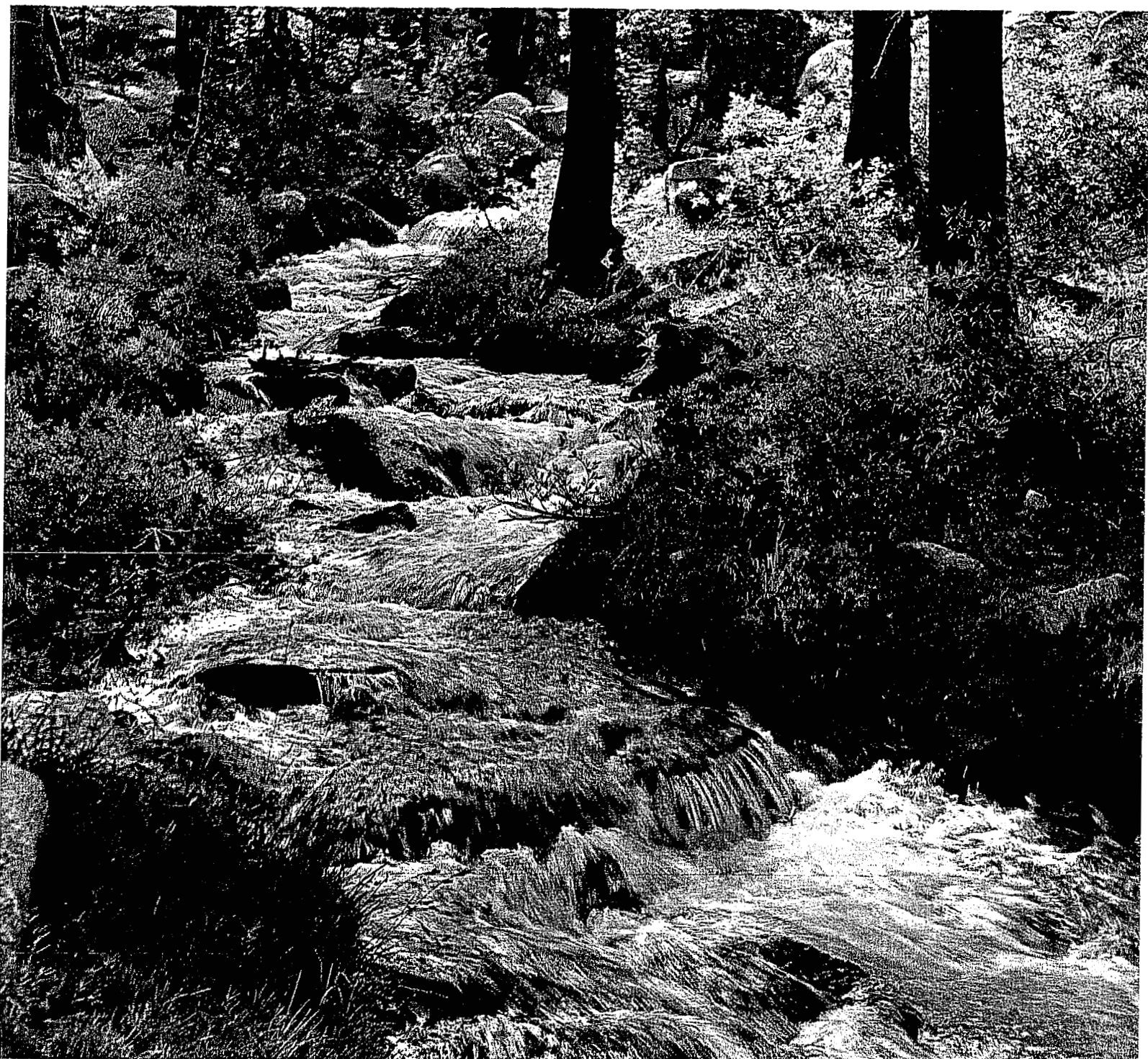


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# The Ecological Impact of Large Scale Defoliation in Vietnam

*Mangrove forest, sprayed, ground view. Not sprayed since 1967. Low plant barely visible in right background is *Wedelia biflora*, weed known to grow in damaged mangrove forests. Little if any regeneration of mangrove trees has yet been observed in sprayed areas (Photo, August 1970)*



