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COMMITTEE ON THE EFFECTS OF HERBICIDES IN VIETNAM

INTERIM REPORT

December 1970 through December 1971

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NOTICE

The study reported herein was undertaken under the aegis of the National Research Council with the express approval of the Governing Board of the NRC. Such approval indicated that the Board considered that the problem is of national significance; that elucidation and/or solution of the problem required scientific or technical competence and that the resources of NRC were particularly suitable to the conduct of the project. The institutional responsibilities of the NPC were then discharged in the following manner:

The members of the study committee were selected for their individual scholarly competence and judgment with due consideration for the balance and breadth of disciplines. Responsibility for all aspects of this report rests with the study committee, to whom we express our sincere appreciation.

Although the reports of our study committees are not submitted for approval to the Academy membership nor to the Council, each report is reviewed by a second group of scientists according to procedures established and monitored by the Academy's Report Review Committee. Such reviews are intended to determine, inter alia, whether the major questions and relevant points of view have been addressed and whether the reported findings, conclusions and recommendations arose from the available data and information. Distribution of the report is permitted only after satisfactory completion of this review process.

TABLE OF CONTENTS

Introduction	1
Phase I - Planning Phase	2
I Scope and Objectives	2
II Guidelines	6
III Some Considerations of Strategy	8
IV Some Perspectives	10
V Some Questions of Policy	12
Phase II - Reconnaissance Studies	15
I Survey of Activities	15
II Observations and General Conclusions	18
III Modification of Work Plans	23
IV Work Plan Outline for Further Studies	25
V Cooperation with Vietnamese Scientists	28
VI Acknowledgements	29
Appendix A Listing of Committee Members	30
Appendix A-1 Listing of Members of Vietnamese Committee	32
Appendix B Reference Collection	33
Appendix Major Chemicals Used in South Vietnam	34

INTRODUCTION

The Committee on the Effects of Herbicides in Vietnam was established under a Contract between the Department of Defense and the National Academy of Sciences that was negotiated and signed pursuant to Public Law 91-441, the Fiscal Year 1971 Military Procurement Authorization Act, Section 506(c). This Section directed, in paragraph (1), the Secretary of Defense to "undertake to enter into appropriate arrangements with the National Academy of Sciences to conduct a comprehensive study and investigation to determine (A) the ecological and physiological dangers inherent in the use of herbicides, and (B) the ecological and physiological effects of the defoliation program carried out by the Department of Defense in South Vietnam." Paragraph (2) provides that "of the funds authorized by this Act for research, development, testing, and evaluation of chemical warfare agents and for defense against biological warfare agents, such amounts as are required shall be available to carry out the study and investigation authorized by paragraph (1) of this subsection."

The Contract was signed on March 9, 1971. The Public Law called for a completion date (submission of a final report to the Secretary of Defense) of January 31, 1972. As it became immediately apparent that no satisfactory study could be completed by this deadline, the Academy requested an extension of the completion date to August 31, 1973, and the Secretary of Defense, by letter of September 24, 1971 to the chairmen of the House and Senate Armed Services Committees, stated that he planned to accept this revised time schedule for the report. This correspondence, with supporting documentation, has been inserted in the Congressional Record, Senate, Session of October 6, 1971, pages S15995-S16001.

The present report is an interim report, summarizing the activities of the Committee beginning with the signing of the Contract and extending through December 1971. It had been agreed that the study would proceed in two phases, Phase I or the Planning phase, and Phase II or the Working phase. Phase II is in turn being carried out in two stages, a short reconnaissance stage, designed to select the most suitable localities and materials for further work and to obtain information about the range of problems and variables that may be encountered, and the long-range working stage in which the effects of the herbicides will be studied intensively and, as far as possible, using quantitative approaches. The present report covers Phase I and most of the reconnaissance work of Phase II. The conclusions of Phase I have had to be revised in the light of the experience and results of the reconnaissance stage of Phase II. However, they will be presented here without these modifications, and the latter summarized in the section on the reconnaissance stage, since the differences between the two sets of conclusions are indicative of the serious logistical problems and limitations under which the entire study has to be executed.

Phase I - Planning Phase

The objectives for Phase I included -- apart from the selection and appointment of the Committee (Appendix A) -- compilation and preliminary analysis of existing pertinent information on herbicide effects, mainly under tropical conditions, and on the ecology, demography and other features of Vietnam and of comparable countries or regions; consultations with source personnel capable of providing information in these and other disciplines and on a number of scientific and practical problems potentially important for the study; and conferences with personnel from Congress, the Department of Defense, and other agencies to establish contacts and prepare logistics. A reference library of approximately 1000 titles under 19 major and 38 subheadings was assembled (Appendix B); consultations and conferences were held with approximately 200 persons in the U.S. and abroad. On the basis of the information thus gathered, the Committee analyzed and defined the scope and objectives of its "mission"; established some guidelines for its work; considered some problems of strategy and certain longer-range perspectives of its work; gave thought to some questions of policy; and drew up a tentative work plan for the study.

I. Scope and Objectives

a) Definitions

PL 91-441 provides for studies on the dangers inherent in the use of herbicides in general, as well as on the effects of their use in Vietnam. This, especially the first-named provision, is very general language, and if taken in its broadest sense could result in a serious diffusion and dilution of the study. We sought therefore to clarify the intent of Congress and were advised that Congress was primarily concerned with the effects of the military uses of herbicides in Vietnam; if possible, it would like to have, on this basis, some general evaluation of the problems of large-scale use of herbicides, particularly under tropical conditions. It is this delineation of the problem that the Committee proposes to follow.

PL 91-441 calls for studies of the ecological and physiological effects of herbicides. Physiological we understand to mean effects on the function of individual organisms (although in the study of such effects, it is usually necessary to employ groups of similar organisms, so-called populations). Ecological we understand to mean effects on "ecosystems," that is communities of various organisms, including effects on the interactions between and among the affected individuals and populations, and between them and the rest of the environment (such as soil and water).

Both physiological and ecological effects of herbicides may be direct and indirect. Relatively direct effects are, for example, death or failure of growth and reproduction of a treated plant, or lesions produced in man and animals by application to the skin, inhalation or ingestion of the

agent. Indirect effects operate through a chain following from or exacerbated by the more direct effects, and may be very diverse. Intake of the agent by a woman, even if causing no apparent direct or lasting syndrome, might conceivably affect her fertility or the health of her offspring. The destruction of a forest by herbicides could mean loss of income to the wood-cutter. The greatest complexity of indirect effects, however, can be predicted in the realm of ecological responses. Ecosystems are generally characterized by a very finely attuned balance between their living components (animals, plants, microorganisms) and between these and the physical environment (soil, water, microclimate). Moreover, ecosystems are very often not stationary but are evolving, slowly but in a definite sequence ("succession") leading to a so-called "climax," the final stage that, if undisturbed, will not undergo further changes. Injury to, or death of one component as the result of herbicide treatment is thus apt to disturb not only the system as such, but also its further "evolution." These effects may be gradual and progressive, and it may take long periods of time to be certain what direction the disturbance is taking and whether the original balance will be restored at all. All this holds not only for "natural" or "wild" ecosystems but involves man, either indirectly as a dependent of many natural ecosystems, or directly as component of an ecosystem. A change in the floral composition of a forest as result of herbicide treatment may result in changes in the faunal composition, resulting in changes in the distribution of animals (insects, rats) that function as vectors of human diseases, resulting in changes in the incidence of these diseases in adjacent settlements even if these were not directly affected by the herbicide. Crop destruction in a settlement of Montagnards, not only deprives the people of food but may profoundly affect their faith in their own traditional means for coping with crises and disasters, and may result in demoralization.

