spraying. Conversely, the post-spray photography might not cover the sprayed areas or be too delayed (e.g., be taken 1 or more years after the reported termination of spraying). For each of the 25 study areas, a detailed chronology had first to be worked out, correlating the dates and areal coverages of the available air photos with the dates and flight lines of the recorded spray runs. Just as each study area had a unique spray history, so also was its air-photo sequence unique. In all study areas some places reported to have been sprayed could not be interpreted fully because sufficient air-photo coverage was unavailable.

Limitations in Materials

The most frustrating of all limitations was that imposed by the DOD security classification of materials. The only remote-sensing records made available for interpretation were "unclassified" vertical aerial photographs. Thus, because low-latitude oblique photography and other kinds of modern remote-sensing records were not available, e.g., color infra-red photography, thermal scanning, and microwave radiometry, our breadth of vision was severely limited. The records from these different sensors would have provided different kinds of information. Any conclusions

made from the findings of this research project must therefore be considered less complete than otherwise would have been possible.

The scale of the black-and-white photography made available created yet another severe limitation. Thirty percent (2146 individual photos) of the total of 7179 black-and-white photographs made available were at a scale of 1:30,000 or smaller (e.g., 1:50,000 or 1:60,000). Such photography was secured for mapping purposes, to record basic features (e.g., roads, urban areas, rivers, and shorelines) that then can be drawn more simply as dots, lines, and area patterns on topographic maps. Such photos are of little value for interpretation purposes, to make house counts or to determine distress to vegetation that then can be presented as evidence of economic stress and settlement changes. Only 32.5 percent of the black-and-white photographs (but all of the 846 color transparencies) made available were at a scale of 1:10,000 or larger (e.g., 1:6000 or 1:4000), and these applied to only seven of the 25 study areas. There is a direct correlation between the accuracy and completeness of an interpretation and the use of large-scale photography. At a scale of 1:50,000, for example, a hut 20 ft (6 m) long is represented by a dot 0.005 in. (0.125 mm) in diameter, which is extremely difficult to see in the open and nearly impossible if partially shaded by forest or fruit trees. However, at a scale of 1:5000, the same hut would be 0.05 in. (1.25 mm) in diameter and impossible to overlook, along with its evidence of occupation (footpaths, animal pens, latrine, garden, etc.). Despite the handicaps inherent in using small-scale, or mapping, photography, such photos were used for interpretation to the maximum extent possible when other photos were not available.

Limitations in Human Errors

The most worrisome of all limitations were those created by human errors. We have attempted to minimize these errors, but the following should be considered in interpreting the results of this research:

(1) errors in locations of coordinates of spraying runs reported in the computer printouts for each province (e.g., coordinates that locate runs at sea or in another province or are of an unreasonable length for the amount of herbicides sprayed); (2) errors in locations of photographs reported in the computer printouts for each study area; and (3) errors in the selection of photographs made available (e.g., some "available" photography turned out to be "missing" and thus was never received for analysis, some photography was for the wrong time period, and some photography sent had not been ordered).

SOCIOECONOMIC SETTLEMENTS

Mangrove Communities

The results of interpretations made of four study areas located along the shore of the great delta-plain of the Mekong River fronting on the South China Sea are summarized in this section. The locations and names of the study areas (1, 2, 3, and 4) are shown in Figure 1 and Table I.

In all four areas, destruction of the mangrove was extensive. The effect of defoliation was to kill the mangrove forest; the woody stems were removed thereafter by woodcutters. The number of reported spray runs are shown in Table II.

The economic base of the people inhabiting the mangrove forest

Table II.

The number of reported spraying runs in mangrove study areas (by year).^a

Study area	1965	1966	1967	1968	1969	1970	1971	Total
1	-	2	54	12	4	3	1	76
2	-	14	14	1	16	4	2	51
3	6	13	15	-	-	-	-	34
4	-	40	110	115	26	8	-	299

^aRuns = spray paths recorded on computer printouts from HERBS tape

communities prior to spraying was a combination of fishing, woodcutting, and the making of charcoal. Cultivation of rice was minimal and strictly for subsistence. Charcoal production and woodcutting supplied fuel to market towns and cities. The widespread destruction of the mangrove by herbicide spraying drastically reduced the renewable sources for firewood and charcoal production and could be partly responsible for the abandonment of some hamlets and villages and the considerable decline in population of many others.

Study Area 1. In 1965 this study area, located at the tip of the Co-Mau Peninsula, had a population estimated at 4300-4500 people. Only four of 23 hamlets escaped the effects of herbicide spraying that occurred between August 1966 and April 1970. The spraying left wide swaths of destruction through the evergreen forest, but long strips were left unaffected or still living. After spraying, some small areas formerly in mangrove were planted to rice. They were in turn destroyed by later spraying. The overall effect of the war--combining the effects of spraying, ground combat, and bombing--was to reduce the population by 70 to 75 percent. Not all settlements, however, were affected to the same degree. Five settlements were completely destroyed and abandoned; but most, in varying degrees, were only partially affected. There were two cases of hamlets being destroyed by bombing and/or ground action prior to being exposed to herbicide spraying. Post-spray analysis shows the region to be in poor economic condition. Most settlements were near-abandoned by 1969. The fact that much of the mangrove forest cover has been killed will greatly hamper recovery. Yet, by October 1972 (Figure 6), considerable human effort was being expended in converting former mangrove

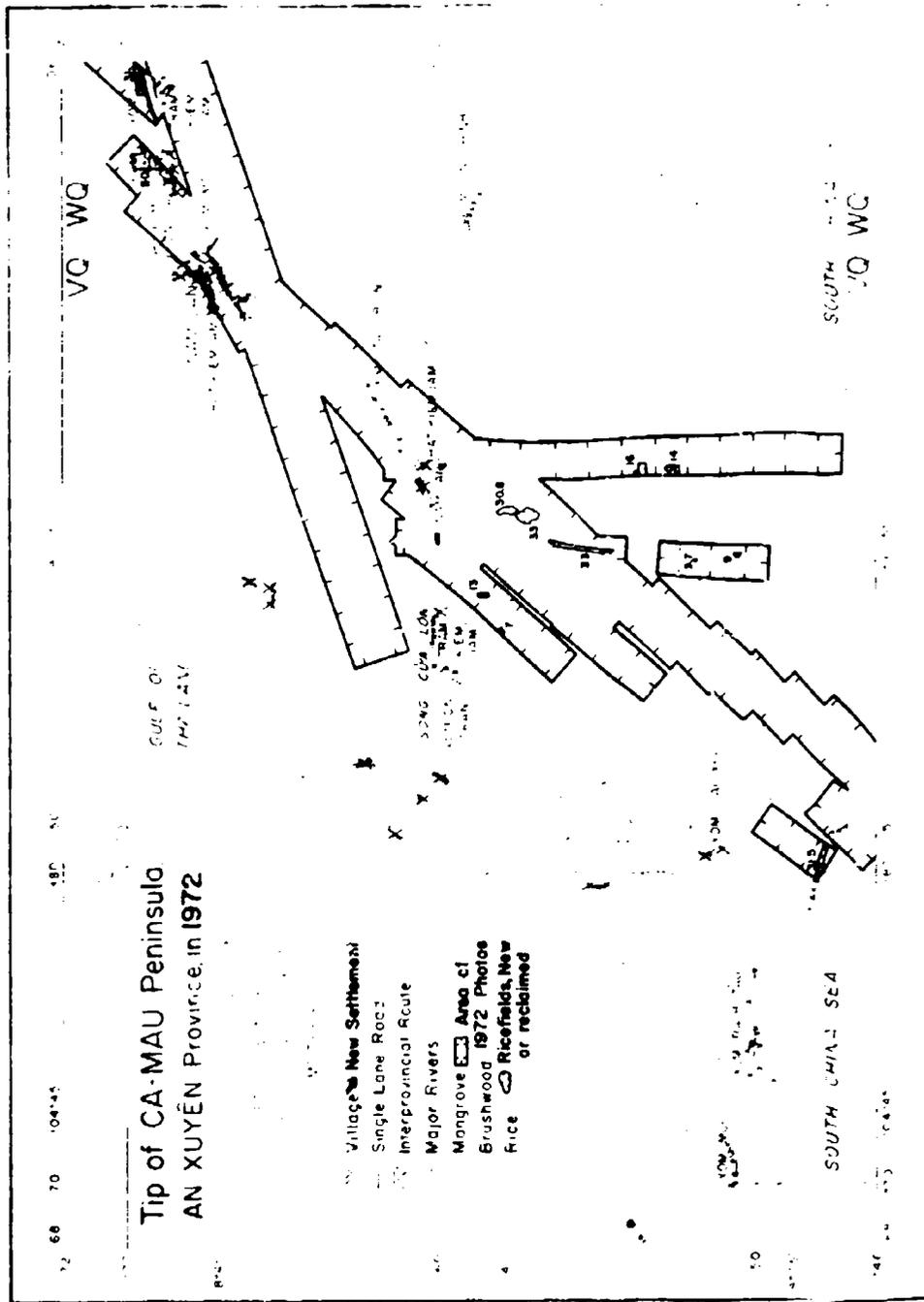


FIG. 6. Post-spray recovery in the Ca-Mau Peninsula, as revealed in February and October 1972 aerial photography. New or reclaimed rice fields cleared and planted since 1969 are outlined; the numbers alongside indicate their size, in hectares. The small x indicates the absence of one or more houses between 1965 and 1969; the large X marks the abandonment of an entire settlement.

forest land, which had been cleared by spraying several years previously, into rice fields. Dikes and drainage ditches and a green crop in the fields are clear evidence of such land use changes.

