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ECOLOGICAL IMPLICATIONS OF INSECT CONTROL: AGRICULTURE, PUBLIC HEALTH, AND DEVELOPMENT IN CENTRAL AMERICA

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ECOLOGICAL IMPLICATIONS OF INSECT CONTROL: AGRICULTURE, PUBLIC HEALTH, AND DEVELOPMENT IN CENTRAL AMERICA

A Preliminary Report*

by

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Introduction

Synthetic organic chemicals are being used on a large scale in many less developed countries for both agricultural and public health purposes. In Central America they have been used in record quantities in agriculture, particularly on cotton in the Pacific coast. Synthetic organic insecticides (principally DDT and sometimes dieldrin) have also

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formed the basis of malaria control operations.

This is a report of an attempt (a) to study the present pest and vector control techniques which depend on intensive use of insecticides, and the ecological consequences of this for agriculture, public health and development in the countries involved, and (b) to develop a model interdisciplinary research strategy for a study of complex environmental problems induced by the introduction and diffusion of modern technological innovations, in the context of less developed countries.

The study concentrates on the ecological consequences of cotton pest control in Central America (with special emphasis on Guatemala), and the relationship of these to certain health and nutritional problems in the region. The study is taking place in the Pacific side of the continental divide where one of the most serious crises in the agricultural history of this region is now unfolding, with many public health hazards accompanying it.

Insecticides in less developed countries

In the United States more than one-half of all chemical insecticides used is applied to cotton. For example, in 1964 alone some 65 million kilograms of insecticides were used on agricultural crops in the United States, of which about 55% was applied to cotton (Eichers et al., 1968). In many less developed countries, such as Egypt, Peru and most of Central America, insecticides on cotton amount to virtually all of the chemicals used for pest control. The use of these materials in the less developed countries has in some cases been astronomical. For example, in Nicaragua, during the 1966-1967 season, 15,381,389 liters of liquid insecticides and 2,897,579 kilograms of dusts were applied on 155,000 hectares, i.e., 99.2 liters plus 18.7 kilograms per hectare on cotton fields alone (Smith, 1971).

It is therefore reasonable to assume that the present system of cotton production in most parts of the world is a significant contributor to environmental pollution. In addition to this, there is a growing body of information now available suggesting that the most serious outbreaks of pests occur on the heel of the application of contact-acting insecticides (Carter, 1969; Henkin, 1969; Farvar and Milton, 1969. See especially Farvar and Milton, 1971). The patterns are usually similar, and consist of the following: (a) The use of synthetic organic insecticides leads to an effective disruption of natural biological control agents (other arthropods which are predatory or parasitic to many insects); (b) many of these insects, initially innocuous, thus escape controls and become "unleashed" pests. Many that caused mild damages then become more serious pests; (c) there is a rapid "resurgence" of pest populations soon after insecticide applications, due to lack of natural control pressures; (d) more intensive and frequent applications are then deemed necessary to control the worsened pest problems; (e) the ensuing heavy insecticidal treatments act as a selective pressure favoring those individuals which have the ability to resist or tolerate the insecticides and to pass on this ability genetically to their offspring; (f) the appearance of these resistant strains then requires higher doses or stronger poisons, which in turn aggravate the chain of processes described above.

An example of such problems is the control of the cotton insect complex in the Cañete Valley of Peru (Boza-Barducci, 1959, 1965; Boza-Barducci et al., 1957). According to Boza Barducci, the early insect pests of cotton in the Cañete Valley were certain species of leaf worm, bud weevil, cotton aphid, minor boll-worm, white scale, and cotton stainer. Control of these pests was obtained by naturally occurring predators and parasites, hand collection of the insects and damaged squares, and by use of arsenical insecticides and nicotine sulphate. In 1939 synthetic chemical pesticides were introduced "for cotton pest control by the same methods as those recommended in the United States. (By 1949) resistance had developed among pest populations and insecticides were no longer effective. Several species of little or no previous importance had become major pests, and disastrous crop failures resulted"(Boza-Barducci, 1959; PSAC, 1967).