From the existence and particularly from the long-range nature of the indirect effects that massive herbicide application is bound to have in ecosystems there follows a crucial conclusion. It is not enough to assess the herbicide effects in Vietnam as they can be seen, "here and now": it is essential to try to reconstruct, as far as possible, the "evolution" that these effects have undergone since herbicides were first applied on a large scale, and to project their further developments. It is only with such information that some genuine evaluation of the ecological and physiological effects of the herbicides, used on the scale they have been used in Vietnam, can be expected. Otherwise, we may end up with not much more than a catalog of incidental observations that, however detailed and complete, will permit few if any meaningful conclusions.

The prospective approach is all the more important since it may help us to learn whether, how, and how soon ill-effects of the herbicides may be overcome, and to consider what uses of the herbicide-treated areas may be possible for the benefit of the country and the people. The Committee feels very strongly that this aspect of repair and rehabilitation is a crucial part of the entire work; this feeling was shared by all persons who have been consulted.

b) Variables

The study of the effects of herbicides used in Vietnam is complicated by many factors. Those that are inherent in any ecosystem have already been pointed out in the preceding pages. Other variables reside in the herbicides used and the modes of their use. At least three agents with differing compositions -- "Orange," "White," "Blue" (see Appendix C) -- have been used. All have been used with different methods of application (fixed-wing aircraft, helicopter, ground vehicles with high-pressure spray attachments, backpack sprays) and with different objectives (defoliation for reconnaissance and surveillance, defoliation for protection of routes of communication on land and by water, defoliation for improved vision and lines of firing around army bases, crop destruction, accidental dispersal, dumping, and perhaps others). Numbers and quantities of treatment have varied, ranging from single light sprays as a result of wind drift from defoliation missions, over the regular application by fixed-wing aircraft, to very massive local treatments as a consequence of total or partial dumping of the load of an aircraft, because of failure of or damage to the latter. The doses used in regular fixed-wing aircraft missions exceeded those used for nonmilitary purposes by about an order of magnitude; doses delivered to dump areas were greater by at least another order of magnitude. Herbicides have also been sometimes used in combination with a variety of other weapons having direct and indirect ecological effects of their own that may interact with the effects of herbicides: high explosive, fragmentation and anti-personnel bombs, artillery, removal of vegetation by means of super-bulldozers (Rome plows). Bomb cratering is evidently very extensive in parts of the country; an influence on the ecological effects of herbicides is not known but conceivable.

Finally, herbicides have been applied, deliberately or accidentally, over a wide series of environmental types, including mangrove, several types of forests, upland rice farms, and probably, at least accidentally, onto heavily (built-up) populated areas. They have impinged on an as yet no fully determined number of human land-use types, probably including woodlands used for lumber, firewood and charcoal, and for gathering wild food and other products; house and kitchen gardens; uplands used for shifting cultivation of rice and other field, garden and tree crops; transportation routes cross-cutting all varieties of terrain and land use; and military bases in a variety of lowland and upland conditions.

c) Selection of objectives

With the complexities and variables discussed in the two preceding sections, the research design begins to look complex and time-consuming indeed. It was therefore necessary to select objectives that could be studied in the time and with the support available, and would yield the highest return in terms of understanding herbicide effects and their repair. The following areas were chosen for study:

- (1) Herbicide, agriculture and animal husbandry studies, with some related toxicological studies, mainly on dioxin
- (2) Soil studies

- (3) Studies of natural biological systems
 - i -- Mangrove
 - ii -- Semi-deciduous forests: disturbed and undisturbed

- (4) Studies in human ecology
 - i -- Medical effects
 - ii -- Epidemiological-ecological effects
 - iii -- Socio-economic and psychological effects

The Committee is of the opinion that these study areas cover the most important problems raised by the military use of herbicides in Vietnam, that is, problems that concern the major ecosystems affected by herbicides, including humans, that may have the longest-range consequences, and that have aroused greatest public concern in the United States and outside. The localities that will be covered under this plan of study should include those likely to have been maximally affected and to have suffered long-term if not permanent consequences; they should, to the extent possible, be typical of widespread situations and also representative of situations, irrespective of their ecological or environmental character, where people, crops and livestock may have been heavily exposed; they would include crop lands, plantations, and if practical gardens and other small cultivated plots where it may still be possible to assess direct herbicide effects and where persistence of the agent may be a particularly critical problem, as well as areas where defoliation may have had maximum, although unintentional, beneficial effects (clearing of land for crop production).

II. Guidelines

The study areas selected have many cross-connections. Thus herbicide (residue) and soil studies are clearly interrelated, and both are connected with studies on the natural biological systems and on agriculture; the epidemiological-ecological studies are in turn closely connected with the studies on ecological changes in the natural systems. On the other hand, each of the study areas has its specific problems and approaches; this is particularly true of the medical and the anthropological (socio-economic and psychological) areas that represent a relatively separate complex of problems. It is therefore difficult to develop guidelines that will be equally applicable to all study areas. Nevertheless, and bearing in mind that a given guideline may apply to one study area much more than to another, the following guidelines should help to maintain consistency in the work on the various problems:

(1) In order to obtain information on the time sequence of herbicide induced changes, studies will be carried out as much as possible on areas that were sprayed at different times, starting with the most recent spray missions and working backwards to the earliest ones. (The first missions in Vietnam were flown in 1962, following some test missions in 1961; large-scale herbicide application, including all fixed-wing aircraft sprays, was terminated in December 1970.) As a supplementary effort along this line, the Committee intends to inspect other sites where herbicides have been applied on a relatively large scale and under tropical or subtropical conditions. The number of such sites is considerable but most of them seem of little use for our purposes, because of different climate and vegetation, a scale too small for meaningful comparison, or incomplete data. The most promising ones are in Thailand and Puerto Rico, where the Department of Defense has carried out relatively extensive test sprays, and Hawaii, where herbicides have been used extensively to convert jungle into pastures.

(2) Projective studies will employ two principal approaches:

- i -- extrapolations from the time-sequence studies described under item (1);
- ii -- experimental studies, mainly planting of selected species.

