ENVIRONMENTAL PROBLEMS AND THE BEHAVIORAL AND POLICY DIMENSIONS OF AGRICULTURAL PRODUCTION SYSTEMS

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PREFACE

The interactions between agriculture and the environment have emerged as important factors linking the concerns of the agriculturist, the economist, and the systems analyst. Recognition of their importance has led to the establishment of a task at IIASA to study the environmental problems of agriculture. During the first year of this task, it has looked at environmental problems at the field level and at the regional and national levels. In addition, it has attempted to provide a framework which can allow the insights made at one level to become meaningful at the others as well.

This paper presents an overview of ways in which views that normally characterize field-oriented or national-oriented studies of environment and agriculture can be joined in the context of a systems analysis of agricultural production systems. It presents a detailed picture of the phenomena comprising agricultural production and related systems, concentrating on the interactions among these phenomena. It summarized these interactions in a series of three cross-impact or contingency matrices which can be used as the basis for a detailed analysis of specific systems.

ACKNOWLEDGEMENTS

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ENVIRONMENTAL PROBLEMS AND THE BEHAVIORAL AND POLICY DIMENSIONS OF AGRICULTURAL PRODUCTION SYSTEMS

Agriculture is characterized by environmental, behavioral, and policy dimensions. More than any other human activity, it represents the conscious maintenance of artificial and unstable ecosystems, and the world's production of food and fiber depends on their maintenance. The management of agricultural production systems is carried out by farmers whose behavior is the most important variable in the stability of the agroecosystem. The policy signals perceived by the farmers constitute one of the most important inputs to farmers' decision-making.

Agricultural policy and farmer behavior have long been discussed and evaluated in practical studies of agricultural production. But the environmental dimensions of agriculture remain much less clear despite the obvious need for ecological integrity of agricultural production systems as preconditions for their sustainability. Dysfunctions of agricultural ecosystems are difficult to understand and deal with, and they pose an analytical problem which often overshadows their potential significance in analyses of development processes or projects, even when these have important environmental components. This paper examines the role of the environment in the context of the overall agricultural production system. It suggests that this view provides an effective and straightfoward mechanism for assessing the significance of environmental problems of agriculture and setting priorities for understanding their component processes and collecting data for their detailed observation. This analysis can be routinely included in analyses of world development and the assessment of development projects.

Environmental Problems and Agricultural Systems

The notion of environmental problems of agriculture means different things to different people. Different things cause problems in different places, and one culture may perceive a given phenomenon as a problem whereas another would not. We can identify three basic types of environmental problem in agriculture (Figure 1). One is an integral part of the production system. It results from human activities based in decisions made by farmers, oriented toward particular goals of agricultural production, and constrained by a spectrum of policy and economic signals generated by society as a whole. Whatever dysfunction arises affects the farmer himself and his posterity most directly, even when the particular problem spills over into adjacent ecosystems. Typical examples are soil degradation and biocide resistance in pests. The second type stems from factors beyond the direct control of the manager. It includes drought, natural disasters, and floods. These may have substantial impact on the system, but their solution or mitigation is difficult, very expensive, or impossible. The influences of the third type are external to agriculture. These are the externalities such as agriculture-related eutrophication ro pesticide runoff commonly referred to as 'environmental impacts.' Their resolution is a function of political tradeoffs and regulatory strategy.

The most significant environmental problems in poor areas affect the agricultural production system directly. This is not because externalities are not as meaningful as in developed countries, but rather because poverty and population pressure put such a high premium on food production that factors which are perceived as externalities to production increases are likely to be accepted as part of the price of development. In the same way, the environmental phenomena beyond the control of the farmer are apt to be taken as given (or as 'acts of God'). By contrast, a rich developed country is likely to try to control some of the external sources which lie within its economic and technological capabilities. Regulations typically exist which force the producer at least to attempt to deal with the externalities of his production. At the same time, the farmer may be able to control phenomena which would be beyond the control of the poor farmer in a developing country. This is simply as part of the cost of doing business.