— by John Constable and Matthew Meselson

Although synthetic chemical herbicides have been widely used in certain areas in the United States over the last fifteen years, there has only recently developed a great deal of interest in their possible toxic effects. This interest has resulted, in part, from the increasing awareness of the possible environmental hazards of many agricultural chemicals and pesticides, but more especially from recent laboratory work suggesting that the herbicide 2,4,5-T has teratogenic effects (the tendency to increase congenital deformities from defects in embryonic growth) in rats, mice and hamsters. It must be emphasized that this toxicity has not been proved in man or in any animal at the quite low doses to which man might ordinarily be exposed. In addition to possible unexpected human toxicity the ecological effects of large-scale herbicide treatment have never been well studied.

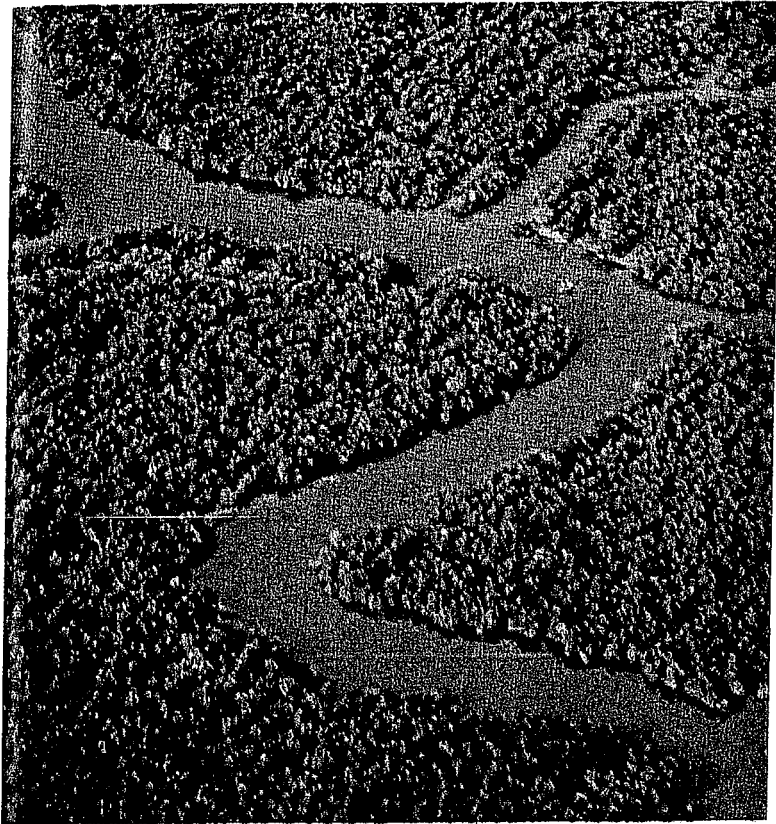
Herbicides are chemicals intended to kill or reduce vegetation. When they cause leaf fall, with or without killing the plant, they may also be called defoliant. Although extensively used in the United States, herbicides have been used in Vietnam on an unprecedented scale both as to the size and nature of the areas treated and also as to the concentration of chemicals applied. In spite of the inevitable difficulties of conducting a study

under unsettled conditions, it seemed that the environmental and toxic effects, if any, of the herbicides should be more grossly apparent in Vietnam than in the United States. In 1969 the American Association for the Advancement of Science appointed Professor Matthew Meselson of Harvard University to head the AAAS Herbicide Assessment Commission, henceforth referred to as the HAC, to investigate in a preliminary way the economic, ecological and health effects of the military use of herbicides in Vietnam and to develop a plan for more detailed studies in the future. He, in turn, appointed Professor Arthur Westing of Windham College to act as director.