A new policy was adopted at this time which emphasized selective control of insects with synthetic organic insecticides, cultural control techniques integrated with the chemicals, and the use of early maturing varieties of cotton. These new chemical control techniques gave results that were considered to be very good for the first five years. Good control of aphids, leaf worms, and bud weevils was obtained.

"A decrease in effectiveness of the insecticides was observed after only three (more) years, however, and new insecticides including aldrin, dieldrin, endrin, and parathion were recommended at increasing rates, decreasing intervals between applications, and in mixtures"(Boza-Barducci, 1965; Boza-Barducci, *et al.*, 1957). In some parts of the valley fifteen and even twenty-five applications of insecticides were not uncommon (Boza-Barducci, 1959). After a few years, leafrollers, major leaf worms, mealybugs and leaf perforators had become serious pests. The situation grew steadily worse and resulted in a disastrous crop failure in 1956. At this time, legislation was passed forbidding the use of synthetic organic insecticides in the valley, and there was a return to control methods based on use of biological control agents and cultural practices. Useful predators and parasites were introduced from other valleys of Peru and by foreign importations. By 1958, cotton yields had returned to their former high levels (Boza-Barducci, 1971).

In this case the farmers of the Canete Valley, helped by an awakened group of entomologists, took steps in time to restore the biological balance that existed before the regime of synthetic organic chemicals which caused the 1956 disaster. Not all areas have been as fortunate. Other valleys in Peru, and many areas of Central America, Mexico and the Middle East have since followed suit. In Mexico, for example, certain areas almost completely went out of cotton production following the development of resistance by the bollworm *Heliothis zea* and the tobacco budworm *H. virescens* to certain insecticides. Using a 1964 tobacco budworm population from College Station, Texas as a baseline, the 1968 Tampico, Mexico populations were 31 times more resistant to methyl parathion. By 1969 the level of resistance had reached 169-fold. The cotton in the Tampico area was planted using the best production techniques known in the United States and Mexico. In 1966 there were some 500,000 acres cultivated to cotton in Tampico. By 1969 it was down to less than 100,000 acres, with a considerable part abandoned before harvest. The decreases in the Matamoros-Reynosa areas in Mexico were even more dramatic, plunging from a 1960 high of 710,715 acres to 24,178 acres in 1967. Very few acres were planted last year. In much of this area there is no insecticide available that will give satisfactory and economic control of these cotton pests (Adkisson, 1970).

In Egypt a drastic decline in both total production and yield per acre of cotton occurred in 1961. In the 1960-61 season 2,205,000 bales were produced on 1,945,000 acres (i.e., 542 pounds/acre). The following year it dropped to 1,548,000 bales even though the area had increased to

2,062,000 acres (i.e., 359 pounds/acre). The drop was attributed chiefly to resistance by the Egyptian cotton leafworm, Spodoptera (Prodenia) littoralis, to insecticides used to control it, as well as to relaxation in the hand collection of egg masses because of the new faith in insecticides (Smith, 1971).

The complete picture of the impact of these chemicals has never been fully investigated in any one region. It is becoming increasingly crucial to examine and analyze the biological consequences of the present pest control strategy. This strategy consists largely of a short-term, economic view of pests as target species. There is usually no consideration of the role of pest species within the total complex biological systems that constitute the basis not only for all agriculture, but also for health. This view has led to a gradual deterioration of pest problems to the point of crisis, both in the developed and less developed countries.

Cotton insect pests, insecticides and resistance

The countries of Central America are heavy growers and exporters of cotton. Except for the cotton-producing area of Honduras, almost all the cotton is grown in the fertile

Pacific plains from Guanocaste Province, Costa Rica to Tapachula, Mexico. Cotton is usually planted in the beginning of the rainy season (about July) and harvested in the dry season (around February or March).

In some countries such as Guatemala and Nicaragua cotton forms more than thirty and forty-six percent, respectively, of the export dollars. The development of this crop was very rapid, as shown in the following table.