Environmental problems of agriculture have a very wide range. For a discussion of some of the more important, see Golubev et al., (1978) or Clapham (in press, b). They may also be tremendously disruptive, leading to widespread debilitating disease, erosion of the resource base upon which agriculture is built, or short-term crop failure. They spell personal disaster for large numbers of people in many developing countries. But what is a personal problem for the small farmer is also multiplied over all producers to constitute a national problem of some magnitude in many places. The people who are too sick to work cannot pull their weight in the development process. The food that is not produced is not available to feed either the rural or the urban poor. Cash crops that are not harvested are not available for export and thus represent a concrete loss for the national economy. Environmental dysfunction may spell personal hardship for a large proportion of the national population, as well as lower food intake and greater instability of the food supply for most of the rest. It thus constitutes a major source of vulnerability for the entire national economy.

Farmers are neither stupid nor perverse, even when they are unschooled or illiterate. They do not try to cause environmental breakdown, although they may not be aware of their role in spreading it. Their management decisions represent a response to the aggregate of the signals they receive. Economic, cultural, and policy signals may seem much more important than the environment, especially if the farmer's poverty precludes a planning horizon beyond the next harvest. Indeed it is often difficult to detect developing environmental dysfunction at all, given all of the other changes that occur within a developing agricultural system (Clapham and Pestel, 1978c). Weather fluctuations confer a stochastic nature to agricultural production phenomena that can bring out problems in marginal systems during bad periods; These can persist for years after the original stimulus has receded (e.g. Picardi and Seifert, 1977).

Development and Change

Environmental problems come hand-in-hand with change. Traditional agricultural systems tend generally to exist in a dynamic balance with the environment, so that ecological vulnerability is minimized by traditions of social behavior, taboos, festivals, and clan territoriality. The significance of these traditions has been demonstrated convincingly in the anthropological literature on human ecology (e.g. Rapoport, 1968). Indeed the reason that such systems are traditional is because the balance between human activity and the environment has become stable over many years. Any activity, particularly in a vulnerable or capricious environment, which did not allow for balance between the needs of the human population and the particular ecological conditions would never have remained stable for a sufficiently long time to be considered traditional.

But rapid change in agriculture generates a dynamic evolution of cultural mechanisms within the rural population. Part of this is due to the 'learning curve' of the farmer, but part is equally due to the expansion in services or expectations of governments or society in general. At the same time, there are major changes in agroecosystems. Change in cultural methods is accompanied by changes in the genetic makeup of crop and noncrop populations, the introduction and biogeochemical dynamics of nutrients and other biologically active chemicals, and the mass movement of soil and water. It is difficult under such conditions to differentiate the effects of cultural change from the long-term dynamics of the environment, and it is often very difficult to assess what is really going on (Clapham and Pestel, 1978c).

Major structural change in the agricultural production system is the essence of agricultural development for most developing countries. Both indigenous development and development projects planned and funded by foreign sources imply much more than the installation of fixed capital, machinery, and advanced technology. They also bring major changes in the way farmers interact with the environment as well as with each other. Indeed many international development agencies are concerned that their projects include among their goals redistribution of income, improvement of nutrition, and ecological stability of the agricultural production system. These goals are not served by documenting the environmental impacts of a project in the usual sense. Real development can bring such fundamental system change that the ramifications of even rather small development projects may be far more significant than the primary environmental impacts.

Developing countries tend to be located in ecologically vulnerable areas (Clapham, 1976; Biswas, in press). Any sort of change in a complex system at least skirts the unknown. Attempts to understand and affect the course of such systems requires sophisticated and effective analytical techniques which can probe this unknown. But this need not mean rigorous mathematical models; such approaches are based on our experience in developed countries and are often not directed toward the questions appropriate to developing countries. Environmental analysis for development means understanding of the role of environmental factors in the dynamic evolution of the agricultural system induced by the development process. In a very practical sense, we do not need to know what changes will be brought about in ecological communities if we can document that the trajectory of agricultural system development is towards increasing ecological stability. Neither do we need a detailed assessment of the direct environmental impacts of a project if the trajectory of the development pattern generated by it is towards destabilization due to either ecologic or socio-economic causes.