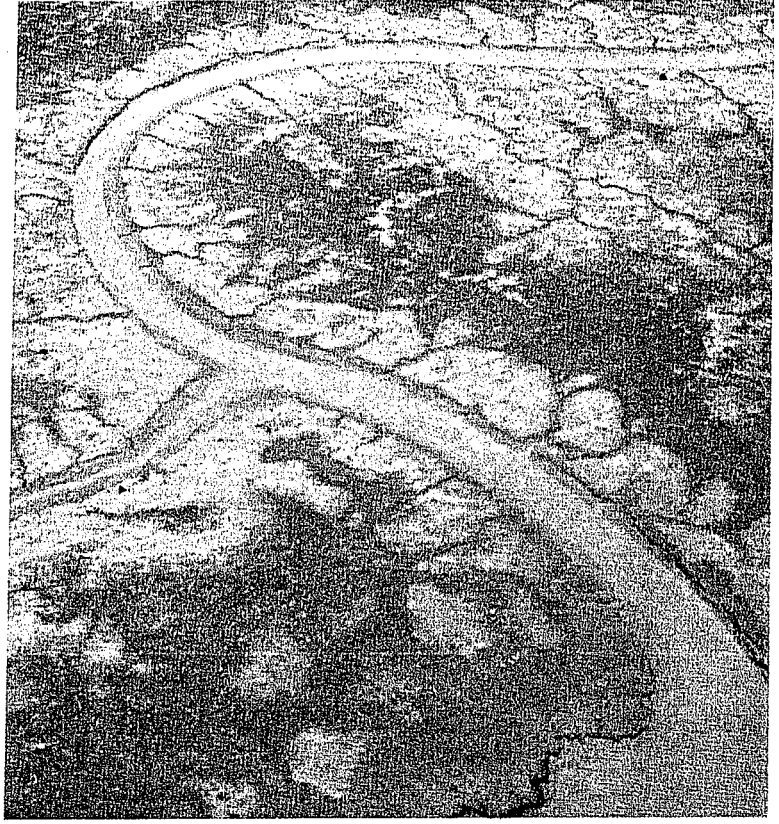
Many months of intense efforts were spent in preparatory study of all known references to the effects of herbicides in the laboratory and in the field. Experts of many countries were consulted — reports both scientific and sensational followed up — and an assessment advisory meeting held at Woods Hole, Massachusetts. In this way, although only about six weeks were spent in Vietnam, we went well prepared and could use the time effectively. The HAC team included Matthew Meselson, Arthur Westing, John Constable, M.D., Professor of Surgery at Harvard Medical School and Robert Cook, Department of Biology, Yale University.

The attitude of the United States Government to the

*Mangrove forest, unsprayed. Aerial photograph of unsprayed mangrove forest near the coast 25 miles southeast of Saigon. Mangroves are important producers of fuel wood and charcoal and also provide food and nursery grounds for fish and shrimp. (Aerial photo, August 1970)*



*Mangrove forest, sprayed. Approximately three years after spraying. Large dark areas are presumably remaining deposits of humus. Half of the total mangrove forest area in South Vietnam, approximately 300,000 acres, has been sprayed with herbicides. (Aerial photo, August 1970)*



survey was curiously equivocal. Without governmental acquiescence, at least, nothing effective could have been done since access to the areas of defoliation can be easily obtained only through the assistance of the military. From the beginning of the study, the State Department in Washington and the Embassy while in Vietnam offered every assistance. The Department of Defense on the other hand, while cooperating in some ways, withheld from the HAC two types of information that only they could provide. The most important and essential was the precise location of previous defoliation missions, including the identity of the herbicide used. Accurate study requires this information and although details as to a few very recent missions were eventually provided by the DOD, records from previous years' spraying, the effects of which we saw, have never been declassified. Even more surprising, it was known that an Army team headed by Dr. Robert Cutting had completed a major study of the rates of stillbirths and congenital abnormalities in Vietnam, specifically in relation to possible herbicide effects, but this information was withheld from the HAC while we were in Vietnam.

In spite of these unfortunate obstacles, the HAC was offered every other assistance in Vietnam. Housing and office space were provided in Saigon by USAID and in the field MACV (Military Assistance Command Viet-

nam) outdid themselves in providing helicopters and other special transport.

Important, too, is the attitude of the Vietnamese themselves. The government of the Republic of Vietnam is deeply concerned with the long-term results of herbicides quite apart from any considerations of current military usefulness. Full cooperation was offered and given by the Prime Minister, Ministry of Health and the Vietnamese military. We were fortunate indeed in being able to enlist the help of a number of very competent Vietnamese scientists, botanists, biologists, and physicians all anxious to help. Most Vietnamese seem agreed on the need for evaluation of the effects of herbicides and offers of help were received from the NLF and the Democratic Republic of Vietnam (Hanoi).