Table 1. Growth of the cotton crop in Central America

Year	Acreage	Yield (bales)
1950-51	100,000	55,000
1958-59	300,000	340,000
1964-65 (peak year)	928,000	1,335,000

(Data from Smith, 1971)

Since then, however, the yields have continuously dropped, mostly attributable to the development of resistance in the cotton pests. In Nicaragua, for example, production has dropped from 821 pounds of lint per acre in 1964-65 (peak year) to 621 pounds in 1967-68. More than a third of the production costs are due to insecticides; the number of applications per year have sometimes set world records and costs per unit area of land have more than doubled in recent years (Smith, 1969).

Along with this change in the economics of cotton production has gone a drastic change in the ecological constitution of the cotton agro-ecosystems. Many species of formerly innocuous insects have become serious pests, including the following:

Table 2. Pest species composition of formerly innocuous insects

gusano negro (yellow striped armyworm, *Spodoptera sunia*)
gusano falso medidor (cabbage looper, *Trichoplusia ni*)
mosca blanca (cotton whitefly, *Bemisia tabaci*)
gusano peludo (salt-marsh caterpillar, *Estigmene acrea*)
gusano soldado (beet armyworm, *Spodoptera exigua*)
picudo (bollweevil, *Anthonomus grandis*))
)-Have become
gusano bellotero (bollworm, *Heliothis zea*)) much more
serious pests

(Smith, 1969)

In the last few years many *Spodoptera* spp. have assumed a major role. The ecology and relative importance of these lepidopterous insects (mostly *S. sunia*, *ornithogalli*, *eridamia*, *dolichos* and *latifascia*) are still poorly understood. There have been outbreaks of cabbage loopers

(*Trichoplusia ni*) and a species of the looper *Pseudoplusia*. In 1961-62 an outbreak of the cotton whitefly *Bemisia tabaci* occurred in El Salvador. In 1964 it appeared in Honduras, and by 1965 it was a major pest in Nicaragua and Guatemala. This pest spreads cotton viruses and has now become very difficult to control, presumably because it has escaped natural controls (Smith, 1971).

Much of this unleashing of pests has been due to the destruction of the natural predators and parasites which formerly controlled the pest population (Smith, 1969; 1970). Our own observations have shown an almost complete absence of natural enemies in the growing season while heavy applications of pesticides are going on. When there is a lull in the spraying and during the dry season after spraying is halted, we have seen large numbers of the aphid lion *Chrysopa* spp., trash bugs, various parasitic flies, etc. (Farvar and Castro, 1970). Excessive use of chemical pesticides is responsible. Only some ten applications of insecticides per year are required in Costa Rica where the relatively isolated cotton fields are in the midst of much undeveloped or pasture land. The rest of the Central American countries spray, on the average, some thirty or more times a year (Smith, 1971). Often the same field may be sprayed aerially as many as 45-50 times, sometimes, every other day (unpublished data and Smith, 1971). In an effort to increase the chances of killing the many pests, a "cocktail" of insecticides is often applied. For example, a mixture of one organochlorine (e.g. DDT), one carbamate (e.g. Sevin) and one organophosphate (e.g. methyl-parathion) is employed with formidable frequencies as mentioned above (Scaillet, personal communication). As the resistance problem increases, the costs of cotton production go up. Many cotton fields have already become unprofitable. The possibilities of a complete crop failure in Central America are very great (Smith, 1971).

Effect of cotton insecticides on other crop insects

This intensive spraying of cotton fields has so disrupted the ecological factors governing the Pacific plains that little seems to have remained unharmed. The intricate elements in the network of natural control mechanisms have become inoperative not only in the cotton agro-ecosystems, but also in the ecological systems of other crops.

Two studies of other crops illustrate this point. Both are from George D. Peterson's unpublished data from Nicaragua.