Study Area 2. Villages^a in or near the band of mangrove forests in this study area along the coast are of three classes: (1) those that had been destroyed before the reported herbicide spraying began in 1966 and remained abandoned throughout the spraying period, 1966-70; (2) those that had been destroyed before the reported herbicide spraying began in 1966 but were partially reoccupied by 1969; and (3) those villages that existed before, during, and after the spraying and other wartime destruction, and thus survived. The southern and eastern portion of the study area that was affected by spraying had a population of about 21,000 to 28,000 in 1965, and hence was much more densely settled than Study Area 1. About one-fifth of the people lived in villages wholly within the mangrove area (along, near to, and not more than 6-8 miles [9.6-13 km] from the shore); these had been destroyed and their small adjacent rice fields were abandoned before the reported aerial spraying began in 1966. Generally, the villages inland on sand ridges free of mangrove were not destroyed, but their total population was reduced by from 2800 to 4200 concurrently with the destruction of the adjacent mangrove forest during the reported spraying period, 1966-70. There is evidence, however, from air photos of November 21, 1965,

^a"Village" is here used as a form of settlement intermediate in size and function between "hamlet" and "town," and not in the political meaning of a territorial area containing a number of hamlets, as the word "village" is used in the administrative hierarchy of the RVN.

that previous herbicide spraying of the mangrove occurred over much of the northeastern sector and elsewhere along either side of stream channels that lead out to the sea. The reported aerial spraying dates only from January 2, 1966.

Study Area 3. This study area is (or was) almost completely a mangrove forest, occupying a seaward fringe of the Mekong River delta very similar to that of Study Area 2. The population and settlements had been drastically affected by warfare prior to the reported beginning (December 7, 1965) of the herbicide spraying from the air. There is no air-photo evidence of spraying prior to December 7, 1965, but the photos of November 20, 1965 indicated 90 percent destruction of the hamlets and villages in the mangrove, presumably by bombing and ground action. Destruction was also heavy on the sand ridges landward of the mangrove where villages were about 80 percent destroyed and 85 percent of the rice fields were lying fallow by November 20, 1965. On the basis of counts of house foundations visible in the air photos, the total population of Study Area 3 had been approximately 7000, with about 4200 of these people having lived in 13 mangrove communities.

The air photos of December 10, 1967 show, as a result of spraying in May-June 1966 and June-November 1967, widespread destruction of the mangrove vegetation. About 80 percent of the mangrove in the northern half of the area had been killed by spraying. In the south the most intensive spraying occurred in 1967, with the result that by December 10, 1967, the mangrove was 90 percent destroyed. Between 1965 and 1967, the only mangroves left unsprayed were in such areas as isolated peninsulas (sand spits along the coast) or in pockets of the far interior. Only in these

locations did villages appear to recover from the ground destruction that had occurred prior to November 1965.

There is no evidence of further spraying after its reported termination in November 1967, judging from the air photos of March and June 1969. The 1969 photos indicate, however, that quite different settlement patterns had occurred in the study area. Along the northern coastal zone recovery of three villages and rice plantings is evident, but along the coast south of the Con-Tret Peninsula, in the southern sector, there was even more widespread destruction since all 10 hamlets and villages had been obliterated and their rice fields abandoned. This presumably resulted from ground action and some bombing.

Study Area 4. This study area, which comprises the Rung-Sat Special Zone, was one of the most intensively sprayed areas in SVN. Initial spraying prior to January 1966 was along the banks of major tidal and river channels in order to defoliate immediate bankside vegetation (Figure 7). Since this was apparently not sufficient to deny sanctuary to hostile forces, large portions of the zone were then sprayed at repeated intervals in an attempt to defoliate almost all of the area. Agent Orange was most frequently used (188 spray runs), followed by Agent White (94 spray runs) and Agent Blue (17 spray runs).

With the killing of the mangrove and the removal of the woody stems, the renewable economic base for woodcutting and charcoal-making was eliminated. Fishing still remained as a key activity, however, supplemented by small patches of rice for local subsistence. Only one Rung-Sat settlement existing in 1965, with a population of about 1400, actually disappeared during the spraying period of 1966 to 1969 (see the large X on Figure 5).



FIG. 7. The Rung-Sat Special Zone, Gia-Dinh and Bien-Hoa Provinces, in 1965 prior to the reported herbicide spraying. Note, however, that aerial photo evidence indicates that both banks of the main shipping channel to Saigon had already been sprayed and defoliated prior to January 1966.

Its obliteration appears to have been caused by bombing and ground action; herbicide spraying approached no closer than 0.75 miles (1.2 km) away. Only three hamlets present in 1965 declined in population--from a total of about 310 persons to approximately 155 (see the small x's in Figure 5). Most of the pre-spray settlements actually increased in population during the spray period. Although the effects of spraying the mangrove were devastating, the spraying apparently did not reduce population totals or upset rice cultivation, water transport, communication, and the local economy. Xom-An-Thit and its vicinity (see Figure 5), for example, grew from about 600 people in 1965 to 3500 in 1969; Quang-Xuyen Village expanded from about 1400 to 1700. Whereas the former is linear along stream embankments, the latter is compactly rectangular with grid-pattern streets. The growth of both settlements is the result of people relocating in the Rung-Sat from other areas, sometimes under government auspices and subsidy. Tran-Hung-Dao (or Tach-Ong-Nghia as it is referred to by local residents) is an example of a new Rung-Sat community (Figure 8) occupying land formerly covered by mangrove but cleared as a result of herbicide spraying. (This community served as the study site for the Committee's investigation of the epidemiological effects of herbicides resulting from ecological changes.^a)

The Rung-Sat Special Zone, unlike Study Areas 1, 2, and 3, has steadily increased in population despite herbicide spraying of the area throughout the period 1966-70. This was mainly because the agricultural hamlets on the periphery, whose populations relied on rice and other crops, were not directly sprayed. Because the source of their raw material was

^aSee Desowitz, R.S., S.J. Berman, D.J. Gubler, C. Harinasuta, P. Guptavani, and C. Vasuvat. Epidemiological-ecological effects: studies on intact and deforested mangrove ecosystems, Part B of the Report on the Effects of Herbicides in South Vietnam.

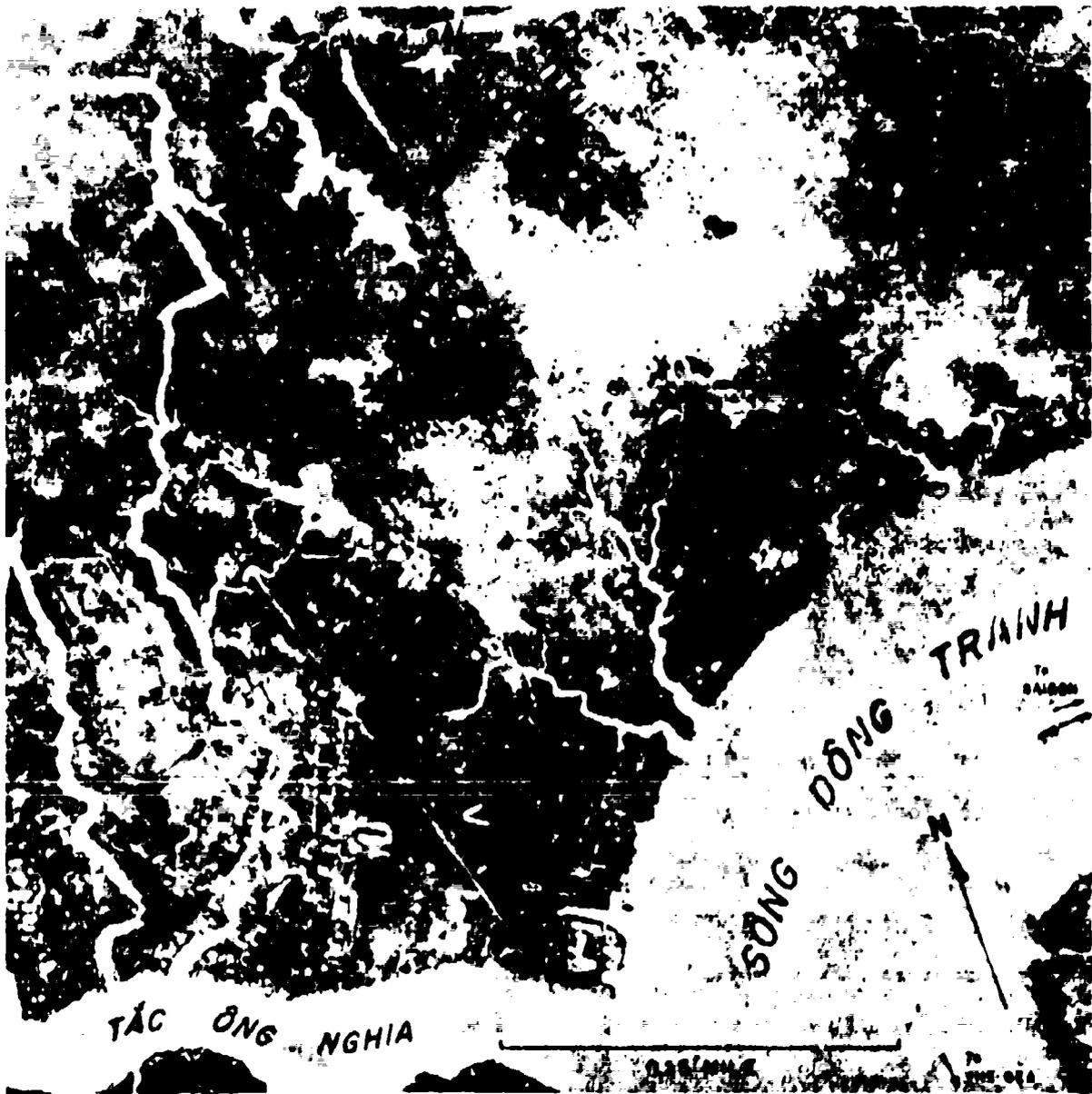


FIG. 8. Tran-Hung-Dao, a new settlement, is situated along the north bank of Tac-Ong-Nghia and adjacent to the main shipping channel through the Rung-Sat to Saigon. Here shown on February 9, 1972 in air-photo sortie 040-4016, print number 88 Right, center of photo YS011706.