Some Concrete Environmental Problems of Agriculture

Let us look briefly at two typical environmental problems in the context of the production system of which they are parts. The purpose of these particular examples is to show the subtlety which characterizes many environmental problems and to suggest the kinds of constraints and opportunities which arise from the nature of the system.

Cotton Leafworm Infestation in Egypt

The first example concerns pest infestation by the cotton leafworm, *Spodoptera littoralis* (Boisduval) in Egypt. This is a very serious pest which causes annual losses running to tens of millions of Egyptian pounds. The insect flourishes because its favored food, cotton, is widely planted in the Nile Valley, and both climate and agricultural conditions allow it to thrive. The circumstances which make it a problem are clearly under the farmer's control, and its direct effects on him and on the agricultural economy are severe. The cotton leafworm represents an obvious and concrete environmental problem whose role in the dynamics of the production system are clear.

Cotton is by far the most important cash crop in Egypt, and its export accounts for a very substantial portion of her total foreign exchange revenues (46% of total exports, 76% of agricultural exports; El-Tobgy, 1976). Thus the production of cotton is a matter of tremendous national importance, and the government has instituted a number of measures to insure a high level of production. These controls include regulation of producer prices, the provision of high-quality seed to the producer by the government, and the establishment of strict 2- or 3-year rotations (Figure 2). Furthermore, the fields are organized so that a given farmer's holdings are split among several crop-growing units. Even if an individual has but a few hectares in his total holdings, they are likely to be in several blocks apportioned roughly equally among the different year-stages of the rotation scheme. But the blocks belonging to all the members of a village or cooperative are arranged so that fields in the same crop are contiguous, and the smallholdings of many individuals are, in essence, combined to resemble a large field planted to a single crop. The contiguous area in each crop may thus be quite large, allowing for certain economies of scale for activities which can be carried out at the village or cooperative level, such as mechanized plowing or aerial spraying for pest control. This system would appear to be an ideal compromise between the realities of small landholdings and the need for an efficient and modern cotton production system with minimal losses to pests. But there are problems.

The optimal planting date for cotton varies from early February to mid-March, depending on the part of the country. It is preceded in most areas by a catch-crop of berseem clover (Trifolium alexandrinum) from which the farmer should take one or two cuttings for fodder before plowing his field for cotton. Berseem clover is the main forage crop for livestock, and there is a substantial shortfall of fodder over the annual cycle. Indeed this shortage is so severe that farmers often defoliate their corn in the summer to feed their animals, even though this may cause substantial reductions in corn yields. Still, the limitations of one or two cuttings of berseem for fodder purposes would not appear too restrictive on the surface. The adjacent fields of full-season clover preceding the summer corn or rice crop provide almost 80% of the high-grade fodder. But producer prices for cotton are set significantly lower than the world equivalent, and the producer price of meat is not controlled. This creates a strong incentive to emphasize fodder production at the expense of cotton, and it is quite common for producers to ignore the regulations governing the cotton planting date and to take an additional one or two cuttings (Colorado State University, 1977; Webb, 1978). The result is a delay in cotton planting so that it has less time in the ground. Such delays in planting can result in significant reductions in yield (Brown, 1955).

The most important pest on cotton in the Nile Valley is the cotton leafworm. It can cause the loss of major portions of the cotton crop. Indeed, the losses of 1/3 of the crop to the leafworm in 1961 sparked a major change in land reform and the coordination of plantings in farmers' fields (El-Tobgy, 1976, p. 56). But berseem clover is the alternate host of the cotton leafworm. Roughly 90% of the adult moths ovipositing on cotton in the critical late-spring generation of the leafworm hatch from pupae matured under full-season berseem clover in adjacent fields which will be planted to corn or rice in June. Regulations exist which prohibit the irrigation of clover after 10 May. Their intent is to allow the soil to dry out and heat up, leading to pupal mortality of up to 40%. But these regulations are not rigorously enforced, and their breach favors both the late growth of clover and the spring outbreak of the cotton leafworm.