Peterson studied the insect pest complex of corn and bean plantings situated from zero up to a mile from cotton fields. Both crops were so heavily damaged by insects that very little, if anything, could be harvested. Fifty to ninety percent of the individual plants examined had been decimated. The following tables show the major insect pests of each crop:

Table 3. Insect pest composition of corn plantings within one mile of cotton

corn earworm (or cotton bollworm), *Heliothis zea*

fall armyworm, *Spodoptera frugiperda*

yellow-striped armyworm, *Prodenia* (or *Spodoptera*) *sunia*

lesser corn stalk borer, *Elasmopalpus lignosellus*

cutworm, *Feltia subterranea*

corn stalk borer*, *Zeadiatrea lineolata*

*Does not attack cotton

Table 4. Insect pest composition of bean plantings within one mile of cotton

weevils*, *Apion* spp.

whitefly, *Bemisia tabaci*

cotton aphid, *Aphis gossypii*

cabbage looper, *Trichoplusia ni*

yellow-striped armyworm, *Prodenia sunia*

fall armyworm, *Spodoptera frugiperda*

lesser corn stalk borer, *Elasmopalpus lignosellus*

*Does not attack cotton

Table 4 (Continued)

spider mites, *Tetranychus* spp.

salt marsh caterpillar, *Estigmene acrea*

cutworm, *Feltia subterranea*

leafminer*, *Liriomyza* sp.

leafhopper, *Empoasca* spp.

*Does not attack cotton

With the [redacted] exception of (1) the corn stalk borer *Ziadiatrea* in Table 3, and (2) the weevil *Apion* and the leafminer *Liriomyza* in Table 4, every species listed is a common and damaging pest of cotton. The complex of natural enemies of these insects is for the most part the same as that found on cotton. Peterson's work indicated an absence of natural enemies among these plantings. Due to the relentless spraying, unleashed pest species are attacking and decimating not only the major export crop, cotton, but also the subsistence crops of corn, beans, and perhaps other staple foods. In addition some of these pests, such as the cotton whitefly, spread pathogenic viruses which contribute to crop losses.

Health, nutrition and insecticides in Central America

Declining yields of cotton and the evolution of a new complex of insect pests, many of which have developed resistant strains, are not the only consequences of this intensive reliance on chemical insecticides. Naturally, serious health hazards have resulted from this strategy of pest control. In Nicaragua, for example, with some 400,000 acres devoted to cotton, the insecticide drift from the cotton agro-ecosystem is very considerable. During 1966 and 1967 both widespread human poisoning and pesticide residues in beef were noticed. In 1967 Nicaragua witnessed the rejection of huge quantities of Nicaraguan boneless beef by FDA officials in Miami. With beef amounting to ten percent of export earnings, this was a disturbing problem. In addition, it is likely that there are also pesticide residues in milk (George D. Peterson, unpublished data).

The sources are thought to be, in order of importance:

1. Some of the chemicals applied to cotton inevitably drift away from the cotton fields. In the Pacific plains most pastures are adjacent to cotton.

2. Often cattle are allowed to graze on the roadside adjacent to cotton fields or on harvest leftovers. Pilots

spraying cotton fields are usually careful to "dress" the margins of the fields and the roadsides, where grass and other potential forage would almost certainly become contaminated with chlorinated hydrocarbons.

3. When cattle are treated with insecticides during lactation or prior to slaughter, residues will find their way into the milk and meat. There are a number of ectoparasites that infect cattle, including the torsalo fly *Dermatobia hominis*, the screw-worm fly *Cochliomyia hominivorax*, ticks and lice. The first two larvae are controlled with organophosphates; however, the organochlorines toxaphene, DDT or BHC are used in actual practice (Peterson, unpublished data).

In 1967-68 in Nicaragua there were some 500 cases of human poisoning by insecticides, with 80 deaths (Peterson, unpublished data). In Guatemala during the same year, there were 1,200 cases of *reported* toxicity, of which 350 were severe, probably largely deaths (Instituto Guatemalteco de Seguridad Social, unpublished data).

Effect of agricultural spraying on insects of public health importance

At least one insect of critical public health importance is known to have become resistant to insecticides used in agriculture but not in public health. Anopheles albimanus is the major vector of the parasite Plasmodium falciparum, the pathogen responsible for the most severe form of malaria. In much of Central America, malaria appeared to have been relegated to a role of minor importance as a public health problem. The development of resistance, however, has drastically changed the picture.

A. albimanus is believed to have developed resistance not only to organochlorines, which have been used by the WHO in its malaria "eradication" programs, but also to carbamates such as Sevin and organophosphorous material such as Malathion. Most of these have never been tried on Anopheles for mosquito control (Lelio Calheiros, personal communication).