destroyed, hamlets dependent on woodcutting were forced to alter their subsistence base as a result of herbicide spraying. Most settlements of this type in all of the study areas (1, 2, 3, and 4) turned more completely to fishing. There is evidence from February and October 1972 and January 1973 large-scale photography of the northern half of the Rung-Sat that vigorous resettlement activity is taking place (Figure 9). All former forts have been reoccupied at or near former positions, and people living in the resettlement villages are both restoring and then extending the areas planted to rice. These people occupied previously uncultivated or sparsely cultivated areas, using them first for woodcutting and then for fishing and farming. Since the resettlement of the Rung-Sat contrasts markedly with the lack of resettlement in the other mangrove areas studied, the question remains whether the resettlement has less to do with the inherent quality of the Rung-Sat and more to do with its location (near Saigon) and its availability and military security to the RVN as an otherwise unoccupied place to put refugees. The questions of whether the Rung-Sat can support its present population (1973) without government subsidy and whether most of its inhabitants will remain there, given free choice of location under peacetime conditions, are problems for future research.

Delta Canal-Bank Settlements

This section summarizes the results of interpretation of three study areas that are located in, or on the margin of, the delta of the Mekong River: 5, 6, and 7. These areas are much more densely settled than the mangrove areas previously discussed, with communities

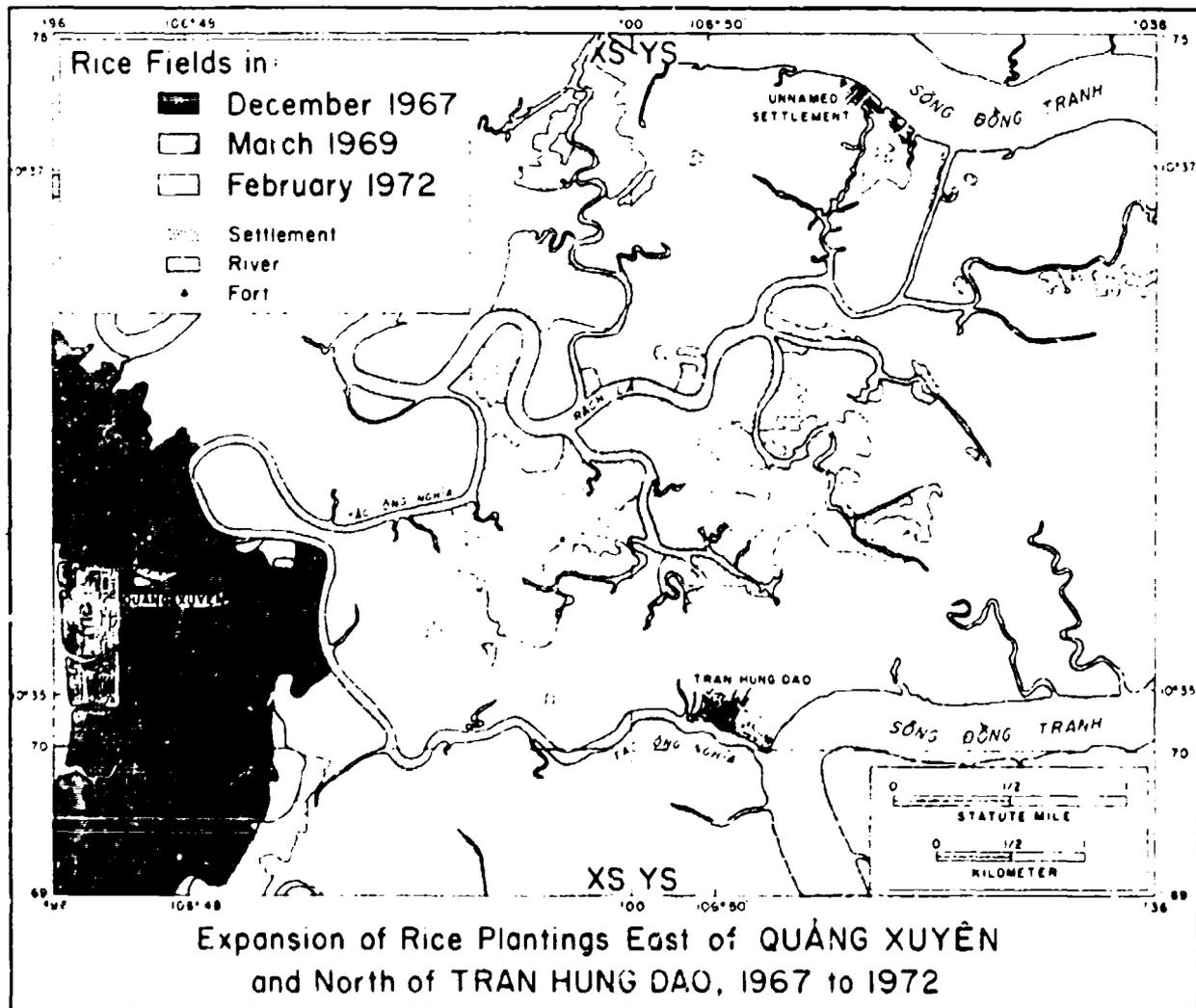


FIG. 9. Expansion of rice fields east of Quang-Xuyen and north of Tran-Hung-Dao between 1967 and 1972. The Vietnamese have taken advantage of the clearing of the mangrove cover by herbicide spraying to move onto the land and, following removal of the woody trunks and roots, put the land into cultivation. The area planted to rice has doubled in extent since 1969.

ranging from sizable towns (not sprayed) to compact settlements; and from linear settlements lining both banks of rivers, streams, canals, and roads, to scattered hamlets. Because the density of settlement does not permit people to live distant from others (except in the interior of swamps), individual scattered homes are rare.

In the Mekong River delta the economic base of all settlements is the year-round production of rice, primarily as a commercial crop for sale to the cities and other parts of the country or for export overseas. Differences in land use among the three study areas are in the importance and distribution of other economic activities and agricultural crops. For example, fishing is important along the coast of Study Area 5, one of the country's most important regions for the production of coconuts and coconut products is in Study Area 6, and plantings of sugarcane are extensive in Study Area 7.

Herbicide spraying in these three study areas was never as widespread nor as intensive as in the mangrove areas studied. There was never an attempt to destroy all of the vegetation cover. The effects upon settlements in the three areas and their associated cultivated crops were nevertheless dramatic, often as a by-product of spraying the vegetation in a nearby swamp or along a canal or river bank. The aerial photographs show that crops can be destroyed or damaged whatever the herbicide used and whatever the intent of the spraying mission. Thus, a defoliation mission, waterway/landing zone mission, or spraying of an enemy cache site can all do as much damage or destruction--resulting in economic stress and settlement changes--as can a spraying mission with the specific objective of crop destruction.

Study Area 5. This study area is the southwestern corner of the U-Minh forest, an extensive freshwater swamp covered by nearly pure stands of Melaleuca and separated from the Gulf of Thailand to the west by a low sandy ridge 2 to 3 miles (3.2 to 4.8 km) wide (see Figure 4). Small hamlets line the banks of the man-made canals, which link all parts of the area west and south of the swamp forest that has been converted almost entirely into rice fields. Herbicide spray runs to defoliate the forest in the inland swamp were flown eastward from the seacoast, as shown in Figure 4, thereby exposing the people, settlements, and crops as the flights crossed the coastal strip between the Gulf of Thailand and the Melaleuca swamp. Three rice-cultivation villages and two fishing hamlets were reportedly exposed to spraying between April and December 1967. The principal effects on the settlements were to defoliate the fruit trees shading the house yards and to kill the rice growing in the surrounding paddies. By 1969, a significant time lapse since the 1967 spraying, the population had declined by two-thirds--from about 3500 to 1100 people. The more densely settled area south of the tree-covered swamp, where the canals closely parallel one another, was not directly sprayed, but it probably was subjected to drift. The population decline there, based upon a count of occupied houses, is estimated at 30 percent. The decline, however, appears to be the result of the combined effects of spraying, bombing, and ground action.

Study Area 6. Centered in the Mekong River delta about 43 miles (69 km) southwest of Saigon and directly south across the river from the town of My-Tho, this study area comprises the western half of Kien-Hoa Province. Several major distributaries of the Mekong pass through the

area on their way to the South China Sea, and these are intricately connected by many canals and streams. Outside of the several towns, the land is used for agriculture; rice and coconuts predominate, but they are augmented by intensive market-gardening and fruit orchards. This area is heavily commercialized and supports a diverse rural population in its many hamlets. Herbicide spraying for defoliation of the coconut trees is reported to have occurred in only four zones (see sub-areas "A" to "D" in Figure 10), not over the entire area. There is also photo evidence of a swath of dead coconut trees along one highway (sub-area "E"), although no reported spraying at this locality was included on the computer printout for Kien-Hoa Province. In sub-area "A," containing three hamlets along or near the principal north-south highway, the number of houses decreased considerably: from 310 in 1967 to 135 in 1968. Sub-area "B," sprayed in March 1968, showed a subsequent decrease in the number of buildings in four hamlets: from 87 in December 1967 to 26 by December 1968.