With this background, our evaluation of the effects of herbicides in Vietnam can be divided roughly into those on the forests (subdivided into mangroves and upland forests), those on human health and those resulting from the crop destruction program.

Herbicides were first used in Vietnam in 1961 on an experimental basis and became operational in 1962. The amounts used were relatively limited until 1966 when about 800,000 acres were sprayed while in 1967, 1968 and 1969, even larger areas were treated (see Table). The total area of Vietnam sprayed is estimated to be about



*Upland hardwood forest, unsprayed. Near-climax tropical hardwood forest 60 miles northwest of Saigon. Such forests are one of the most valuable natural resources of South Vietnam and are rich in plant and animal species. (Aerial photo, August 1970)*

one-seventh of the total area of the country.

The table does not distinguish the specific herbicides used at any period. Three herbicide agents have been commonly used. These are Agent Orange, Agent White and Agent Blue. Agent Orange, the most widely used, until it was suspended in 1969 as possibly being teratogenic, consists of a 50-50 mixture of 2,4,5-T and 2,4-D. Agent White is an 80-20 mixture of 2,4-D and picloram.

Although White is more persistent than Orange, they are equally effective as defoliants, but White is considerably more expensive and has been used less widely. Agent Blue is cacodylic acid, an arsenical compound mostly used in crop destruction.

*The Mangroves*

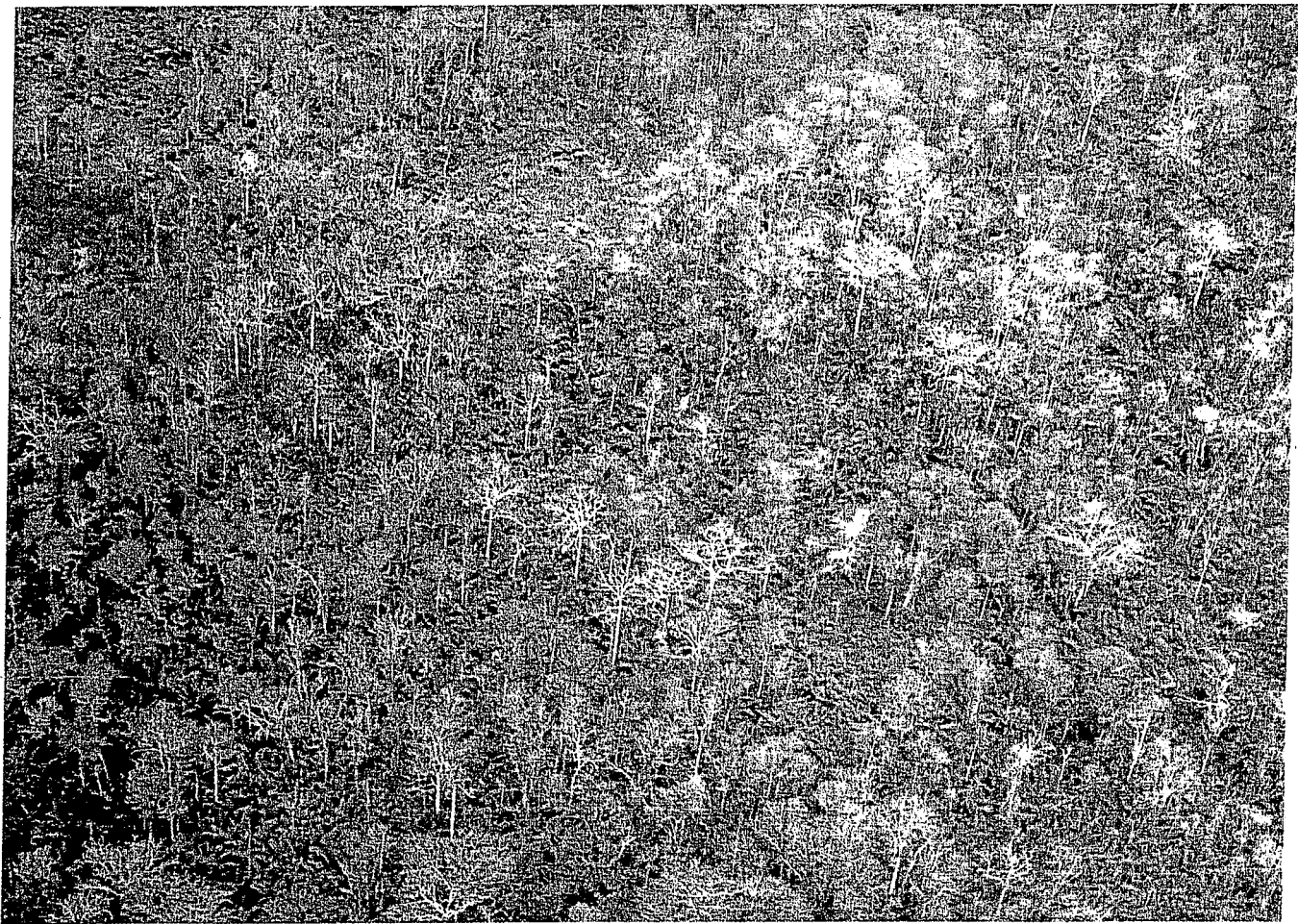
The mangrove forest is a well-localized and specialized feature of the Vietnamese coast. With only a few northern extensions, it starts near Saigon and extends south around the Mekong Delta. This mangrove forest is not merely a swamp with low bushes characteristic of mangroves in some other parts of the world but includes trees up to forty feet high. These mangrove forests grow rapidly and are of great importance as a source of wood and charcoal, Vietnam's principal source of home fuel.