In areas with relatively light herbicide effects, the extrapolative approach may permit rather accurate estimates of the further progress of the induced changes and of the time needed for recovery. In areas with heavy damage, particularly in the mangrove and probably also in parts of the forests, the time period for which data can be obtained -- at the very best, 10 years -- is most likely too short for better than an order of magnitude of time estimate. It is particularly in these areas that the replanting approach should be useful. The limitations of such experiments are quite clear to us. Even successful replanting of mangrove seedlings in a heavily damaged mangrove does

not mean, of course, that the mangrove is going to be ultimately restored to its original condition. Nor would a successful planting of vegetables on the site of a destroyed forest mean that this site should be converted to vegetable plantations. But such results would indicate that the damaged ecosystem is not irretrievably lost to the ecology and economy of the country; failure of replanting would indicate existence of adverse factors not yet understood and would point up the need of more studies. The replanting approach may be particularly useful also in sprayed agricultural areas, as an assessment and a demonstration of the usefulness of such areas.

(3) It is obvious that undisturbed areas should be studied as controls, and that such control areas should be selected to be as close as possible, spatially and with respect to their climatic, physical and biological conditions, to the test areas. In addition, however, at least in the major natural biological systems to be studied, particularly the forests, efforts should be made to include in the studies, areas that have been disturbed in other ways: by clear-cutting, bulldozing, fire, bombing and perhaps otherwise. This should help to pinpoint the specific effects of herbicides, and may provide some information, although probably only of a preliminary nature, on interactions between herbicide and other war-related effects.

(4) Particularly in the natural biological systems, close attention should be directed at the condition of the system before spraying with herbicides (and before any other war-related disturbance) -- whether it is in its natural "primary" condition or whether it has been previously disturbed in some manner, such as by shifting cultivation, extensive logging (especially so-called high-grading, where the valuable timber species are removed totally while less valuable species, vines, etc. are left to take over), or other. The effect of herbicides on primary forest may be rather different from that on forest already heavily disturbed; preservation of primary forest is of particular significance both for ecological and economic reasons.

(5) Parallel with the field studies, literature studies, designed to obtain further data on effects of herbicides under tropical conditions, will be continued. It should not be forgotten that herbicides have been used in the tropics and subtropics also in peacetime; in underdeveloped countries, there is considerable interest in continuing and expanding such uses. Comparisons of available information on this kind of application and the military use in Vietnam should help to bring both aspects into better perspective. Some information, particularly on contaminants and on degradation, will be sought from the manufacturers of the agents and from other sources.

III. Some Considerations of Strategy

Referring, again, to the complexities inherent in the study the Committee has decided -- as already mentioned -- to carry out the work in two stages: a reconnaissance survey designed to pinpoint problems and localities; and a longer-range study the details of which will be determined using the results of the reconnaissance study.

a) Reconnaissance stage: site selection

The main objectives of the reconnaissance stage will be twofold: firstly, to identify the most suitable localities (sites) for the longer-range work; secondly, to obtain an idea of the range of variables that may be encountered. The details of the approaches will differ, depending on the study area concerned; in particular, whether the work is to deal with nonhuman subjects or with humans. However, the following outline should convey the overall rationale.

The first source for site selection -- and for most purposes the principal one -- are the records of herbicide use that have been maintained by the Department of Defense for all airborne missions (fixed-wing aircraft and helicopter). Using these records -- a large part of which has been computerized -- the spray missions can be printed out on overlay maps, according to such criteria as type of agent used, date of spray, objective of mission (defoliation or crop destruction). These overlays, in combination with vegetation maps, should permit us to select herbicide treated areas in different ecosystems, according to a time scale, to the extent of treatment (single or repeated sprays, dump sites), and other criteria that may be of interest. The selected areas will then be inspected from the air, and examined on the ground. By this process it ought to be possible to identify suitable sites and conditions necessary for the comprehensive study.

The second source for site and sample selection will be records and other information from local sources. This may include hospital records, records of midwives, records of herbicide damage claims submitted and approved, information from American and Vietnamese source persons (agricultural advisers, medical personnel, officials) and any other information that can be obtained at the country, province, district and village levels. This kind of information should be particularly useful in the study areas dealing with humans and should help in identifying areas where humans may have been exposed to herbicides on a substantial scale, with a minimum of other disturbances such as resettlement of populations. The information may be useful also in certain other study areas, particularly those dealing with herbicide damage to crops and livestock.

b) Reconnaissance stage: other activities

Along with the site selection, some sampling, particularly of soil for residue and preliminary fertility analyses, and some observational as well as experimental studies will be carried out, focusing attention on extreme situations. Thus, soil for herbicide residue analyses will if possible be sampled from recent dump sites, since the prospects of finding substantial

levels of persisting herbicides are obviously greatest here. Should dump sites not be available because of problems of identification, security or other circumstance, search would be shifted to areas of recent multiple sprayings. For studies on ecological effects in natural systems, sites will be selected representing heavy treatment and no treatment. Observations will be made on the extent of destruction, presence or absence of recolonization from seeds and of regeneration by vegetative means, invasion by "foreign" species, and signs of erosion. Experimental studies will consist of belt transects designed to determine species diversity and condition of the plants (trees), and sampling and subsequent analysis of soil, water, organic matter, aquatic microorganisms (plankton) and possibly fish. The objective is to bracket the range of situations that will have to be taken into account in the main or longer-range studies.

c) Long-range studies

The results of the reconnaissance studies will permit, it is hoped, a much more precise and specific planning for the main part of the work, the longer-range studies, than is possible at present. For example, if no herbicide residues should be found in the soil of recent dump or other heavily sprayed sites, further analyses can be limited to spot tests in soils, perhaps some analyses of persistent plant material and plant products (concentrates, oil) -- if these can be related to sprayed localities -- and analyses of animals high in the food chain. More effort could then be directed to field experiments with various agri- and horticultural crops in defoliated areas. If herbicide residues are discovered in dump or other heavy-treatment areas the amounts found should still provide a very useful guide to the concentrations at which further tests would have to be aimed. In principle, while the reconnaissance studies are designed to identify the extremes of the spectrum of possible effects and while the information will be of a semiquantitative nature, the main or longer-range studies will use quantitative approaches, as much as possible, both with regard to the "timing" of the effects (that is, analysis of sites sprayed in a sequence of years) and to the parameters investigated, and will place special emphasis on repair and rehabilitation.

d) Cooperation with Vietnamese

The study will center on effects of herbicides in Vietnam. Thus, it is almost axiomatic that staffing and administration should include Vietnamese. It will be impossible to carry out the longer-range studies without Vietnamese collaboration, and it is the Vietnamese people who must live with the results of defoliation and who, we hope, may derive some benefit from the results of the study. Some Vietnamese personnel may have to be given special training for work in various specific aspects of the study. Some of this can probably be done in Vietnam; for other, they may have to be brought for two to four weeks to a laboratory in the United States.