Farm management decisions are made by individual farmers whose interests are best served by maximizing clover production, even though the national interest as expressed by the central government would be better served by increasing cotton production. As a result, cotton suffers somewhat greater losses than would be expected, due to excess pest attack and delay in planting. Pesticide application must also be higher than would otherwise be required, and pesticide resistance becomes accordingly more important. The leafworm gets an important head start in its destruction of cotton because of the presence of clover during the critical period of the spring. Its spread is helped along by the fact that the contiguous acreage in cotton within a given area is quite high.

Many measures might be able to reduce losses to pests, in principle. One of these is to increase the level of spraying. But this is expensive, and it represents a drain on foreign exchange stocks. Before the advent of chemical pesticides, it was common practice for large numbers of children to go through the fields hand-picking leafworm egg-masses. This practice is somewhat less common today than it used to be. In addition to the perceived effectiveness of chemical insecticides, the children who used to be the main egg-mass pickers are now likely to be in school. Nevertheless, hand-picking and chemical pest control are the two control mechanisms now available, and both are carried out at relatively intensive rates. Either could be increased, but the price would be high, and the marginal effect on the leafworm population would not be very great.

The production system in Egypt is a tightly constrained one, but it is not static. It is limited by available technology, foreign exchange stocks, and manpower. Change would require new stimuli at points to which the system is sensitive. The fellahin are capable of responding strongly and quickly to changes in the signals which enter their decision-making calculus. This can be seen in the almost complete shift in the planting season for corn in upper Egypt following the availability of year-round irrigation water from the High Dam at Aswan (El-Tobgy, 1976). But the relative benefit of feeding clover to livestock versus concentrating on cotton is such that the rational behavior of the farmer is to maximize his clover production, prolong his catch-crop of berseem as long as possible, and plant his cotton as late as he could get away with it. Until this changes, the role of the cotton leafworm can be expected to hold to its current state.

The roots of the cotton leafworm problem in Egypt extend beyond the moth itself. They include the pricing policies of the government which discourage incentive in cotton production and increase demand for meat and dairy products. They include the rigidities imposed by the shared-block system of land organization. They include the behavior of the fellah to a large number of policy and economic signals, many of which have nothing directly to do with the cotton leafworm. No amount of study or efforts to control the leafworm is likely to be able to solve the problem of pest attack unless they bring about a change in the way that the *fellah* determines his behavior. And the obvious policy of adjusting the relative price levels to structure changes in farmers' behavior would likely open a Pandora's box in the delicately balanced economy of Egypt.

The Egyptian cotton leafworm is typical of a class of environmental problems which is widespread throughout the world. That there is a problem is clear, and its behavior can be documented. But the system which includes it is constrained in ways which limit the effectiveness of direct solutions which might seem most appropriate. Indeed such approaches may even 'paint' the manager 'into a corner,' as it were, and prevent him from returning to measures which used to be considered adequate (Holling, 1978). Real improvements require a comprehensive view of the system which considers the biological manifestations of the problem along with the needs and decision framework of the farmer and the instruments available to the policy-maker. Only then can a sufficiently imaginative mixture of measures be suggested to move the system from points to which it is sensitive (see Clapham, in press, a, for such an analysis of the leafworm problem).

Transmigration to the Outer Islands of Indonesia

A different kind of problem is shown by the responses of the Indonesian government to the tremendous population pressure within the heavily populated areas of the country. Over 65% of the Indonesian population lives on less than 7% of the land area on the islands of Java, Madura, and Bali (Hanson and Koesoebiono, 1977). The sparsely populated outer islands such as Sumatra, Kalimantan, and Sulawesi are seen as a way of relieving this pressure. But one of the reasons that the inner islands are as heavily populated as they are is because their soils are volcanically derived and inherently fertile. They can maintain very high levels of agricultural production, as they have indeed done for many hundreds of years (Geertz, 1963). The outer islands, on the other hand, are characterized by 'problem soils' which are not as fertile, and which are subject to rapid depletion if they are managed in the wrong way. In order for transmigration to be successful, a *modus vivendi* with these problem soils must exist, so that transmigrant populations can survive with a stable agricultural base.