The HAC flew over most of the mangrove forests of Vietnam and estimated that about half had been destroyed, approximately 350,000 acres. The southern tip of Vietnam, the Camau Peninsula, is too insecure for ground studies to be made, but in the Rung-Sat area at the mouth of the Saigon River, we were able to make brief ground surveys at several sites within the sprayed forest. We were deeply impressed by the total destruction of *all* vegetation even by a single spraying and by the absence of any mangrove seedlings or other evidence of forest regeneration. On the ground only a few specimens

**Estimated Area Treated with Herbicides in South Vietnam\***

Year	Acres		Total
	Forest Land	Crop Land	
1962	4,940	741	<b>5,681</b>
1963	24,700	247	<b>24,947</b>
1964	83,486	10,374	<b>93,860</b>
1965	155,610	65,949	<b>221,559</b>
1966	741,247	101,517	<b>842,764</b>
1967	1,486,446	221,312	<b>1,707,758</b>
1968	1,267,110	63,726	<b>1,330,836</b>
1969	1,221,415	65,700	<b>1,287,115</b>
1970	DATA NOT YET AVAILABLE		
1971	"	"	"
Total	4,984,954	529,566	<b>5,514,410</b>

\*Department of Defense data. Includes areas sprayed repeatedly.



*Upland hardwood forest, sprayed. Nearly all trees appear dead. With the availability of sunlight, area has been invaded by bamboo, seen as a dense green cover. About one-fifth of the mature upland forest of South Vietnam, approximately 4,000,000 acres, has been sprayed. (Aerial photo, August 1970)*

of a very few species of weeds were found, and this three years after the spraying. Large numbers of crabs were present and they may be helping to prevent the re-growth of the mangroves by eating any seedlings that might appear. Most of this spraying was probably with Agent Orange and both 2,4,5-T and 2,4-D are usually inactivated in the soil, lasting only a few months at the most. However, specific studies of their persistence under mangrove conditions have not been done.