IV. Some Perspectives

Because of the complexity of the study as a whole, the Committee wishes to point out that, whereas in some study areas or problems it should be possible to arrive at reasonably specific answers, in many others the most that can be expected is a better definition of the problem and an indication of the direction or directions in which further work should go.

a) Studies on nonhuman subjects

First considering studies on natural ecological systems, it appears on the basis of all available information that large areas of mangrove have been heavily damaged if not outright destroyed, and that there is little if any evidence of natural recolonization in this ecosystem. If soil analyses should show persistence of the herbicides it would be useful to perform experimental tests on the sensitivity of mangrove species (which is not well known) and thus obtain a firm basis for further strategy in this system. If residue analyses are negative, immediate planting of mangrove seedlings of several appropriate species should give rapid indications of the possibilities of repair through this direct and simple means. Similar attempts should be made, as mentioned earlier, in forests to determine the ability to replant and regrow what appear to be especially sensitive and economically and ecologically important species such as dipterocarps, and perhaps to determine ways of controlling the growth of bamboo and grasses such as Imperata cylindrica which, at least according to some information, are thought to "take over" defoliated areas and adversely affect natural regeneration. But to determine the consequences of restoring or not restoring mangroves or dipterocarps -- quite apart from the political problems involved that will be touched upon later -- would be a much longer task. Consequences in these two examples might include: effects of presence or absence of mangrove on erosion of the shore line; ability to use defoliated mangrove areas for agriculture or other human-beneficial purposes, effects on understory plants of presence or absence of dipterocarps. Natural succession in dipterocarp forests is poorly understood. As already pointed out, in areas with heavy damage, that is areas where the herbicides have been applied at particularly massive levels, we do not expect more than to arrive at order of magnitude estimates on recovery, and perhaps to be able to say that some sort of restoration is (or is not) possible. To analyze the chain of effects of the application of such massive doses of herbicides in quantitative, precise terms requires systematic longitudinal observations with special emphasis on floral and faunal successional sequences in treated and untreated areas and large-scale experimental restoration studies with a wide range of variables and under a wide range of conditions, and most probably including the establishment of reserve forests and similar measures which transgress the confines of physiological and ecological work. It is clear that this is outside the charge, the time limits, and the financial resources of this Committee.

b) Studies on humans

The situation in those areas that deal with humans and quite especially in

the areas of socio-economic and of psychological effects is particularly difficult, for two reasons. Firstly, it must be kept in mind that many things have happened to influence and alter human lives in Vietnam simultaneously with the military use of herbicides: increase of population, relocations of populations, urbanization, changes from subsistence agriculture to wage labor, plus directly war-related phenomena including changes of diet, changes of living conditions, changes of family structure, and direct assault by a variety of weapons. Because of this, it will be extremely difficult if at all possible, and may moreover be meaningless, to divorce defoliation effects on human subjects from the effects of all these other changes.

Secondly, work on humans is long-term work. In the case of the Atomic Bomb Casualty Commission study in Japan, one year was required for preliminary planning and formation of the working team. The situation in Vietnam in 1971 seems far more complicated than that in Japan in 1945, and the planning alone for a comprehensive study of the effects of defoliants could easily take the entire period of time in which the Committee should complete its work. This means that most of the work with humans that can be carried out under this Committee will be not more than a preliminary survey that will hopefully bring into better focus the problems that should be investigated -- and the organizational, logistical and similar problems that may have to be faced in carrying out such an investigation.

c) Conclusions

The foregoing statements should not be interpreted as misgivings on the part of the Committee to embark on its assignment. The sole purpose of the foregoing analysis is to make one point -- however, a very important one. The present study should be considered as a first step. We feel it is definitely a step in the right direction, but it is only one step. It should be followed up by further studies that could pursue and expand those lines of approach that we hope to uncover. They should emphasize longitudinal analyses and include large-scale efforts at restoration or rehabilitation. They should have a longer life expectancy than our enterprise, and as broad a base as possible. For the latter reason, as well as for maximum effectiveness and impact, it seems advisable to include the Vietnamese right from the planning stages of any such studies, and to place the studies on some international basis, e.g. through the United Nations (WHO, FAO, UNESCO), organizations such as the International Congress of Scientific Unions, or perhaps an independent international commission formed for this specific purpose.

V. Some Questions of Policy

a) Political questions in connection with herbicide effects

In developing its plans of action the Committee has been well aware that the use of herbicides in Vietnam was in part an outcome of political decisions and has in recent years become a highly emotional political problem. The results of our study may well be put to political uses, especially since the point at which political questions and considerations begin to intrude on the physiological and ecological ones is by no means well-defined and consistent. We may be able to determine whether and how soon herbicide damaged mangrove or the semi-deciduous forest can be restored, and whether certain crop plants can be grown on such sites in place of the original vegetation. But the decision whether mangrove or forest should be restored, or should be used for other purposes involves clearly political considerations. The Government of the Republic of Vietnam may have plans for areas that have been exposed to herbicides, e.g. for the establishment of agro-villes, resettlement programs for veterans, and mechanized commercial agriculture and forestry. FULRO (a Montagnard organization) and the National Liberation Front may have their own plans. Once more, the problems become particularly complex where human aspects are involved. People may be unable or unwilling to return to their conditions prior to the war and the use of herbicides, even if we could show that the ecosystem on which they were depending could be restored. Will the Montagnards -- quite likely the population group that has suffered as much or more than any other from the effects of herbicides -- want to, or be able to return to slash and burn agriculture after they have been exposed to more modern conditions? The psychological responses to herbicides, upon which we have touched at an earlier occasion, would of course also enter into this picture.

While the Committee realizes that political uses of its work cannot be avoided or prevented, it feels that they can easily result in an impairment and negation of the scientific results of this work. It therefore plans to follow certain policies of its own; it furthermore insists that certain provisions are included in the Phase II Contract with the Department of Defense; and it suggests certain public relations steps, all of which should have the effect of minimizing uses and abuses of the Committee's results and conclusions for political purposes.

b) Committee policies

The work of the Committee will be strictly limited to the objectives stated in Section 506(c) of Public Law 91-441, that is physiological and ecological effects of herbicide application, primarily in Vietnam. Any conclusions and judgments that carry political implications or involve political decisions will be excluded. For example, in studies on mangrove or semi-deciduous forest we will ask, can the mangrove or the forest be restored?; how long may restoration take?; can it be enhanced and by what measures? We will not state whether or not the mangrove or the forest should be restored, except if restoration is justified on purely natural reasons (e.g., if the mangrove should be essential for prevention of coastal erosion). We shall

also study whether some plants that may be useful for the ecology and the people of the country can be grown on defoliated mangrove and forest areas, and under what conditions or natural premises. But we shall not try to tell the Vietnamese whether to grow these crops, and which. In specific cases, most probably in the first place again those involving human subjects, it may be difficult to find the precise dividing line, but on the whole this approach should help to avoid involvement in problems in which, for one thing, the Committee does not feel at all competent.

c) Provisions to be included in the Contract

(1) Planning, direction and execution of the study are the exclusive responsibility of the Academy; so is the selection and appointment of all scientific and technical personnel needed to carry out the work.

(2) During the course of its work, the Committee will continue to have, through the Chairman and the Staff Officer, access to any information in the hands of the Department of Defense that may be pertinent for its work. The decision on this latter point rests with the Committee. Classified information needed for inclusion in or as backup material for the final report will be declassified by the DOD.

(3) Ownership and control of all data resulting from the studies resides in the National Academy of Sciences, including full rights of publication. To assure Committee members of freedom of publication, they should also be given rights to publish the materials they have gathered, after completion of and with credit to the study but otherwise subject to no limitations except as outlined below.