There seems to be a close correspondence between spraying in cotton plantations and up to 100% resistance in A. albimanus in the Pacific coast. In 1968 outbreaks of malaria carried by resistant strains of Anopheles occurred in Honduras, where cotton production on a major scale had only started three years earlier. In the Danlí area of Honduras (population 32,000) up to a quarter of the population is suffering from this disease. Table 5 shows an alarming relative increase in Plasmodium falciparum infection since 1966:

Table 5. Plasmodium falciparum infection as the percentage of all fever cases in the Danlí area of Honduras

Year	P. falciparum outbreaks as a percentage of all fever cases
1966	5.6%
1967	13.9%
1968	54.0%
1969	?

(Calheiros, personal communication)

Even as far back as the late 1950's there was evidence that agricultural spraying could lead to resistance in anopheline mosquitoes. A 1965 PAHO conference on malaria in Central America contains the following statement:

> Almost concomitantly with the discovery of resistance in albimanus to dieldrin, a certain resistance to DDT was found (in the coastal provinces) of El Salvador where they had been cultivating cotton on a large scale for many years and were using insecticides to control the pests on the plantations (PAHO, 1965).

There is a long history of resistance to organochlorines. About 1959 Anopheles albimanus resistance to dieldrin was discovered in Guatemala, El Salvador, Honduras, Nicaragua, and Belice. These countries then abandoned the use of dieldrin in their eradication campaigns. Almost simultaneously, resistance to DDT was also found in Guatemala, El Salvador, Honduras, Costa Rica and others. Nevertheless, the "eradication" programs adopted the use of DDT as the fundamental method of control (PAHO, 1965).

Sometimes, insecticides will produce a reaction of irritation, causing the mosquitoes to become exophilic. Endophilic mosquitoes will rest indoors on the walls before and/or after a blood meal. The irritation of insecticides will sometimes cause a behavioristic change to exophilia. Usually this means the mosquito will leave the wall and go outside before the insecticide has had a chance to affect it. Nevertheless exophilia may mean a diminished infection rate due to increased environmental hazards to the mosquito outdoors. However, in Nicaragua the vector is not only resistant, but insensitive to this irritating effect of DDT in a large part of the most densely inhabited area of the country (PAHO, 1965). The insecticide has thus become completely useless.

In fact, a recent analysis of the impact of a three year DDT spraying program in El Salvador implies that the net effect of the spraying has been nil, judging by the annual parasite incidence (a.p.i.) rates (Lassen, unpublished data). The study included some 556 localities in four departments of El Salvador. An attempt is underway to experiment with insecticides such as OMS-33 which at the present seems to be effective against anophelines. However, any chemical insecticidal approach, even if a safe one were found, has the potential of inducing resistant varieties of vectors. Furthermore, OMS-33 is a carbamate insecticide; carbamates (e.g., carbaryl) are used extensively in agriculture over wide areas of the coastal provinces. Cross-resistance is a reasonably common phenomenon. It is therefore possible that resistance can easily be induced if the potential exists. The appearance of resistance can be expected to be more rapid were the number of applications per season to increase.

It is thought by some WHO epidemiologists that the development of resistance in the anopheline vectors is usually accompanied by increased severity and spread of the disease. This is attributed to the biological factors affecting the evolution of resistance to insecticides. The phenomenon of resistance is, naturally enough, an outcome of the very effectiveness of insecticides in killing the mosquitoes. Current biological theory dictates that there must be a certain number of individuals in almost every population of insects which are not susceptible to the insecticide used. The faster, therefore, the susceptible majority are killed off, the surer will be the development of resistant strains, because the resistant mosquitoes will then have a chance to breed and reoccupy the niche.

It is plausible that mosquitoes surviving this natural selection are not only resistant to insecticides, but also generally more "fit" to survive any environmental hazard. This implies that any individual mosquito in the new strain will be more likely to successfully live out its biological life expectancy. Because the primary (sexual) life cycle of the parasite Plasmodium has a definite developmental period in the mosquito the parasite will have a better chance to successfully complete its life cycle and infect new human hosts (Javadian, personal communication).