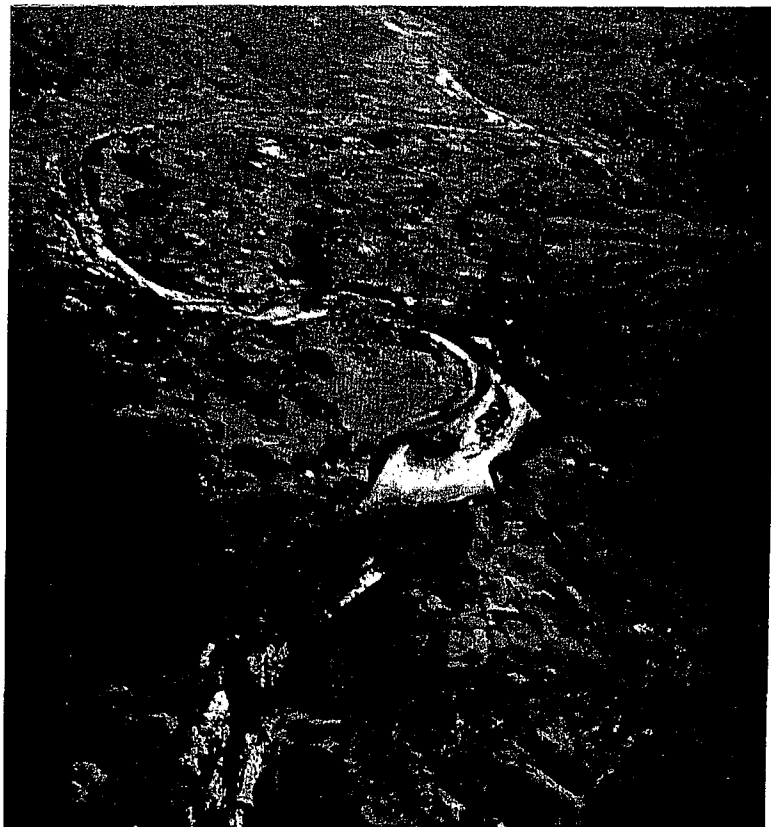
In these devastated areas most of the animals and birds must have been driven out or perished as a result of being cut off from a new habitat by excessive distance or waterways.

The HAC looked for the possible effects of erosion. Only small scale changes were visible at this time, but it should be noted that the Delta has had no real typhoon since the time of destruction of the mangrove forests. Although mangroves provide food and shelter for fish and crustaceans, no adequate studies of effects on these organisms could be made. The fate of these "cleared" mangroves is of great interest. Perhaps eventually they will re-forest themselves but possibly the ecological chain characterized by the transformation of front mangroves, subject to tidal flooding, to back mangroves on higher land has been indefinitely interrupted. Deliberate reforesting is likely to be needed if the mangroves are to be

restored. Replanting of the denuded tidal areas with mangroves would stabilize the shore line and restore the productive aquatic habitat.

#### *The Upland Forest*

Although precise figures cannot be given it would appear that approximately 4 million acres, more than a fifth, of the relatively mature upland forest of Vietnam has been sprayed. These beautiful forests are made up of a deep luxuriant canopy sheltering a relatively open forest floor. Unlike the mangrove, this forest is not totally destroyed by a single spraying of herbicide. Although the lack of official data precludes certainty, it was our impression that most of the sprayed areas we overflew had been treated only once. However, whether the spraying was in fact single or multiple, it appears to have destroyed most of the larger trees. The larger forest trees being eliminated, sunlight reaches deeper into the forest and extensive invasion with bamboo and coarse grasses, especially *Imperata cylindrica*, occurs. As a result, the relatively open forest floor is replaced by a dense underbrush. In the case of the upland forest, security precluded ground inspection of defoliated areas, although low overflights by helicopter were occasionally possible. Whether this upland forest can ever be restored is uncertain, for the invading bamboo and other species may persist. Even if spontaneous recovery should eventually occur



*Crop destruction area. Valley of Song Re River, in Montagnard section of Quang Ngai Province. Brown swaths along the valley show paths of planes. Photo was taken eleven days later. Herbicide used was Agent Blue, which prevents rice from forming grains. (Aerial photo, August 1970)*