A very detailed study was possible of a third zone (sub-area "C") for which large-scale photography was available (Figure 11). This zone, planted predominantly to coconut palms, is about 2 miles (3.2 km) wide north-south and 6 miles (9.6 km) long east-west, and is across the river from and west of the town of My-Tho. In March 1968 there were 558 houses occupied by about 3900 people. Herbicide spraying occurred on April 1 and 10. By November a 45 percent reduction had occurred in the number of occupied houses. Not all of this decrease, however, can be attributed to the effects of herbicides. During the same time period, 84 new bomb craters (25 ft [7.5 m] or larger in diameter) appeared as a result of aerial bombardment. The

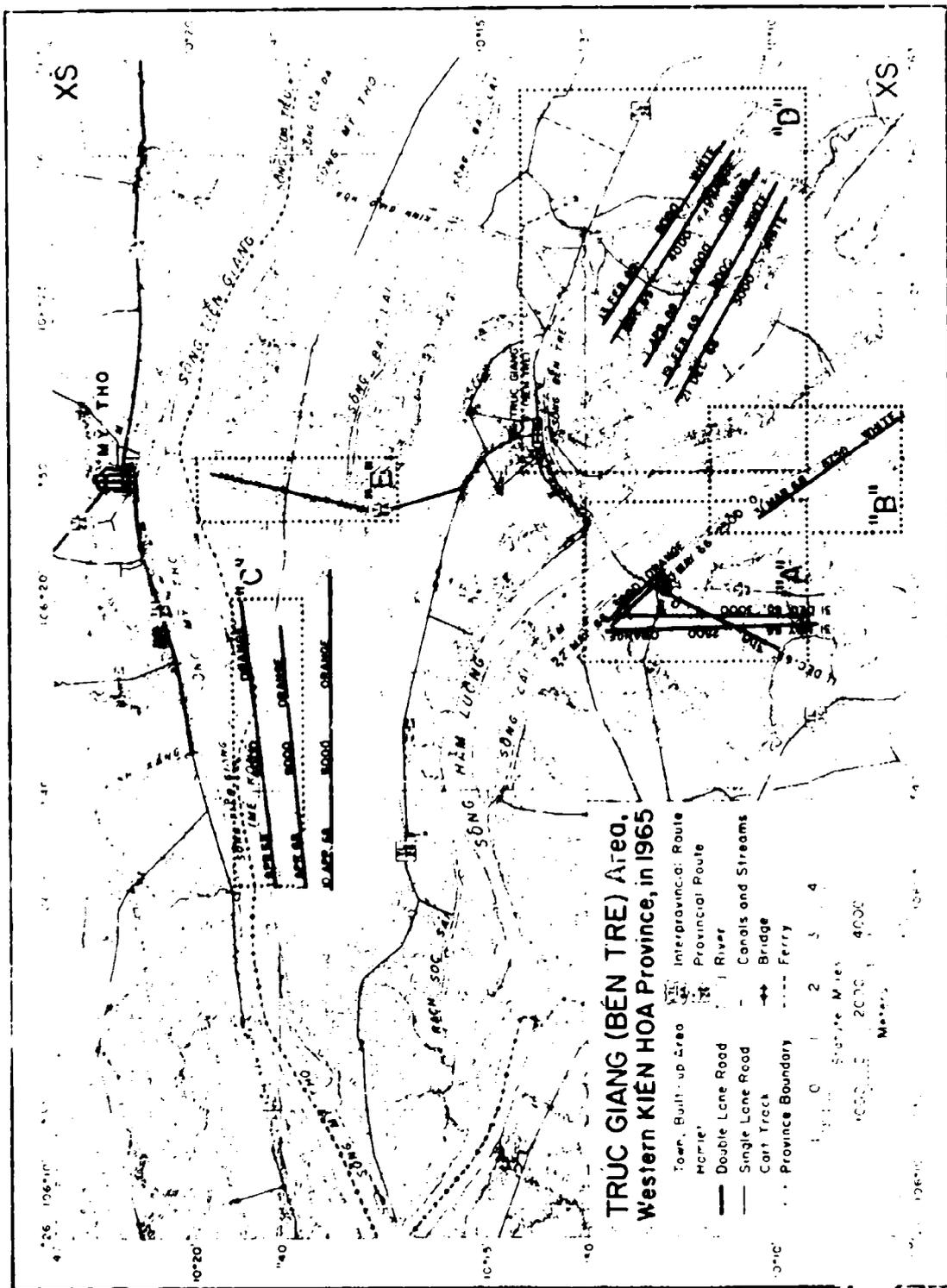


FIG. 10. Herbicide spraying runs reported for the Truc-Giang (Ben-Tre) area, 1965-69. Also shown are the location of the sub-areas "A" through "E," given detailed study.

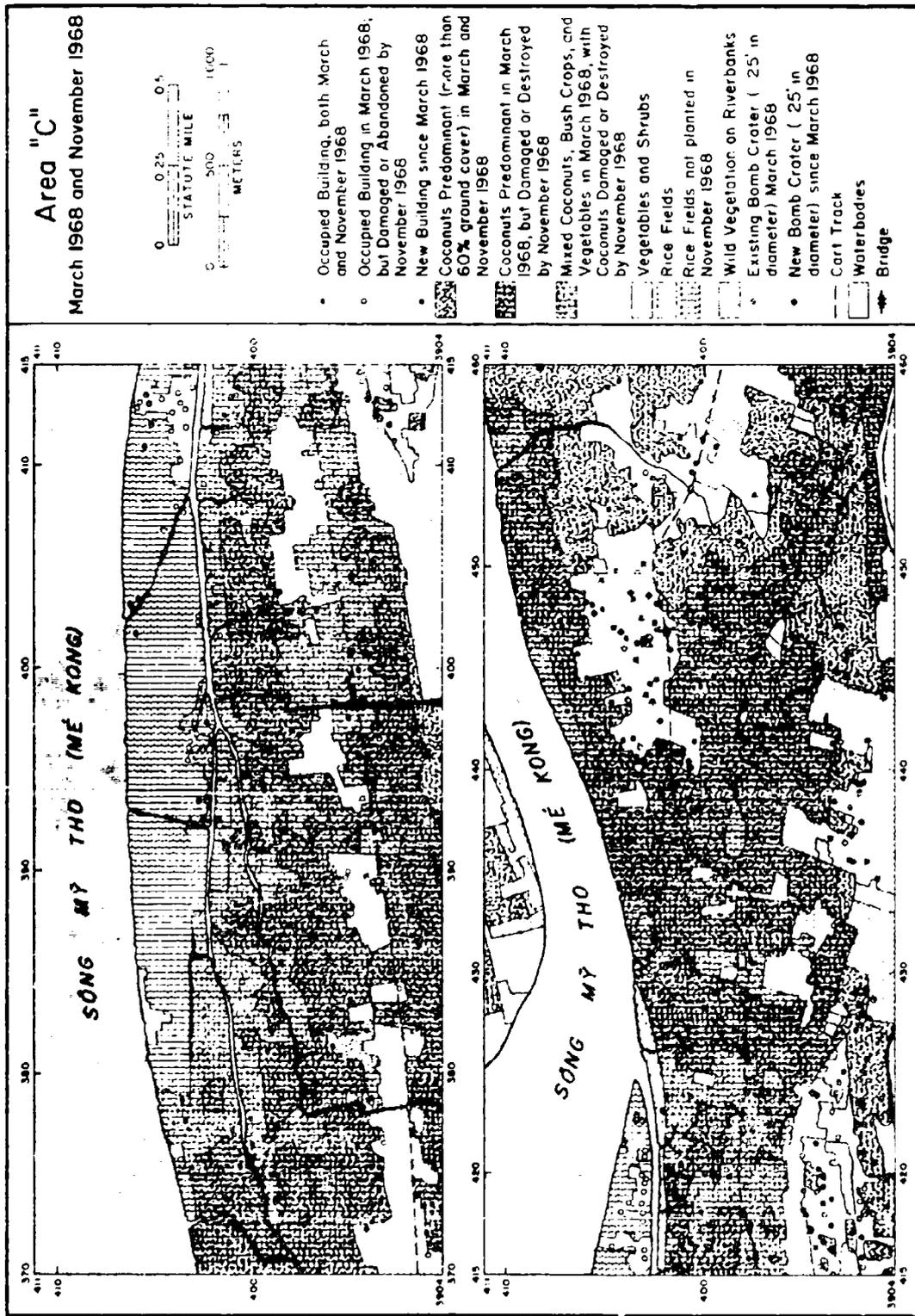


FIG. 11. The effects of spraying in sub-area "C" of the Truc-Giang (Ben-Tre) area between March and November 1968.

spray runs on the coconut planting brought about an overall decrease of 77 percent in the acreage covered by coconut palms between March and November 1968. Great stretches of palms were completely killed and barren.

This study area was one of the principal coconut-producing regions of the province, and the spraying greatly diminished the commercial supply of coconut products (nuts, oil, and copra) shipped to Saigon (Figure 12).