Even before the advent of the organophosphate and carbamate insecticides the epidemiological problems were accumulating:

> In various places in Guatemala, El Salvador, Honduras and Costa Rica where DDT spraying was regularly carried out, the epidemiological evaluation revealed persistence of transmission not only in areas of proven resistance but also in areas where complete susceptibility to the insecticide had existed (PAHO, 1965).

The recent developments in Central America show that there is an intimate ecological relationship between agriculture, health, and nutrition. The large scale use of chemical insecticides in both agriculture and public health has caused a disruption in the intricate network of living things that constitute the basis for all three areas affecting human survival and well-being.

If the experience with the use of synthetic organic chemicals in agriculture (and with mosquito control operations in California and elsewhere) is relevant, it can be safely concluded that, in spite of short-term gains, insect control by chemical means does not hold much promise in the long run. Research on alternative strategies must be intensified. At the same time many more efforts are necessary to understand the consequences of our present insect control strategies.

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The impact of technological intrusions into the environment of less developed countries is often more drastic than in developed nations, yet it is far more difficult to assess the impact in a less developed area of the world. Several factors contribute to the exaggerated manifestations in the less developed areas. First, most of these countries are located in the tropics, where the environmental interactions are more complex. The ecology of these areas is as yet poorly understood. There are far fewer baseline studies available. Yet technology is being introduced in the absence of adequate baseline data. This fact provides the second reason why effects of environmental alterations are more drastic and often unexpected in the tropics. Thirdly, the rate of the introduction of changes is greater in the less developed countries. Development projects usually aim at a compensatory acceleration of steps to modernize agriculture and lifeways in traditional societies. Added to this is the propensity to regard any innovation which originates in the developed countries of North America and Europe as inherently superior to the old ways. In the case of a chemical such as DDT, for example, even while its use in the U.S. is being discouraged, the export of this product to less developed countries has increased in recent years. In 1966, for example, while the total sales of synthetic organic pesticides produced by U.S. manufacturers were up 18% over 1965, exports rose 34 percent in the same period (Natural Resources Council of America, <u>Executive News Service</u>, <u>10</u> (23), Dec. 5, 1967).

It has thus become increasingly urgent to develop strategies for assessing the impact of new technologies on the environment of less developed countries. Such strategies must be based on an interdisciplinary approach. The need for an interdisciplinary methodology for attacking these problems becomes even more pronounced in considering the intrinsically more complex nature of environmental interactions in tropical habitats. With increasing technological development the pressure on the ecosystems of the poorer countries also increases. It is thus more urgent than ever to extend the experience gained in certain environmental studies centers and to bring our expertise and know-how to bear on developing model impact-assessment strategies in such regions.

The case of the less developed countries is of added interest to the inhabitants of the developed countries because it provides an opportunity to see the effects of new technologies in the extreme. The trends in the less developed countries should provide a warning of things to come in the developed countries if they are pushed to the limit.

The field of pest control provides a good model for the development of this interdisciplinary strategy. As described above, the problems are extremely complex. A study of pesticides used in Guatemala in particular and in Central America provides a good example of the interdependence of agriculture, health and nutrition on a common network of ecological systems. To the extent that this supportive system of life is damaged, human health and well-being are endangered.

The study of innovation as an approach to interdisciplinary ecological research*

The study of the interrelation of man and his environment has received considerable attention for over a century. However, in much of this effort, diachronic, evolutionary, and macroscopic views have been adopted with a consequent loss of detail in the mutual interdependence. Moreover, since these studies have derived from particular disciplines such as anthropology, geography and plant or animal ecology, they have arrived at partial views. Hence there is a need for studies in which the interrelation of man, as part of social groups, and the biota are seen as components of a single system for which purpose a synchronic, microscopic and interdisciplinary approach seems most useful.