(4) Statements of individuals are privileged communications and are not to be disclosed to anyone without prior consent of the respondent, under circumstances in which he or she could be identified.

(5) Data from surveys should be handled as "pooled" data unless permission has been received to make direct attributed quotations.

(6) The Contract should state explicitly the intention to include studies on repair and rehabilitation. (We suspect this is neither legally binding, nor legally limiting, but it should make the study more convincing.)

(7) Every effort should be made to safeguard the privacy and welfare of all respondents in the study, regardless of their political positions or their responsibilities regarding defoliation. It should be clear to respondents that it is not and cannot be the task of the Committee to assign blame or establish guilt.

(8) All publicity should be in advance agreed upon and coordinated between the Contract partners, i.e. Department of Defense and NAS. It should always precisely reflect the basic set-up of the study: origin in Congress; contract with DOD; a Committee appointed by the President of NAS; planning and execution of the study the exclusive responsibility

of this Committee; all personnel working on the study selected and appointed by, and responsible to the Academy. It should also be made clear that the Committee has no objectives of a political or military nature; quite specifically, it is not concerned with an evaluation of the military usefulness of herbicides, and is quite independent from any other group that may be studying this particular question or any other political or military issue related to herbicides.

Phase II - Reconnaissance Studies

I. Survey of Activities

The reconnaissance stage of Phase II was carried out in the period September 16 to October 23, 1971. A. Lang, Committee Chairman, and P. Ross, Staff Officer, arrived in Saigon on September 16, established contacts with the U.S. and Vietnamese military and civilian authorities necessary for conducting further work; analyzed the information on location, time and nature of the spray missions that have been flown, particularly since 1965; and made extensive helicopter flights over those parts of the country where herbicides have been used on a major scale, taking a considerable number of photographs. A list of these overflights follows:

- 1) Agricultural regions in the Mekong River Delta (herbicide applications mainly along rivers and canals); mangrove along an arm of the Mekong River; the Plain of Reeds in the southwestern part of the country, near the Cambodian border (herbicide sprays mainly in 1968, with agents Orange and Blue);
- 2) U Minh Forest on the western coast of the southernmost part of the country and the mangroves of the Ca Mau region, near the Vietnamese naval base Nam Can ("Solid Anchor") in the southernmost tip of the country (sprays mainly in 1967-69, agent Orange; some in early 1970 with agent White);
- 3) Mountain regions in the northern part of the country in Quang Nam, Thua Thien, and Quang Tri Provinces where crop destruction missions with agent Blue have been flown in the valleys in 1968-69;
- 4) The mangroves in the Rung Sat Special Zone, southeast of Saigon in the Saigon River Delta, and forests in the so-called War Zones C and D, north and northeast of Saigon (in either region, heavy sprays with Orange and White between 1965 and 1969); also, rubber plantations near Quan Loa (claims of herbicide damage by drift).

(Flights over the Rung Sat mangroves were later also arranged for several Committee members.)

On September 27 Lang and Ross proceeded to Bangkok, Thailand, where they met with seven members of the Committee (Blackman, Drew, Fryer, Golley, Richards, Tschirley, Zinke), and the group, accompanied by Dr. Charles E. Minarik, Director, Plant Sciences Laboratory, Department of the Army, and Dr. Roy Linsenmyer, Science Advisor, CINCPAC, visited and studied some of the test plots for herbicide application that had been established by DOD near Pran Buri in 1964-65.

On October 5 the entire group travelled to Saigon; the various members left, depending on their commitments, between October 13 and 23. During this stay, the group made the following studies in the field:

- 1) A reconnaissance trip by boat along the waterways in the Rung Sat mangrove region, with a short foray on land near Loi Giang on the Scong Dong Tranh channel, near the center of the region and a site heavily sprayed with Orange and White between 1965 and 1969;
- 2) On the ground, visits to
 - a) mangrove in the Ca Mau region, near Nam Can: one site that had been sprayed with agent Orange in 1968, and one with agent White early in 1970, plus adjacent unsprayed "control" sites (2 days);
 - b) sprayed (agents Orange and White, 1969) and unsprayed forest sites near Dong Xoai, Phuoc Luong Province, 55 miles north of Saigon (2 days);
 - c) three dump sites (that is, sites where an entire planeload of a herbicide had been released within a time of ca. 30 seconds, because of aircraft trouble) near Bien Hoa, north of Saigon (one day). One site - agent Blue, November 1968; two sites - agent Orange, December 1968 and April 1969.

In Phan Buri and on all field trips in Vietnam, soil samples were taken for herbicide analyses (total, ca. 100 samples) and for studies of fertility factors (ca. 100 samples). These samples have been analyzed for residues in the laboratories of the Weed Research Organization, Agricultural Research Council (Great Britain), Oxford, England (Director, Committee member J. D. Fryer); for soil fertility in the laboratory of Committee member P. Zinke, University of California, Berkeley. Also collected was plant material from different sites, and water and plankton samples in one of the canals in the Rung Sat mangrove area on the boat trip through this region. Finally, qualitative surveys and a few at least semi-quantitative transect determinations of vegetation were made.

In addition to the field work, more contacts were established, particularly with personnel in USAID, CORDS and ARPA; these will be important sources for information on such matters as agricultural effects of herbicides, effects on forests and forest utilization, and effects on people. Cooperation with Vietnamese scientists was also established and formalized; this will be reported separately (see below, section V).

A separate field trip, which also formed part of the Phase II reconnaissance work, was undertaken on November 21 when, following a Committee meeting in San Juan, Puerto Rico, nine members of the Committee visited herbicide application test plots in the Luquillo Mountains.

It should be pointed out that the reconnaissance work covered only part of the problem areas selected for study, namely those dealing with the

herbicides themselves (residue problem), soils, and natural biological systems (mangrove, semi-deciduous forests). All problems concerning human ecology and also some effects on agriculture had to be excluded because the Committee members most knowledgeable in these problems were not available for this visit and because at the time of the reconnaissance visit we did not have any Committee members in the area of anthropology. In retrospect it appears however that because of the logistical problems to be outlined, it would not have been possible to do, in the time available, more than was actually done. Work in human ecology is to be initiated in the near future; the first question to be considered is how much, if any, of such work is practical under the existing conditions and within the time available.

II. Observations and General Conclusions

In the tropics, what seems a reasonable plan of action at a distance seldom can be accomplished in situ because of various logistical, technical and personnel limitations. Obviously, in Vietnam, the problems are greatly aggravated by the fact that the country continues to be involved in a war, and moreover a war with no clear front lines and no clear distinctive marks for friend and foe. The visit to the country enabled us on the one hand to have a look at those ecological "systems" that we want to study, and to collect some factual information that has helped us greatly in pinpointing certain objectives. On the other hand, we got a first-hand concept of the logistical difficulties under which the studies have to be carried out. In the following, those observations that have had the greatest bearing for the planning and conduct of further studies will be summarized.