Study Area 7. This study area is located immediately east and southeast of the "Parrot's Beak" along the Cambodian border some 4.5 miles (7.25 km) northeast of Tan-An, and is centered about 25 miles (40 km) due west of Saigon. The area comprises an extensive swamp lying between two meandering streams, Vam-Co-Dong on the north and east and Vam-Co-Tay on the southeast. The two streams are connected by an intricate net of man-made canals that criss-cross the swamp. Settlements and associated cultivated areas are located in the slightly higher ground (natural levees and their backswamps) adjacent to the two stream courses. Rice cultivation is the predominant economic activity, and rice fields occupy most of the areas in human use. However, in the north and east, for 2-3 miles (3.2-4.8 km) along both sides of Vam-Co-Dong, extensive fields of sugarcane are being grown on a plantation-like scale. Herbicide spraying was concentrated along the waterways, to defoliate areas around the major canals and the two large streams. Herbicide spraying began early (in 1965) and was conducted intensively (nearly every month between June 1968 and July 1969). The southwestern settled areas along Vam-Co-Tay were sprayed after intensive bombing; the result was a 50 percent decrease



FIG. 12. Sub-area "D," the sprayed area southeast of Truc-Giang on June 14, 1969. The light-colored streaks resulted from the drying, fading, and yellowing of the fronds of the coconuts and other fruit trees. Compare with Figure 10 and note that the spray runs extended well beyond those limits officially reported. The small x indicates the area visited by Dr. Alexander H. Leighton and Dr. Jane M. Murphy on March 30, 1972, just inside the northernmost line of herbicide spraying (air-photo sortie 145, print number 14256, center of photo XS555275).

in population, varying from small decreases in some villages to complete abandonment and destruction of some hamlets. Bombing and spraying rendered the plantation zone in the north and east completely untenable for habitation, and all of the plantation settlements were abandoned. Towns and dispersed farmsteads in the extreme northeast and southeast were not sprayed. By 1969, near the end of the period of herbicide spraying, the areas that had been sprayed had long since been depopulated and their fields abandoned. Nearness to the Cambodian border, the huge swampy area, and the prevalent water routes for enemy movement toward Saigon and the delta had determined the region's strategic importance, overriding any consideration of its continued occupation by rice farmers or by those producing sugarcane on a vast scale for commercial purposes. However, the most densely populated areas (towns and dispersed farmsteads in the extreme northeast and southeast) were not sprayed.

Plantation Settlements

This section summarizes the results of interpretation of Study Areas 8, 9, and 10 (see Figure 1 for locations and Table I for names). In all cases, the dominant plantation crop is rubber; the pure stands of rubber trees are orderly (usually rectangular) groves of man-made forest that have replaced the natural tropical forest in the zones of low terraces just north of the Mekong River delta.

The center of Study Area 8, the Ben-Cat area, is located 22 miles (35.2 km) northwest of Saigon. It is bisected (northwest to southeast) by the Saigon River. Rice cultivation is the predominant activity on the floodplains of the several rivers, and several rubber plantations

interspersed with forests and scrub occupy the better drained interfluves (see Figure 2). About 5500 persons inhabited the many densely-settled villages that lined the slopes between the terraces and inner edges of the floodplain. Defoliation missions sprayed forests, clearings, riceland, and settlements alike. The rubber plantations alone stand out on the plot of the spray runs as unsprayed areas, but even they did not totally escape: each of the four main rubber groves was directly hit by two to five spray runs and probably caught the drift from numerous spray runs at its perimeter. For example, between December 15, 1969 and February 7, 1970 there were 30 different days when an identical spray run was flown around four sides of the largest rubber plantation. Military activity in this area has been heavy; carpet bombing from the air in 1965 preceded the herbicide spraying that began in August 1966. Further heavy bombing recurred in 1967 along with much more spraying. Operation Cedar Falls was conducted in this area January 8-31, 1967; B-52 bombing was heavy, U.S. forces made the first use of the Rome plow to clear forests, and a large number of people were forcibly evacuated from their homes, some to the Binh-Hoa resettlement village near Saigon.^a The intensity of warfare had driven almost all of the resident population from the area by late 1967. Photo evidence reveals wholesale decimation of villages, forest cover, and abandonment of rice fields. Even some of the rubber groves along the roads were subjected to clearing by bulldozers. Owing to frequent spraying each year from 1966 to 1970, the rice fields could not have been very productive.

^aSee Murphy, J.M., G.D. Murfin, N.L. Jamieson, III, A.T. Rambo, J.A. Glenn, and A.H. Leighton. Beliefs, attitudes, and behavior of lowland Vietnamese, Part B of the Report on the Effects of Herbicides in South Vietnam, for interviews with Binh-Hoa refugees. This lengthy report may be found in the office files of the NAS/NRC Committee on the Effects of Herbicides in Vietnam.

Study Area 9 is centered on the town of Tri-Tam, 33 miles (53 km) northwest of Saigon and 14 miles (22.4 km) east of the city of Tay-Ninh. Immediately northeast of Tri-Tam is the Michelin rubber plantation, the largest in SVN, occupying approximately 36 square miles (94 km²). Five other small rubber groves are located south and west of the town.

The heaviest herbicide spraying occurred over the forested area-- including three small hillocks--lying immediately west of the rubber plantation and north of Tri-Tam. There is no photo evidence that this area was ever populated; no house sites or cultivated clearings can be seen. However, the spraying was accompanied by extensive carpet bombing of the forest zone. The Michelin plantation appears to be free of any damage from herbicide spraying or bombing. The computer printout of the herbicide spraying missions for Binh-Duong Province does indicate at least three spray runs over the plantation in 1966, but there is no evidence of this on any aerial photo. Either the spray had minimal effect on the rubber trees or the coordinates of the reported spray mission are erroneous. On the other hand, the southern one-fourth of this study area was subjected to damage very similar to that in Study Area 8, which is contiguous on the southeast toward Saigon. A 60 percent reduction in population occurred between January 1966 and December 1968, together with roadside clearing and extensive aerial bombing. Heavy spraying occurred in 1966 and 1967, principally over the rice fields, and probably was a contributing factor in the emigration of the population.

Study Area 10 comprises the southern two-thirds of Long-Khanh Province and encompasses the principal zone of rubber plantations in SVN centered on the town of Xuan-Loc, the provincial capital (Figure 13).

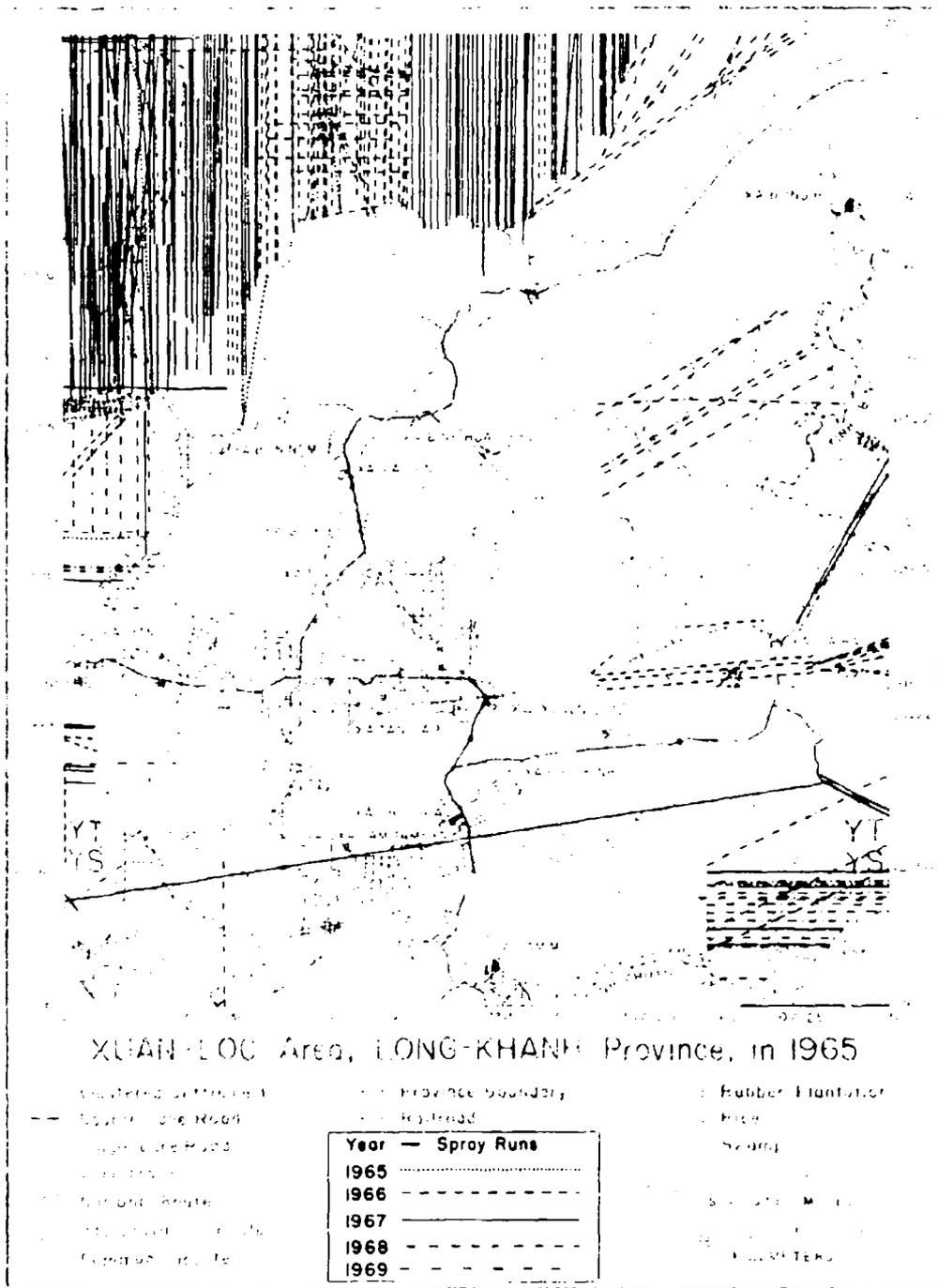


FIG. 13. Herbicide spraying runs reported for the Xuan-Loc area, Long-Khanh Province, 1965-69. The great size of the area (1147 square miles) and the large number of spray runs (313) prevents identification of each run by date, agent, and number of gallons, as provided on maps of all other study areas.