The description of the interrelation of such a system

*In portions of what follows there has been a strong input from Dr. Alfredo Méndez, Professor of Anthropology, Universidad del Valle de Guatemala.

may be done under the assumption of structural balance, or homeostasis. The introduction in the research design of a "disturbing factor" may prove a useful device for bringing out not only the major structural principles or features of the system but also such processes as the development of defense mechanisms, self regulation, and change, which would otherwise remain beyond the scope of our knowledge gain.

The choice of pesticides as the "disturbing factor" provides a good opportunity to achieve a systematic view because of its intimate relation to the biota and the fact that it is man made. It also allows for a better understanding of the processes and causal relations of the impact of "diffused disturbing factors" upon ecological settings of less developed areas in a world of rapid technological change.

The role of the biological sciences within this framework is, therefore, to elucidate the nature of the specific intrusions into the ecological setting, which can be assumed to have been homeostatic prior to the diffusion of the innovation. The dynamics of change can be viewed in general within the concepts of diversity/stability. Ecologically speaking an agricultural ecosystem is an artificial one, in which the photosynthetic productivity of the systems is channeled to the output of a very small number of "useful" crops. A plantation system--the next "innovation" diffused in the system--attempts to simplify further the components of an agricultural ecosystem through restricting plants to a single crop. In each step the stability of the system--hitherto maintained through the diversity of interacting species--is reduced. The next intrusion, pest control, represents still another step in the direction of simplification. The aim is to restrict the composition of the "agro-ecosystem" (see Smith, 1971) to a single desired species. The innovation "works" until certain "defense mechanisms" of the system begin to intervene. The appearance of resistance, of resurgence of pests after pesticide applications and of unleashed pests are among the factors contributing to the unstability--and hence the vulnerability--of this very simplified system.

The purpose of the entomological part of this study* is to attempt a detailed study of certain of those elements in the system that are defined as "pests" and the relationship between these and certain other elements we can call "natural

*Carried out with the help of Dr. José Castro U., Professor of Entomology, Universidad de San Carlos de Guatemala and several field assistants.

enemies" of these pests or biological control agents. The definition of a pest is often arbitrary and haphazard, and one of our goals will be to examine the "pest status" of the most common ones. We are also attempting to study the role (degree of effectiveness) of the most prevalent biological control agents in the insect communities, using various sampling devices (Leigh et al., in press).

Another part of the biological studies is a determination of levels of pesticide residues* in various levels of the food chains. The food chains are one of the principal elements that account for the interdependence of the various elements in the system. In the process of each species consuming those which are lower in the food "pyramid", residues of contaminants in the system are passed on through the biological systems and build up in the tissues of organisms.

Of special significance are those food chains which lead to man (e.g., grass-cow-man or phytoplankton-zooplankton-fish-man), but of course other elements in the ecosystem are involved, particularly birds of prey and other predators such as cats. Samples of human milk are also being collected from

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*With the help of Dr. Steven Herman, Department of Zoology, University of California, Davis; Dr. Robert Risebrough, Institute of Marine Resources, Department of Nutrition Sciences, University of California, Berkeley, and Professor Mario Dary, Head, Department of Biology, School of Pharmacy, Universidad de San Carlos de Guatemala.

mothers in various socio-economic levels for a determination of residue levels.

Within the general framework set out earlier the contribution of social scientists to the total study* can be a description of three major processes.

1. The relation of man to selected elements of the biota. This includes concepts, attitudes, uses and treatment of selected elements of the biota. It also includes those notions which, though little systematized, when compounded give origin to what may be appropriately called ethnoecology.

2. The role of man in the introduction of the disturbing factor, including the description of the diffusion process, rate of adoption, and individual differences of the capacity to innovate, the forms of use of pesticides and the expectations of the users.

3. The development, diffusion and implementation of counter-active measures as part of defense mechanisms, born out of actual or imaginary dangers derived from the innovation itself, or its side effects. This also includes the processing and adoption of preventive measures even if they are generated outside the system and have arrived simultaneously with the pesticides.

*With the collaboration of Dr. Alfredo Mendez and several field workers.