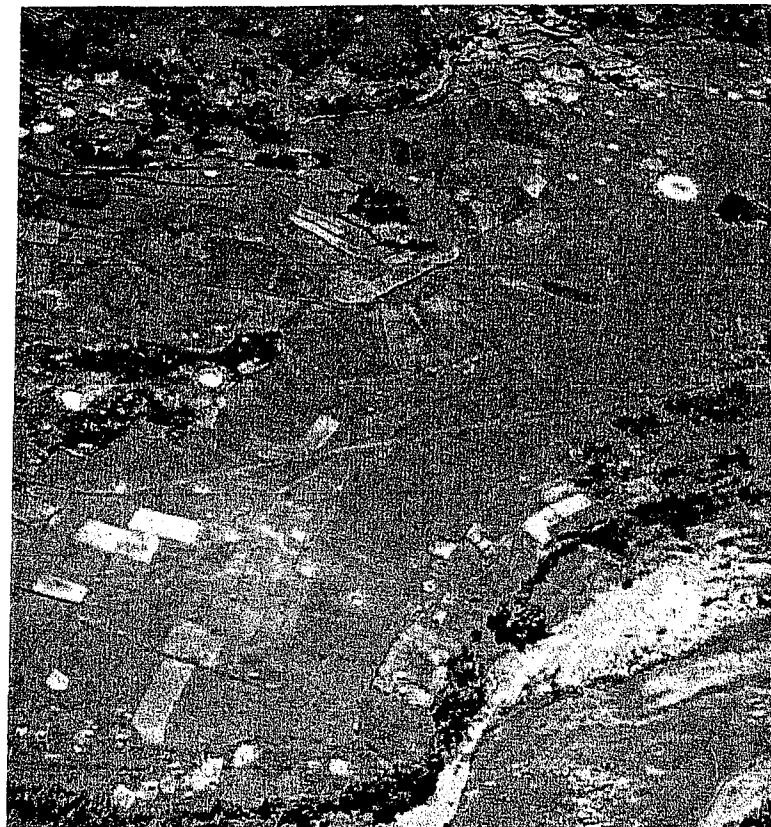
cur, if man does not further manipulate natural succession, this may take a century or longer. No definite information could be obtained as to the fate of the magnificent animals and birds in these forests which include elephants, tigers, monkeys and several very rare pheasants, but the populations must certainly have been very severely changed.

An additional risk from extensive defoliation is so-called nutrient dumping. Many tropical soils are not intrinsically rich in plant nutrients, and as a result a considerable percentage of the total available nutrient supply is in the vegetation at any one time. If all the leaves fall at once and rapidly decompose, much of their nutrient content may be washed into the rivers by the heavy tropical rains and lost to the local ecosystem. Even larger losses could occur if the trees are killed.

The long-term economic effects of the loss of the large trees in this forest will probably be even more severe than in the mangroves. Although in the past Vietnam has not exported much wood, having been in pre-war days basically an agricultural nation with some rubber exports, the presumptive future needs for extensive outside earnings may make the precious woods from her forests (teak, rosewood, ebony, camphor, etc.) one of Vietnam's major assets.

#### *The Crop Destruction Program*

The crop destruction program exhibits a different military use of herbicides in that it does not aim at the improvement of terrain for fighting or the dislodging of



*Close-up of crop destruction area. Path of spray planes shown by brown swath, running right to left. Brown discoloration indicates overdose region directly beneath spray planes. Rice to both sides, still green, will nonetheless be affected and will not form grain. (Aerial photo, August 1970)*

the concealed enemy but rather attempts to destroy crops destined for enemy use. For this purpose, Agent Blue (cacodylic acid) is commonly used, although Orange or White have also been used. Blue is sprayed on crops, principally rice, shortly before fruition and they are damaged so that there is no harvest. The program has been carried out principally in the mountainous parts of South Vietnam. A total of about 530,000 acres has been sprayed through 1969, destroying enough rice to feed an estimated 600,000 people for a year. The HAC had the opportunity of studying in some detail the site of a crop destruction mission carried out several weeks before our visit in the Song Re Valley in Quang Ngai Province. This survey was made by helicopter in company with the area chemical warfare officer. We subsequently visited the Montagnard refugee camps in the secure towns outside the valley, which in itself is not secure and is patrolled only very occasionally by United States or South Vietnamese soldiers. We were very much disturbed by the inadequate criteria for the legitimacy of the destruction caused by spraying this valley and presumably for other similar flights. The avowed object of the crop destruction program is to eliminate crops being grown by enemy soldiers for their own use. In fact, the fields in this valley are apparently the traditional home and fields of Montagnards with little or no additional cultivation by NLF or North Vietnamese soldiers.