The area was delineated by Dr. Alexander Leighton, the Committee member whose survey team conducted interviews with Vietnamese who were living, or had recently lived, in the area during the period of herbicide spraying. The addition of this area for photo interpretation study was requested by the Committee Chairman on December 24, 1972, to augment and coordinate with the findings reported by these interviewers.

This study area is the largest of the 25, measuring 31 miles (50 km) east-west by 37 miles (60 km) north-south for a total of 1147 square miles (2982 km²). It is bisected east-west by the railroad and National Route 1 (the coastal road) and northeast-southwest by National Route 20 (to the Dalat highland) and the hydroelectric power line to Saigon. The southeast corner of this study area is 21 miles (34 km) due east of Saigon, and its center is 42 miles (68 km) east-northeast of Saigon and 7 miles (11.3 km) due north of Xuan-Loc.

The reported spraying period extended from October 21, 1965 to March 28, 1970, and the 313 spray runs in the study area may be summarized as follows:

<u>Year</u>	<u>Defoliation</u>	<u>Mission and Agent^a</u>			<u>Total</u>
		<u>Crop Destruction</u>	<u>Perimeter of Military Installation</u>	<u>Enemy Route</u>	
1965	7(O)	8(O)	--	--	15
1966	55(O)+22(W)	--	--	--	77
1967	89(O)+57(W)+7(B)	--	--	--	153
1968	3(O)+41(W)+2(B)	--	1(W)+2(B)	--	49
1969	11(O)+7(W)	--	--	--	18
1970	--	--	--	1(O)	1
Total	301	8	3	1	313

^a(O) = Agent Orange, (W) = Agent White, (B) = Agent Blue

The concentration and orientation of the 313 spray runs is unusual. Some 215 (69%) were flown over the northernmost sector of the study area, almost all beginning at the Dong-Nai River and extending due north across the nearly solid forest cover. This entire forest zone was sprayed during 1966 and 1967, with repeated spraying in 1969 along the two major north-south roads, routes 322 and 323. There are only two reported spraying runs over the southwestern quadrant (i.e., over the most densely populated sector that also contains nearly all of the rubber plantations), but no photo evidence exists for the long east-west run across the southern sector of the study area. Four clusters of predominantly east-west spraying runs are located near the eastern margin of the study area: (1) in the far northeast corner, east of the Dong-Nai River and north of Route 20; (2) within the southern loop of La-Ngai River; (3) along and south of the railroad line and the settlement of Gia-Ray, focussing on Mt. Chua-Chan; and (4) in the extreme southeast corner, north of route 330.

Interpretation of the 1316 aerial photographs for this study area verifies the location of the sprayed areas as being those reported in the computer printout for Long-Khanh Province, and supplemented by the spray runs that began in the adjacent provinces of Bien-Hoa, Phuoc-Tuy, and Binh-Tuy. There is considerable evidence of settlement changes in this study area between 1965 and 1969. For example, an area of dispersed settlement containing about 2800 people was 90 percent evacuated, and several resettlement villages came into existence and then were abandoned. But there is no evidence (e.g., defoliation swaths) on any aerial photo

that indicates any settlement was passed over and sprayed directly.^a Route 333 extends north from Gia-Ray, a town straddling the railroad near the eastern border of the study area. In 1967 the west side of this road was sprayed, but the run ended 0.5 km (0.3 miles) north of the town and there was no apparent effect upon the settlement itself. On the other hand, there is abundant evidence for the defoliation of the forests wherever sprayed; clearings in these forests for shifting cultivation that were planted to rice and other subsistence crops thus were included in the defoliation spraying. These areas had their crops destroyed; also in one case a spraying run extended beyond its reported limits and some damage is apparent to young trees in one rubber plantation.

Lowland Valley Communities

This section summarizes the results of interpretation of Study Areas 11 through 14, all four of which are located close to the narrow discontinuous coastal plain that fringes the South China Sea (see Figure 1 for locations and Table I for names). All of these except Study Area 11 are valleys of small tributary rivers and streams that flow out of the hills and mountains to reach the sea some 6 to 20 miles (9.6 to 32 km) eastward. The intensity of human use in these valleys varied markedly, as did the use of herbicide sprays and their effects on settlements and economic productivity.

Study Area 11 is on the coast, and represents the zone of tremendous sand hills along the shoreline of Vietnam. The whole study area, up to 12

^aFor information about herbicide damage as perceived by Vietnamese interviewees in Long-Khanh Province, see Murphy et al. Beliefs, attitudes, and behavior of lowland Vietnamese, Part B of the Report on the Effects of Herbicides in South Vietnam. This lengthy report may be found in the office files of the NAS/NRC Committee on the Effects of Herbicides in Vietnam.

miles (19.2 km) inland, is composed of old dunes as high as 650 ft (200 m), stabilized by a cover of forest and bush, with a patch of active dune accumulation near the sea. Settlement in the area always was minimal owing to the scarcity of fresh water; three small villages existed only where ground water had become impounded to form small lakes, one near the center of the study area, and two others close together at the eastern edge, about 2 miles from the sea. The forest and scrub over the southern three-fourths of the study area were defoliated by 25 west-east spraying runs during 1967, which followed upon five rather scattered flights during 1966. By January 1968 (time of the first available post-spray photography), all settlements and their adjacent small rice fields and vegetable gardens had been abandoned. All of the houses had disappeared; only foundations and vacant spaces remained. About 840 persons were thus affected. In the photos of January 1970 the regeneration of the wild vegetation is evident (darker and more dense). Ground action was necessary to clear swaths of vegetation along both sides of routeways (cart tracks) through the forest; this operation explains the peculiar linear patterns of clearings on the 1970 topographic map (scale 1:50,000) of the area.

Study Area 12 is a 9-mile-long section of the An-Lao River valley, 11 miles (17.6 km) east of the coastline of the South China Sea. In 1965, several dozen densely-settled compact villages and hamlets lined the narrow valley bottom along either side of Provincial Road 514 (Figure 14, left). The valley floor was intensively cultivated, mostly in irrigated rice fields, with lesser space devoted to house gardens and fruit trees, and one very small plantation of coconuts. Some 71 spray runs, principally for crop destruction, were flown over the valley with Agent Orange as the



FIG. 14. Devastation and abandonment of the An-Lao River valley between October 28, 1965 (left) and June 24, 1968 (right). The productively cultivated valley floor was densely settled (at least 6400 people in 915 houses) in 1965. Ten spray runs are reported over this area between March 12, 1967 and June 1968; another nine were flown in late 1968 and 1969, all for the purpose of "crop destruction" (1965 air-photo sortie 3617, print number 128; 1969 air-photo sortie 46, print number S4824A; center of both photos BS743102).

Spray Runs Flown Over Valley

	<u>Total</u>	<u>Crop Destruction</u>
Agent Orange	45	26
Agent Blue	24	18
Agent White	2	2
	<hr/> 71	<hr/> 46

main defoliant. Spray runs were distributed over time as follows: 1 in 1965, 3 in 1966, 26 in 1967, 3 in 1968, 34 in 1969, and 4 in 1970. The large number of runs in 1967 had a devastating effect, since the air photos of June 24, 1968 reveal an abandoned valley (Figure 14, right). Water stands in the otherwise empty rice paddies, the houses are gone, and the gardens and fruit trees are almost completely defoliated. There is a marked decrease, also, in swidden cultivation in the forests of the adjacent uplands. The valley floor shows almost no bomb craters, whereas its hillsides are scarred with many crater lines. Respraying (23 runs) in May-June 1969, all for crop destruction, prevented any effective resettlement of the valley, and denied the harvest of any crops that may have been growing. The air photos of January 27, 1970 indicate that attempts to resettle the formerly densely populated valley lowland had not yet been made.

Study Area 13 is located midway along the Dak-(River) Drinh valley about 30 miles (48 km) west of the coast of the South China Sea and 22 miles (35.2 km) west of the city of Quang-Ngai. Provincial Route 5B connects the eastern (lower) edge of the valley to National Highway 1 at Quang-Ngai. This is the first of the study areas discussed that is inhabited by non-Vietnamese peoples--in this case a Highlander group called the Hre. All of the 16 herbicide spraying runs during 1966 and 1967 were for crop destruction (1 Agent White, 3 Agent Orange, and 12 Agent Blue), and all were

concentrated over the valley bottom rice fields and adjacent hamlets in the eastern third of the study area. A considerable time gap occurred between September 30, 1967 (the end of the 1967 spraying) and April-June 1968 (the next available air photos). Neither the April-June 1968 nor January 1969 photos revealed much evidence of spray damage; presumably, the effects of Agent Blue were restricted to the crops growing in 1967. Only one settlement area had abandoned its irrigated rice fields by January 1969. Further spraying occurred throughout the western three-fourths of the valley area in 1969 by 16 defoliation missions, all with Agent Orange, and limited crop destruction was carried out with Agent Blue in 1970. The December 1969 photography is inadequate in its scale (1:55,000) to assess the effects on cultivation and the dispersed settlement, but no extensive defoliation of the forest cover is apparent.