It has usually been argued that societies differ in terms of their capacity to innovate and their efficiency to process innovations. It is our contention that both preventive and counter-active measures can be treated as innovations in themselves whether they are originated inside or outside the system, although their nature, generally, is more abstract than the case of a new product. Consequently, it is likely that societies also differ not only in terms of the nature of their defense measures but also in terms of their capacity to generate and process them.

The net ecological effect of a "disturbing factor" can then be at least partially ascribed to the difference between the efficiency in generating innovations and the efficiency in generating and/or processing preventive and counter-active measures. If the efficiency in processing these two kinds of innovations were equal in a number of given societies, we could expect the ecological effect to be approximately equal, other things being equal. This implies, for example, that if a society could effectively adopt counter-measures at the same rate as it accepts the disturbing factors, the net ecological effect would be zero, regardless of the state of technological advance or innovativeness of the society. But this is unlikely.

The very nature of innovation makes one suspect a necessary lag, even though this may be none other than a time lag and not necessarily an efficiency lag, between the introduction and diffusion of the innovation versus the preventive and counter-active measures. Thus, for societies for which a great number of innovations are alien and lack a cultural basis, it may be more difficult to start and process adequate defensive measures. A similar case may be that of the half educated peasant in an otherwise innovative society. Furthermore, the degree of innovative capacity may be regarded as dependent on an adequate perception and implementation of measures to satisfy needs. Consequently, some slow changing societies or even some social segments of a rapidly changing society may also suffer from an inadequate and slow generation of defense mechanisms which would necessarily increase the lag.

When high and low efficiency in generating and processing these two sets of innovations are considered, four logical possibilities become apparent:

Table 6. Efficiency in societies and social segments

Innovation	Defense
+ (high)	+ (high)
+	-
-	+
-	-

The typing of societies into schemes such as this, and the definition of vulnerable segments and individuals within them, would undoubtedly provide useful guides for change programs and avoid much unnecessary human suffering derived from otherwise useful innovations.

It is our purpose to investigate some of the social and individual correlates which give origin to these differences, if they do actually exist. Aside from economic and political factors which obviously bear upon the issue, it is suspected that the structure of the interpersonal communication system and the "degree of modernity" would provide much understanding of the behavioral differences and hence of the net impact of change upon the ecological settings.

A selection of several peasant communities in the Guatemalan Pacific coast would provide ample opportunity for the study of the use of pesticides in an underdeveloped area.

These communities chosen among those with a loose or tight interpersonal communication system and exposed to different levels of use of insecticides with or without a particular crop, will permit a testing of some of the hypotheses set forth here, and a better understanding of the three processes mentioned above. Examples of the questions one can ask are: "Given the same level of pesticide use and the same type of crop, do societies with loose structure of interpersonal communication differ from those with a tight structure in terms of their processing of innovations versus preventive and counter-active measure and in the lags between these two sets of innovations?", and: "Do these differences, if found, relate to the differences in the net ecological impact of pesticides?" Also, from a study of communities with similar interpersonal communication systems and the same type of crop but with high and low use of pesticides, we can infer at what levels of use different defensive mechanisms emerge, and why. Or again, we can detect differences in the ecological environment which would depend upon the type of crop used with little or no relation to the structure of the communication system or the degree of use of pesticides.

We foresee the community sample, then, as a partial selection of the logical possibilities of combining these three variables: interpersonal communication, level of pesticide use, and kind of crop.

Table 7. Variables selected as criteria

Communication	Insecticides	Crops
+ (high)	+ (high)	+ (cotton)
-	+ -	-
	-	

An individual rating scale will be constructed for the study of modernity to be used in the same village sample. The analysis by village and by total population will permit an appreciation of the part that individuals along the path of modernity play in the generation and diffusion of innovations of both kinds. It will also permit the testing of the lag hypothesis.

We have already carried out a pilot study in a community with low interpersonal communication, medium intensity of use of pesticides and varied crops. We plan to modify and adapt this study to a set of communities selected with criteria set forth in Table 7. We are attempting to conduct these studies as a truly interdisciplinary venture, not just a multidisciplinary one. For this purpose all of us involved in the project have been meeting frequently in a group "tutorial" to discuss our collaborative research, to formulate hypotheses, and to educate each other through a sharing of information and ideas.

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