This conclusion seems inescapable in view of the fact that every indicator of enemy presence relied upon by the chemical staff proved mistaken. We were told there

were no dwellings in the valley—but our photographs show hundreds. We were told that extensive new fields had recently been put under cultivation by the enemy—but our photographs show no change from the pattern of land use seen in a 1965 Army aerial survey. We were also told that the terracing of fields seen in the valley was a technique unknown to the Montagnards, giving evidence of North Vietnamese farm units—but we later found from the army's own manuals that the Montagnards of this area had grown rice on terraced land for decades.

The Montagnard refugees who came out of areas previously subject to crop destruction told us that water buffalo are killed by eating sprayed grass. They feel that the land is cursed and poisoned from the air; they think that children, in particular, may die from the effects. Official reassurance that there is no proof of ill effects in animals or humans and that the sprayed soil should have recovered its full fertility by the next sowing is of no avail to these sad, dislocated and helpless people.

Even the most optimistic Army studies confirm that only a limited percentage of the rice in any region can be destroyed, and if this is true it is illogical to expect enemy soldiers to go hungry. They will get such rice as remains and the Montagnards will be the sufferers.

#### *Health Effects*

Although in fact comprising a very considerable part of the work of the HAC, only a brief summary of the health evaluation of the herbicides will be given here. Multiple reports of toxicity from cacodylic acid (Blue) among the Montagnards could not be further investigated. Hair samples from exposed individuals have been collected for arsenic analysis, still in progress.

Our principal interest centered on possible changes in the rate of stillbirths and congenital abnormalities in the population exposed to Agents White or Orange. (There is no laboratory evidence of teratogenic effects from Agent Blue.) The exposed group is extraordinarily hard to isolate. The sprayed upland forests, but not the waterways within the mangrove forests, are normally very sparsely inhabited, but significant exposure has certainly occurred. Also, there has been spraying along canals in the Delta which are usually densely populated. The heavy fighting usual in sprayed areas further dislocates the population, adding to the difficulty in conducting medical surveys.

We found no evidence of the sudden or new appearance of any dramatic congenital abnormalities as have been reported in some newspapers — Vietnamese and American.

We believe that the figures from the army report of Dr. Cutting, unfortunately not available to us while in Vietnam, are so weighted by data from Saigon (unsprayed) as to make it impossible to draw any significant conclusions. The HAC study of one province (Tay Ninh) with severe herbicide exposure did show a higher stillbirth

rate than any provincial hospital reported by Cutting. Interestingly, if Cutting's own figures for provincial hospitals are isolated, they do show a recent increase in stillbirth rate, in contrast to Saigon.

Considering that dioxin, a teratogenic contaminant of 2,4,5-T, may accumulate like DDT in the food chain, we collected mothers' milk from those mothers eating fish from rivers draining defoliated forests. Analysis of these samples for dioxin is still in progress.

Unfortunately, any statistical health study in Vietnam is fraught with extreme difficulty, even with maximum local cooperation, and there can be no question but that the population exposed directly to herbicides could, in fact, have suffered a tenfold increase in congenital abnormalities without our having detected it with the methods at our disposal.

The HAC made its field study in August and September 1970 and reported to the AAAS in December. Three days before this report was made, but with our findings having been previously made available to the Administration, the White House announced a phasing out of all herbicide use in Vietnam, although at the time of this writing herbicides are still being used. More recently, the U. S. command in Saigon and the Secretary of State have announced the cessation of the crop destruction program. The military effectiveness of the use of herbicides will be debated for some time to come. Although this was not a subject which we studied, it was of interest to find a wide-range of views among military officers in Vietnam — ranging from enthusiastic support to outright condemnation.

The HAC survey raises more questions than we have even tried to answer: Why have the mangroves not recovered? What has happened to the fish and crustacean population? What will happen to the bamboo in the upland forests? Are animals really poisoned by cacodylic acid? What will happen to the Montagnards made refugees by the crop destruction program? Are there real effects on stillbirths and congenital defects in man?

We believe that herbicides in Vietnam have fundamentally changed the vegetation over very extensive areas and many decades will pass before the full effects of a transient military "necessity" are known. At the scene of Waterloo or Gettysburg almost no trace of the battle remains and even the scars of Verdun or Guadalcanal are hard to find; Vietnam's defoliated forests may be a more permanent memorial.

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*Dr. Matthew S. Meselson is Professor of Biology at Harvard University and was appointed by the AAAS to head its Herbicide Assessment Commission.*