Study Area 14 is reached by travelling 16 miles (25.6 km) southeast from the city of Hue along National Highway 1, then turning left onto Provincial Road 545 and following it southward for 15 miles (24 km) into the hill and mountain country drained by the Ta-Trach River. This valley and its tributaries, some 16 miles (25.5 km) from the South China Sea, were inhabited by the Katu, a group of nonVietnamese Highlanders. Provincial Road 545 passed through six small agricultural centers inhabited by Vietnamese and terminated at the largest, containing a market and an administrative office. The total population of these settlements was estimated at 1000. Each center had an orderly pattern of small rectangular lots, each with a house and garden facing one of the grid-pattern streets. The absence of large trees indicated the recency of these settlements. In 1965 and 1966, the settlements were flourishing; by July 1968, all had been obliterated.

ated. There is clear evidence of herbicide spraying across the longest settlement and extending up-valley to the southwest. A sizable increase (practically a doubling) in the number of forest clearings for shifting cultivation in the hill areas to the southeast, south, and west occurred between 1966 and 1968. This would seem to indicate that the Highlanders had left the valley bottoms and returned to the type of livelihood previously practiced.

Upland Valley Settlements

This section summarizes the results of interpretation of Study Area 15, located in the mountainous zone of the northern half of SVN (see Figure 1 for location and Table I for name). This area is--or was--inhabited principally by an indigenous Highland group (nonVietnamese).

Study Area 15 straddles the boundary between the provinces of Quang-Nam and Quang-Tin and spans the area between two northward-flowing rivers, the Cai on the west and the Thu-Bon on the east. The principal settlements are the several Vietnamese villages clustered along both banks of the Thu-Bon River in the northeastern corner of the study area. These and one other, in a small valley at the east edge, contain more than 700 people, and are surrounded by irrigated rice fields in the valley bottoms. A 10-mile-long valley tributary to the Thu-Bon drains the area to the west and forms a natural connection to the Cai River drainage. This tributary valley and the Cai River drainage are inhabited by nonVietnamese Highlanders known as Katu, who practice shifting cultivation in the forest that covers the valleys and slopes in the study area. Their houses are scattered, except for a few hamlets along National Road 14, which parallels

the west bank of the Cai River. The first evidence of herbicide spraying appears on the photos of June 15, 1968, showing runs as broad, light-colored strips along the tributary valley leading northwest to the village on the Thu-Bon River. The most recent photography available (September 23, 1969) unfortunately does not follow the last reported spraying; there were further sprayings reported for October 1969 and January-February-October 1970. The September 23, 1969 photos, however, indicate several spray runs over the slopes of the lower end of the tributary valley. Also, there are many clusters and strings of bomb craters throughout the tributary valley, the forested hills to the north, and along the western side of the northern two-thirds of the Cai River. By September 1969, the number of forest clearings being cultivated had decreased by more than one-half (compared to 1966), an indication of a lessened Katu population. For the Vietnamese, the stress induced was complete; owing to a combination of bombing, herbicide spraying, and possibly ground action, all settlements along the Thu-Bon River (and based upon irrigated rice) had been abandoned.

Swidden Settlements

This section summarizes the results of interpretation of Study Areas 16 through 18, all of which are located in the interior of SVN (see Figure 1 for locations and Table I for names). The term "swidden" refers to the practice of shifting cultivation, by cutting and burning small plots of forest or other vegetation, growing one or more crops using the ash as fertilizer, and then creating a new clearing nearby as yields decline and weeds become too difficult to clear. Another term for this practice is "forest-fallow," since it is a long-term cyclic rotation system allowing

time for the forest to regrow before burning and clearing it once again to use its ash for plant nutrients. When viewed on air photos, a swidden area resembles a patchwork quilt with forest clearings ranging from strikingly new (just cleared, or including felled and partly burned logs) to abandoned clearings in all stages of regrowth as the forest, grass, or bamboo regenerates. People who practice swidden usually build permanent or semipermanent settlements, oftentimes as isolated huts hidden in the shade of trees at the edge of a clearing, and infrequently as a cluster of huts in a hamlet near a water source. Swidden areas already have been discussed in Study Areas 13, 14, and 15.

Study Area 16 is the central portion of the narrow linear A-Shau valley, which trends northwest-southeast, paralleling the border with Laos along a stream that lies 4 to 8 miles (6.4 to 12.8 km) to the west. National Road 547 connects the valley to the city of Hue near the coast, 25 miles (40 km) to the northwest. In 1958, the territory from the A-Shau valley to the Laos border was almost completely speckled with clearings and the scars of former clearings that denote swiddens. These were the basis for subsistence cultivation practiced by the Pacoh, a group of nonVietnamese Highlanders. Clearing of the vegetation throughout the valley and its margin has been going on for a long time to result in such extensive removal of the forest cover. Dr. Gerald Hickey visited the valley in 1964 and reported most of the villages gone; Pacoh refugees subsequently were reported to have moved to the vicinity of Hue, close to the tomb of Emperor Tu-Duc. In 1966 five hamlets were located at distant intervals in the central A-Shau valley, with a total population of not more than 210. Between September 1965 and May 1966 nine crop des-

truction missions and three defoliation missions, all 12 with Agent Orange, are reported. A defoliation line is evident along the eastern margin of the valley in the January 1966 photos. Between August 1966 and April 1970, an intensive defoliation campaign was conducted (all but 21 of the 110 spray runs used Agent Orange), with over half of the spraying being done in 1969. Prior to June 1969, but continuing into 1970, very intensive carpet bombing of the area also occurred, destroying both airstrips that had been built in the valley. By June 1968, the area of new swiddens in the A-Shau valley was nil and in the area between the valley and the Laos border only one-tenth that of 1958. By 1969, all cultivation essentially had ceased. The combined effects of massive bombing and repeated spraying, together with ground action, had rendered the area untenable for its indigenous inhabitants. All of the hamlets occupied in 1966 were in the path of the spraying runs and by 1969 no longer existed. To the west and south, outside of the zone of greatest destruction owing to warfare, there appears to be an increase in the number of new swiddens; apparently those Highlanders who survived have shifted not only their cultivated fields but their homes as well.

Study Area 17 consists of a linear series of small open valleys that have the same nearly west-east trend. Their alignment is controlled by the structure of the underlying rocks, and the effect is to create a relatively easy overland routeway that ascends one valley with gentle gradient, crosses over a low divide and descends the next linear valley, repeating this three times in a distance of 25 miles (40 km), gradually descending eastward to reach the coastal lowlands 15 miles (24 km) west of the city of Da-Nang. This upland area in northern Quang-Nam Province

is inhabited by the nonVietnamese Katu, a group of Highlanders who practice shifting cultivation. Eight crop destruction runs in 1966 and 1967 (4 Orange, 3 White, 1 Blue) were neither extensive nor very damaging. However, an intensive spraying campaign to expose the communication route and deny food resources to those passing through the area occurred in 1968 (29 reported spray runs) and 1969 (40 reported spray runs), all of which were defoliation missions (29 using Agent Orange, 11 Agent White). Large-scale photography during 1966 gives good evidence of conditions in the study area prior to the beginning of spraying in September-October. The next available photos were in June-July 1968, just after the beginning of intensive spraying. The several spray runs in the western half of the study area are clearly visible, and so is scattered bombing. Post-spray conditions are indicated by October 1969 photography, which depicts the reported spray runs in the eastern half of the study area. But there was intensive bombing also, combined with shelling, in the eastern quarter of the study area. Between 1966 and 1969 there was a two-thirds decrease in the area placed into new swiddens; presumably, most of the former occupants evacuated the area when it became a war zone.

Study Area 18 is located in the headwaters of the Dong-Nai River 68 miles (109 km) northeast of Saigon where the northern border of the province of Long-Khanh joins that of the provinces of Lam-Dong and Phuoc-Long. Several tributaries draining the adjacent hills flow into a huge freshwater upland swamp from which the southward-flowing Dong-Nai emerges. The area was inhabited by the Ma and Stieng, groups of nonVietnamese Highlanders, who practiced swidden cultivation on the hillsides. The

flat-floored, grassy, and brush-covered marsh and swamp occupy the central third of the study area extending 10 miles (16 km) north-south and are surrounded on the east and west by forest-covered knobby hills of limestone resembling a swarm of gigantic haystacks. After the first 8 spraying runs in October-December 1965 (all using Agent Orange), the continuous and intensive spraying (137 runs) between February 1967 and March 1970 was intended to defoliate the entire study area.

The Stieng and Ma occupied isolated buildings or scattered hamlets of a few huts along forest clearings, river banks, or marsh edges. In late 1965 the predominant activity was swidden cultivation (some 36 clearings), but there were also five different places around the northern and western edge of the swamp where diked and levelled rice fields had been constructed and were in use. By 1968, after repeated defoliation, all of the rice fields had been abandoned, and only 11 swidden clearings were in cultivation, a fact suggesting marked decline in population, presumably by migration. By February 1970, no additional clearings were visible; the conclusion is that the study area was wholly depopulated. Since bombing evidence is very slight, there is little doubt that herbicide spraying was the primary causal factor in the displacement of the Stieng and Ma population (probably about 280-350 people) and the deserted appearance of the area.

SUMMARY 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 that follow are representative of the findings about the effects of herbicide spraying.