1) Factual observations

(a) A very important general reaction one carries away from both aerial and ground inspections is that it is impossible to arrive at meaningful conclusions both from random checks on the ground and from qualitative surveys from the air. The reason is the very great diversity of situations on which the stress by herbicides has been superimposed. In the mangrove, while recovery (meaning both recolonization by seedlings and regeneration of surviving individuals) is on the whole limited and slow, one can observe in very close proximity, definitely within a site that was subjected to the same herbicide treatment, areas where seedlings are as dense as in so-called pioneer mangrove, and areas with almost no sign of vegetation. If one happened to see only the latter situation he could make a persuasive case for complete and rapid recovery; if he saw only the other he could make an equally good case for complete lack of recovery, i.e. total and permanent destruction of the mangrove. In the semi-deciduous forests, the diversity is even greater. In part, this is due to natural factors (differences in surface physiognomy, proximity of rivers, and other); in part, to disturbances that have been introduced, both before and after herbicide spraying, by logging; or slash and burn agriculture, and perhaps other forest uses. In the forest region near Dong Xoai the Committee inspected two sites, one sprayed, one unsprayed, ca. 10 miles apart. The first site had rather dense tree stands, dense undergrowth and very little if any bamboo; the other had very few tall trees left and very vigorous development of bamboo. The first site was flat and with no nearby river; the second hilly and next to a river. Both areas were heavily disturbed forest, as evidenced, for example, by the complete absence of Dipterocarpus species, the most characteristic trees in primary forests of this part of the world. However, degree and nature of disturbance - aside from the herbicide treatment - were different. Part of the difference must have existed before the spray. Thus, the bamboo were of a size that could not have developed in a matter of two years (the spray missions were flown in 1969-70). Part may have been introduced afterwards, as suggested from the different degrees of

logging that was going on in the two sites. In some parts of the country the situation has been aggravated by military activities other than herbicide application, mainly, clearing vegetation by mechanical means (Rome plows), and heavy bombing. The Committee feels strongly reinforced in its belief that a meaningful analysis of the effects of herbicide application in Vietnam requires objective quantitative evaluations. This holds in the first place for the natural vegetation but by extrapolation undoubtedly also for any other aspect of herbicide effects when herbicides have been used on the scale and in the amounts they have been used in Vietnam. In studies on natural biological systems, the best approach would be to conduct extensive on the ground studies of plants, animals and soils, using the theoretical designs and quantitative techniques available for such work. Special care would have to be directed at a representative but random selection of sites and it would be optimal of include unsprayed areas, areas subjected to different spray programs, and areas in undisturbed primary forest and in forest disturbed in varying degrees and by different means. If this is not possible - and it is not; see below! - the next best choice is use of techniques that permit coverage of large areas and an unbiased evaluation. The most likely candidate is aerial photography, with flights over a sufficient number of "transects" and followed by visual or even better photomechanical analysis. Other techniques of remote sensing may also be useful.

(b) The visits to the spray test sites in Pran Buri (Thailand) and Puerto Rico were of distinct but limited value. The gains were four-fold: First, the visit to Pran Buri offered the Committee members an opportunity to carry out "dry runs" of their projected studies under comparable conditions of vegetation and climate but without concern for security problems, a severe handicap in Vietnam (see below). Second, the analyses of soils from the Pran Buri sites for fertility provided useful data and some will, in fact, be continued. Third, trees at the Puerto Rico site may be useful for preliminary studies on wood cores, as a basis for efforts to assess the effects of herbicides on the growth of trees that survive the treatment. Forth, it became apparent, particularly at Puerto Rico, from inspection and from reports by the local forestry scientists, that it may take a herbicide-treated tree as many as five years to die. This lag in the killing effect seems not to have been properly appreciated. Assessment of damage after short periods of time (1-2 years) may thus fail to give a complete picture; repeated assessments over a five- or six-year period would probably be optimal when they are possible. The limitations on the value of the test sites for our study were threefold. First, as may be anticipated, vegetation and climate in Pran Buri and Puerto Rico, while having similarities with Vietnam, also exhibit marked dissimilarities. The species composition in Puerto Rico and in Vietnam is quite different; the rainfall in Pran Buri is only little more than half that in Vietnam. Second, the forest of the test sites in Pran Buri was secondary forest (no dipterocarps), i.e. had been subjected to considerable disturbance already before the sprays. Since the disturbance factors are unknown it is very difficult to apply any data to the situation in

another forest. Third, disturbance has continued since the test sprays: a road and a canal have been built through one of the areas; farmers (squatters) have moved in and put part of the land under cultivation - apparently, with good success -; charcoal was being made; and the Thai Army seems to use the region for fire practice and other purposes.

(c) The overflights that we have made have shown that in the mangrove there are still areas that show very little if any vegetation. In the semi-deciduous forests, in contrast, no such areas were observed. Even in regions, such as parts of War Zones C and D, where the large trees to a large extent have been apparently killed, there was heavy growth on the ground, and it was practically impossible to see the soil. It seems that rapid re-vegetation is taking place, but the nature of this re-vegetation is not known. This places great urgency on the studies for the early stages of re-vegetation are very important for understanding its course, that is, successional trends, and even more important if it should be desirable and possible to influence this trend.

(d) Among all soil samples that were analyzed for this purpose, herbicide residues were found only in samples from one location. The herbicide was 2,4,5-T, one of the components of agent Orange, and the site was in a heavily sprayed area of the Rung Sat mangrove. The level found was low - about an order of magnitude below the minimal level resulting in a biological response in the most sensitive test plants. This finding should not be generalized to mean that the herbicides have largely disappeared from the soils in Vietnam since our checks were spot checks. But it does indicate that degradation has made considerable progress, and that it may be difficult if not impossible to determine with any degree of accuracy both the speed of degradation, and its kinetics. These are, however, parameters that are very important to know, both in order to understand the effects of herbicides on vegetation and in order to determine the re-use of treated lands.

2) Logistical problems

(a) Difficulties were encountered in identifying suitable sites for studies. Our choices were based on the spray missions data, as printed out for us by the computer (see above, p.8), combined with information from vegetation maps for Vietnam, plus any other information, e.g. from local sources, military personnel familiar with herbicide missions, etc., that could be found. For the mangrove, this procedure seems in general satisfactory. But in the semi-deciduous forest, it may lead one astray. The main reason is the great diversity that can be found in this ecosystem even within quite a limited area and that has been mentioned above (section 1, item (a)). In addition, the computer print-outs of the spray missions are not always as exact as they may appear. They are based on the coordinates of the starting and the end point of the mission and show the mission almost with no exception as a straight line. In very many cases this is correct, but in some when a mission was flown along a road or a waterway, it followed the course

of these and the direction between the two endpoints was changed. The sprayed area in Dong Xoai that was selected for a visit on the ground, not only differed from the control (unsprayed) area in physiographic characteristics and degree of pre- and post-spray disturbance, but whereas from the mission print-outs it appeared to be within the confines of a single treatment with agent Orange, it seems in fact to have been on the boundary between swathes treated with Orange and White. It must be said that in this particular case "experiment" and "control" were as poorly matched as one can imagine, and this was the most serious gap in our reconnaissance observations. It is quite possible that a few miles away a much more suitable area could have been found, but the information at hand was not enough to be certain, and the security situation, which will be discussed in the next section, did not permit to explore this on location. In one case, the information from the military records appears to have been entirely erroneous. We landed at a village (Thanh Binh, Binh Duong Province), which according to these records had been the site of a dump of agent White, but the village chief denied that there had been a dump (or indeed any herbicide damage except possibly a little from drift). The chief had been in his post at the time of the alleged dump; he was familiar with herbicide effects as he knew of another, near-by dump site we had visited before. There appears to be no reason for him to deny a dump if one had indeed happened. Possibly, there was a coordinates error in the original flight report by the crew of the plane. In future site selections, it will be necessary to make the ultimate decision on the basis of direct overflights, possibly combined with aerial photography or some other remote sensing investigation, and where possible to seek corroboration from local sources. The latter must still be done in the case of all genuine dump sites that we visited during the reconnaissance trip.

(b) The main logistic problem, however, remains security. For each of our on the ground forays into mangrove or semi-deciduous forest the selected area, about one square kilometer, was first "swept and cordoned off by two companies of Vietnamese troops. Two hours later we could enter the area accompanied by another dozen or more U.S. and/or Vietnamese soldiers. If, as it happened with the sprayed area near Dong Xoai, the selected site turned out to be not suitable it was obviously impossible to repeat the maneuver on the same day. A visit to a near-by site would require the same amount of administrative and military preparations. The time that could be spent on the ground was limited, on the one hand by those preparatory security measures, on the other by such factors as the schedule of helicopters, which were a major means of transportation but which had to return to their base by a fixed time, also because of security. The time available was in fact in most cases sufficient for the studies we wanted to make, but in one case (one of the dump sites) we had to pull out before completing sampling. But this security (or nonsecurity) situation imposes severe limitations on the work of the Committee. It seems clear that work on the ground, particularly in semi-deciduous forests, will have to be considerably reduced as compared to our initial plans. It will also have to be done

mainly in locations near so-called population centers, that is, military bases and villages - even though this in itself is a disadvantage since the degree of disturbance increases with the proximity to such centers, because of local herbicide applications around military bases, as well as of logging and other human activities in the forests. Even in such areas, work will have to be limited to short time periods, not exceeding a day and at irregular intervals, since any regularly scheduled activity at a given spot is bound to attract attention and may cause aggregation of unfriendly forces. In view of these difficulties and limitations the question may be asked - and it has been asked by the Committee - whether any useful results can be obtained from studies particularly in the semi-deciduous forests, or whether it would not be preferable to defer any work until peaceful conditions have been re-established in the country. The Committee feels however that at least an effort should be made, for the reason stated under section 1, item (c), that is, the apparent rapid changes that are occurring in the forests and that make it most desirable to obtain some understanding of the nature of these changes and of their possible consequences. Delaying studies for an unknown period of time may deprive them of a firm basis and seriously reduce their usefulness. The Committee is well aware that the results may be far from perfect.

III. Modification of Work Plans

After returning from the reconnaissance trip, the Committee held a meeting at San Juan, Puerto Rico, on November 19-21, 1971 and reviewed its plans for the long-range studies in the problem areas of herbicides, soils, agriculture and natural biological systems in the light of the experiences gained in Vietnam and Thailand. As mentioned before, it also inspected herbicide spray test sites in Puerto Rico. The modified work plans are summarized in the next section. Since work on herbicides, soils, and agricultural problems is closely inter-related, these areas have been combined into one section. The study plans in human ecology are not included in this survey since they have not been substantially changed from the original plans, and are still tentative. In the problem areas of herbicides, soils, agriculture and natural biological systems, the principal modifications fall into three general categories:

- 1) Because of the limitations for on the ground work imposed by the security situation, both in large parts of the mangrove and throughout the semi-deciduous forests, emphasis will be placed on interpretation of aerial photography and if possible and desirable other methods of remote sensing, and complemented with a number of ground checks. Computerized listing of the Department of Defense's stock of aerial photographs of Vietnam will be utilized along with and in a similar manner as the spray mission tapes, making it possible to obtain parallel information on all herbicide applications in a given site, as well as all photographic surveys that have been made of this site, both before and after the spray missions. Where necessary, the photographic information on hand will be supplemented by additional photography. In this manner, it should be possible to obtain important data on total areas treated; degree of kill; extent and progress of revegetation including eventual changes in the major species composition, for example, the development of bamboo in treated areas of the forests.
- 2) Modelling will be useful as another tool to help us understand the interactions in the natural biological systems. Models are extensively and profitably used in ecology; they permit an overall assessment of the productivity and certain other characteristics of an ecosystem, as well as predictions of the trend of changes caused by some external impact, in our case, the herbicides. Some information that is required to build the models is available or can be readily obtained from existing data (e.g., solar energy input from meteorological and climatological data). Other can be safely adopted from existing information in other parts of the world (e.g., productivity of mangroves and tropical forests). Some will have to be determined on the spot, but most of these studies will be made also for other objectives. Modelling may be able to assist in the assessment of the impact of herbicides, parallel to more direct assessments by the more conventional methods, in our case on the ground studies and photogrammetry. It may also pinpoint problems for further studies.

- 3) Because the degradation of herbicides in the forest soils and the growth of vegetation in sprayed areas have clearly made considerable progress, experimental work is planned to provide information on the early stages of herbicide degradation. This will consist of limited application of herbicides to selected test areas, followed by monitoring the herbicide levels in the soil, soil fertility, and survival or recovery of vegetation over a period of one year. In addition, planting experiments with selected species will be made to determine directly when treated soil can again sustain vegetation. To ensure success of this relatively long-range work it will be carried out not only in Vietnam, but in another country with comparable conditions. It is clear that these experiments must be carried out with maximum care and will be limited in extent. Because of the importance of information on the early events after application of a herbicide for an understanding of the longer-range effects and the possibilities for recovery, these studies are however considered as an essential part of the overall plan.

IV. Work Plan Outline for Further Studies

A. Studies of Herbicide Residues, Soils and Agriculture

1. Substantiation of dump sites studied in reconnaissance phase
 - a. Aerial photography of sites
 - b. Interview of local people
2. Field trials: Treated and controls in Mangrove sites - Rung Sat and in other countries
 - a. One acre plots each treated with Orange and White, 3 gal./acre
 - (1) 10 soil samples for residue studies, before treatment, one month and six months after treatment
 - (2) 100 surface samples for fertility studies, before treatment, one month and six months after treatment
 - b. Cleared plots treated with Orange and White
 - (1) 30 plots, 65 x 65 feet, treated with 0, 3 and 9 gal./ acre
 - (2) Soil samples for residue studies before treatment, one month, six months and nine months after treatment
 - (3) Biomass studies of cleared vegetation
 - c. Two half-acre cleared plots treated with Orange and White
 - (1) 28 plots, 6 x 50 feet
 - (2) Spray rates 0.0, 0.3, 1.0 and 3.0 gallons of agent per acre
 - (3) Soil samples for residue studies before treatment, one month, six months and nine months after treatment
 - (4) Crops planted after treatment of plots: Rice, corn, peanuts, sweet potatoes
 - (5) Crops planted one month, six months, nine months after treatment
3. Field trials: Treated and controls in forest sites - rubber plantations in Vietnam, and forests in other countries
 - a. Same as 1.a & 1.b
4. Soil sampling on treated sites in Pran Buri, Thailand
 - a. 100 samples in each of two plots for fertility element analysis
 - b. Samples in profile across calibration grid