Crop Damage and Destruction

A summary of the intention of the spray runs for the 18 study areas is presented in Table III. Of the total of 1659 reported spray runs, 82.8 percent was for defoliation, only 10.6 percent was for crop destruction, and 6.6 percent was for other military purposes. Agent Orange was used for 64.8 percent of all spray runs. Defoliation using Orange was the predominant purpose and agent in 14 of the 18 study areas; the exceptions were Study Area 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 White or Blue.

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 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 marginal 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

Table III.

Summary of reported spray runs for the 18 study areas,
by intended purpose and agent used.

Study area	Size (miles ²)	Total number of reported spray runs	Intended purposes and Agents								
			Defoliation			Crop destruction			Other		
			O	W	B	O	W	B	O	W	B
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	-	-	-	-
Belt											
5	196	43	23	17	3	-	-	-	-	-	-
6	375	13	7	4	-	-	-	-	-	-	-
7	308	64	24	19	3	2	-	-	6	-	-
Plantation											
8	133	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	142	84	51	1	8	-	1	-	-	-
TOTAL	4,292	2,659	899	424	51	90	27	59	86	6	17
TOTAL DEFOLIATION=1374						TOTAL CROP=176			TOTAL OTHER=109		

TOTAL RUNS USING AGENT ORANGE = 2075 (64.8%); TOTAL WHITE = 457 (27.5%);
TOTAL BLUE = 127 (7.7%)

who lacked economic alternatives.^a

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.^b

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).^c Table IV summarizes the findings for all 18 study areas, comparing the location of each settlement with the plotted location of the centerline of each spray run reported on the printout from the HERBS computer tape. Table IV shows a high percentage of settlements sprayed, precisely because each study area was originally

^aFor further discussion of herbicide effects as perceived by Montagnards, see Hickey, G.C. Perceived effects of herbicides used in the highlands of South Vietnam, Part B of the Report on the Effects of Herbicides in South Vietnam.

^bFor information on these effects as seen from the ground, see Murphy et al. Beliefs, attitudes, and behavior of lowland Vietnamese, Part B of the Report on the Effects of Herbicides in South Vietnam. This report can be found in the office files of the NAS/NRC Committee on the Effects of Herbicides in Vietnam.

^cDamage from spraying may be from drift as well as from a spray run directly overhead. The count in Table IV includes all spray runs whose centerline passed 1 km from the center of a settlement. The HERBS locations were used only because the air-photo coverage was not frequent enough to verify the existence of each reported, or actual, spray run. Further, swaths of spray damage overlap one another on the photographs and cannot be separately distinguished as being made by several planes on one day or by one plane on several 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).

Table IV.

Summary of settlements in the 18 study areas that would have been exposed to the reported spray runs.

Number of settlements arranged according to the number of times that the centerline of a reported spray run passed within one kilometer of their centers

Study area number	Total number of settlements in study area	0=Not sprayed	Sprayed 1 time	Sprayed 2 times	Sprayed 3 times	Sprayed 4 or more times	Percent of total settlements sprayed
<u>Mangrove</u>							
1	30	5	2	1	7	15	83.3
2	104	42	15	7	9	29	59.6
3	56	5	4	6	5	36	91.1
4	25	3	2	2	5	13	88.0
<u>Delta</u>							
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
<u>Plantation</u>							
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
<u>Lowland Valley</u>							
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.
<u>Upland Valley</u>							
15	17	2	1	3	1	10	88.2
<u>Swidden</u>							
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	

selected for that criterion. The exception was Study Area 10 (see Figure 13); its addition for aerial photographic interpretation was to correlate with an on-the-ground provincial study.^a

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 spraying from the air may have been only one causal factor among many (fear of insecurity, bombing, ground fighting, or other war-related events) that led people to decide to move. Figure 14 portrays a "before-and-after herbicide spraying" example of massive evacuation of a population and herbicide destruction of crops, fruit trees, and houseyards.

Another example is provided by Study Area 8 (see Figure 2), where the hamlets in the upper left included those evacuated by persons who were resettled in Bien-Hoa.^b

Post-spray photography was absent for most study areas. As far as the evidence permits, only in the Rung-Sat Special Zone (Study Area 4) has post-spray land use and settlement expanded (see Figure 5) so that the Rung-Sat in 1972 had a larger population than was present when herbicide spraying began.

^aSee Murphy et al. Beliefs, attitudes, and behavior of lowland Vietnamese, Part B of the Report on the Effects of Herbicides in South Vietnam. This report is situated in the office files of the NAS/NRC Committee on the Effects of Herbicides in Vietnam.

^bFor interviews with some of these refugees, see Murphy et al., as cited in footnote a above.

The cumulative effect of herbicide spraying 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.

Land Use Recovery in Sprayed Areas

The most heavily affected natural vegetation of those types extensively examined was the mangrove forest along the coast of the Mekong River 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), where large areas were denuded of vegetation. Further discussion of the effects on human activities in the Rung-Sat mangrove area appears in Section VII C, Part A of the Report on the Effects of Herbicides in South Vietnam. The aerial photographs provide evidence that in the inland sector of the Rung-Sat (on land farthest removed from tidal submergence) Vietnamese settlers have been removing the deadened mangrove stumps and roots and planting new rice fields. See Figure 9 for the location and extent of this activity east of Quang-Xuyen and north of Tran-Hung-Dao.

CONCLUSIONS

There is no question but that the application of herbicides by aerial spraying contributed to the dramatic and drastic rearrangement of the population distribution in SVN and the altering of human use of

the sprayed land. There is a strong correlation between herbicide spraying and major changes in vegetation cover, land use, settlement forms, and population. Herbicide spraying, from aerial photographic evidence, was associated with major changes affecting human livelihood; the reports on the study areas depict what happened in sample areas. However, evidence derived from the interpretation of air photos indicates that herbicide spraying was clearly only one of the disruptive factors; bombing and ground action during warfare were often more destructive than herbicide spraying.

The interpretation of photographic evidence leads to the following general conclusions:

1. The most heavily affected natural vegetation was the mangrove forest along the coast of the Mekong River delta and in the Rung-Sat Special Zone, where extensive areas were denuded of vegetation.

2. Since the study areas were selected because they included settlements and had been intensively sprayed, it is not surprising that the cultivated tree, bush, and grain crops in fields surrounding those settlements also were intensively sprayed. Rice was the most important and most commonly sprayed crop. 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 resulted from spraying missions designated as defoliation (except for Study Areas 12 and 13 in which crop destruction predominated). Agent Orange was used almost twice as frequently as Agents White and Blue combined.

3. Except for Study Area 10, all study areas contained numerous settlements that had been repeatedly sprayed, and people in all study

areas were displaced from their houses 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 use of herbicides has contributed to the urbanization of SVN.

4. More Vietnamese were dislocated from their hamlets and economic productivity than were the people of any other ethnic group.

5. NonVietnamese mountain peoples were the groups most seriously affected by the spraying. Since their widdened economy, being dependent upon the forest as a renewable reservoir of plant nutrients, is the most fragile, they suffered the most by crop destruction and forest defoliation. In addition, once displaced from their established territories, these people have no viable alternative skills.

6. The air-photo evidence has been reviewed to determine whether any of the following statements or assumptions are correct: (a) spraying was done only over uninhabited territory; (b) agricultural crops were only destroyed or damaged by that type of mission designated as "crop destruction;" (c) only Agent Blue was used on crop destruction missions. This report has gathered plentiful evidence that inhabited villages, hamlets, and isolated farmsteads were directly and repeatedly subjected to aerial spraying of all three herbicidal agents regardless of the type of mission. Cumulatively, more crop destruction occurred from defoliation missions using Agent Orange than from any other chemical. Consequently, all three foregoing statements are false.

Since the 18 study areas were chosen especially because they had been heavily sprayed, the results of this aerial photographic interpretation cannot be extrapolated for unsprayed or lesser-sprayed areas and hence

should not be used to obtain a nationwide quantitative estimate of total effects.

RECOMMENDATIONS FOR FUTURE STUDIES

The opportunity to view thousands of aerial photographs of selected portions of SVN taken from 1957 to 1973 provides a perspective of time and heightens the awareness of change. Even though herbicides will no longer be applied with the intensity evident during 1966 and 1970, human and environmental changes will continue in the areas that were subjected to extreme stress. The following are the recommendations emerging from the research upon which this report is based:

1. The air photos and other remote-sensing records taken of the territory of SVN during 1957-73 should be preserved as historic documents that record processes of dramatic change to a people and their land. These records are needed to provide a baseline from which to assess and measure the resettlement, rehabilitation, or rearrangement of this unusual portion of the earth's surface. Thus, these records should be declassified and made available to those having need for them (e.g., administrators and/or scholars of whatever nation able to conduct on-the-spot field research in SVN in the future).

2. For each of the 18 study areas in which a detailed photo interpretation study has been made, a reconstruction of its full wartime history should be made in order to sort out the relative importance of each of the actions of war (e.g., bombing, ground action, Rome-plowing, napalm) compared to the effects of the use of herbicide spraying.

3. Further research is needed to combine air-photo interpretation

with on-the-ground surveys of the study areas described in this report, to assess the validity of the conclusions made in the detailed reports of each study area, and to observe the rates of economic and demographic recovery from the war-induced stress, damage, and destruction (including the effects of herbicides).

4. Air photos and other remote-sensing records at interpretation scale (1:4000 to 1:10,000) should be made of all of the territory of SVN at regular intervals (3 to 5 years) in order to record the areal extent of changes in the locations and sizes of settlements and the nature of their associated land use. Such records would be invaluable as base maps for recording census data about people and resources (agriculture and forestry).