5. Information on agricultural problems

a. Interviews with Agricultural Advisors and local farmers

- (1) Information on extent of damage
- (2) Information on growth of crops introduced on sprayed areas

b. Inspection of crops for phytotoxic symptoms

- (1) Areas sprayed, Rome plowed and planted along roads
- (2) Upland, paddy rice areas sprayed with Blue
- (3) Mangrove areas: Rung Sat, Ca Mau

6. Literature survey on laterization of tropical soils

7. Literature survey for effects of herbicide on domestic animals

B. Studies of Natural Biological Systems

1. Mangrove

a. Weed competition on the effect on recolonization of defoliated areas by mangrove species

- (1) Quadrat studies in Rung Sat
- (2) Aerial photography

b. Availability of mangrove seeds for recolonization

- (1) Quantity, viability, and seasonality of mangrove seed in Rung Sat
- (2) Distributional patterns of seeds

c. Extent of recolonization and regeneration

- (1) Aerial photography and ground verification in Rung Sat and Ca Mau for extent and rate of recolonization and regeneration
- (2) Transects in defoliated areas for supplementary information

d. Treatment of one acre plot of intact mangrove - correlated with soil and residue studies

- (1) Differential susceptibility
- (2) Recolonization and regeneration

e. Field trials, planting experiments in Rung Sat

- (1) 100 seeds of each mangrove species
- (2) Measurements on survival and growth, one month and six months after establishment

- f. Fertility indices in estuarian areas of Rung Sat
 - (1) Measurements of pH, salinity, plankton, small fish, mangrove seeds
 - g. Modelling studies of the ecosystem, using input from above, especially f.1
2. Semi-deciduous forests
- a. Analysis of vegetation by aerial photography
 - (1) Areas analyzed from 1965 to end of project
 - b. Role of bamboo in defoliated areas
 - (1) Literature search
 - (2) Aerial photograph interpretation with ground verification
 - c. Composition of undergrowth
 - (1) Analysis of change in successional vegetation in defoliated areas, if any
 - (2) Seedlings and juveniles by species and number
 - d. Species susceptibility
 - (1) Transects to determine differential species susceptibility and percentage of plant kill
 - (2) Aerial photograph interpretation
 - e. Long and short-term economic impact on forestry and forest products
 - (1) Interviews with local forestry personnel
 - (2) Literature review and on-site investigation of reproductive biology of major species
 - f. Economic analysis expressed in terms of energy loss (or gain) to the ecosystem
 - (1) Data gained from above investigations
 - g. Modelling studies

V. Cooperation with Vietnamese Scientists

As explained earlier, the Committee felt strongly from the outset that cooperation with the Vietnamese scientists was most important, not only because of the direct assistance that they could provide to our work, but also because they may have to continue the studies after the Committee has completed its work. Accordingly, contacts with Vietnamese colleagues were initiated before the first trip to Vietnam, and were pursued upon our arrival in Saigon. In consequence of the contracts that were thus established a Vietnamese National Herbicides Committee has been formed, under the chairmanship of Professor Le Van Thoi, Director of the National Scientific Research Council of the Republic of Vietnam. Its membership is listed in Appendix A-1. Professor Le Van Thoi and another member of the Vietnamese Committee, Professor Pham Hoang Ho, are also members of our own Committee, ensuring close liaison and cooperation. Plans for joint work are already under development. Thus, at least part of the soil fertility analyses will be carried out at the Agricultural Research Institute in Saigon. The experimental studies in Vietnam, described in Section III, item (3) are being planned jointly with Professor Ho. Because of their familiarity with the country, and with logistical and other assistance on our part, the Vietnamese can most probably carry out studies in parts of the country that would not be readily accessible to foreigners. On the whole, the Committee on the Effects of Herbicides in Vietnam feels that the establishment of close cooperation with our Vietnamese counterparts will be of great mutual benefit and is a most gratifying and welcome development in our work.

VI. Acknowledgements

In conclusion of this report, it is a pleasure to acknowledge the generous cooperation that the Committee has received from a number of Vietnamese, American, and Thai personnel which has been essential in the successful completion of the reconnaissance work.

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Saigon

Animal Pathology

REFERENCE COLLECTION

AGRICULTURE	A	PUBLIC HEALTH	L
Tropical		1-General	
		2-Nutrition	
AAAS HERB. ASSESS. COMM.	B	SOILS	M
CACODYLIC ACID	C	Tropical	
CBW	D	SOUTHEAST ASIA	N
1-General		1-Agriculture	
2-Military		2-Anthropology	
CONGRESSIONAL	E	3-Climate	
DEMOGRAPHY	F	4-Forestry	
ECOLOGY & PHYSIOLOGY	G	2,4-D	O
1-General		2,4,5-T	P
2-Nutrient Cycling		VEGETATION	Q
HERBICIDES	H	1-Bamboo	
1-General		2-Mangrove	
2-Ecological Effects		3-Rubber	
3-Physiological Effects		4-Teak	
4-Soils		5-Tropical	
5-Toxicity		VIETNAM	R
6-Tropics		1-General	
MAPS	I	2-Agriculture	
PESTICIDES	J	3-Climate	
1-General		4-Fishery	
2-Mammalian Systems		5-Forestry	
3-Public Health		6-Future Development	
4-Toxicity		7-Public Health	
5-Wildlife		8-Soils	
PICLORAM	K	9-Statistics	
		10-Wildlife	
		WEED CONTROL	S

MILITARY USE OF HERBICIDES

MAJOR CHEMICALS USED IN SOUTH VIETNAM

(U.S. Department of Defense Data)

Agent ORANGE: 2,4-D and 2,4,5-T

Composition: A 1:1 mixture of the n-butyl esters of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid.
Active Ingredients: 4.1 and 4.4 lb./gal.
Application: Undiluted at 3 gal. = 12.3 or 13.2 U./acre. Often applied a second time.
Major use: Against forest vegetation.

Agent WHITE: 2,4-D and Picloram

Composition: A 4:1 mixture of the tri-iso-propanolamine salts of 2,4-D and 4-amino-3,5,6-trichloropicolinic acid in water. (Picloram is the same as Dow Co. "Tordon"; the mixture used is the same as Dow Co. "Tordon-101.")
Active Ingredients: 2.0 and 0.54 lb./gal.
Application: Undiluted at 3 gal./acre.
Major use: Same as for agent Orange.

Agent BLUE: Cacodylic Acid

Composition: A 6:1 mixture of sodium dimethyl arsenate and dimethyl arsenic acid in water. (Cacodylic acid is the same as Ansul Co. "Phytar-560G".)
Active Ingredients: 3.1 lb./gal.
Application: Undiluted at 3 gal./acre.
Major use: Against rice and other food crops.