It is not really clear how to use the problem soils intensively and efficiently. The dynamics of the mineral particles and nutrients under different cropping regimes is incompletely understood, and it is very difficult to make *a priori* recommendations on potentially stable means of cultivating them. Pilot projects have suggested several potential means of developing a stable agriculture, but the degree to which these can be implemented on the outer islands themselves is not at all clear.

Once again, the social dimension of the problem is at least as important as the environmental dimension. Successful transmigration obviously requires that the people who are moved to the outer islands be able to develop a new and successful agrarian culture including both cultural behavior and the cultivation techniques which are appropriate to the area and which can be maintained stably under the conditions of the new location. This is by no means a simple job, and the literature is replete with instances of transmigration in which people have not been properly prepared. The cultural base they brought to the new areas was not appropriate to it, and they were simply incapable of dealing adequately with the new realities. The resulting disease or soil degradation quickly left them worse off than they had been originally.

What is required in this case is the simultaneous understanding of the behavior of the soil under different types of management and the way that potential transmigrants respond to the set of signals they perceive and the degree to which these signals are able to change under policy control. Only then is it possible to identify feasible stable alternatives of culture and agriculture. Only then is it possible to carry out a successful transmigration project.

In principle, the levels of analytical detail should be much higher in this case than with the cotton leafworm. Likewise, the ecological factors which must be dealt with are broader and more complex. But our knowledge in such cases is typically poor. Data on soils and biogeochemical phenomena are typically sparse and noisy. The qualitative information on what might constitute management options is not always clear. The level of confidence in an analysis made under these conditions is necessarily relatively low. On one hand, this would normally mean that one must be much more conservative in one's project design. But conservatism may not be possible in the Indonesian case because of population pressure. If there is a risk inherent in the ecological basis of the system, there is also a risk to doing nothing, and both of these risks may be considerable. It is often necessary to make decisions on the basis of very poor information. Given this, it may be necessary to identify indicators of potential problems and possible solutions. Both the social behavior of a transmigrant community and its agricultural resource base can then be monitored for many years after the community is established. This is virtually the only way to verify the assumptions and decisions which were made in the transmigration project and to insure that a stable solution to the problem has been reached.

Placement of transmigrant populations in ecologically vulnerable areas is typical of a great many environmental problems thoughout the world. Only change is certain, and the analyst cannot depend on his understanding of the situation or the data base available to him. Certain aspects of the problem may be well-defined, but others will remain fuzzy and ill-defined. Feasible resolution depends on the willingness of policy-makers to understand both what they know and do not know about the ecological as well as the human factors of the change and to try to head off specific problems 'on the fly' as they begin to develop. Like the cotton leafworm, this requires a comprehensive view of the biological, geochemical, socio-economic, and policy dimensions of the system. But it is less focused, and if anything, the stakes are higher.

An Operational View of Agricultural Systems

It is most meaningful for our purposes to characterize agricultural systems in terms of three domains: the environmental, the individual-management, and the policy-making. The scope of these domains, as well as their most important characteristics, are summarized in Table 1. It should be noted that 'environment' is defined here in a rather broad and inclusive way. Each of the domains is characterized by a relatively well-defined set of phenomena, as well as a set of disciplinary approaches (Table 2). Nevertheless all three are present in all real-world agricultural systems. The geobiological production phenomena include crop growth, interactions with pests and weeds, nutrient movement within soils, movement of soil particles, and the impact of these phenomena on adjacent ecosystems and non-crop populations. Farmers are the individual managers who oversee crops, soils, and related factors under their control, and their behavior is directed and/or constrained by economic and policy signals.

Each domain can be represented by a series of processes with information flowing among them. The domains are also connected by a pattern of information flow (Figure 3). Producers have instruments by which they manage field crops and livestock. They monitor certain geobiological phenomena such as crop growth, disease, etc., and these signals enter their decision-making calculus. Economic and policy signals transmitted from national governments to producers are also considered in producer decision-making. Policy-makers also monitor the behavior of farmers (Clapham and Pestel, 1978a-c; Clapham, in press, b)

This view lets us characterize the system in a rapid and useful way. Indeed Figure 3 demonstrates that we can identify sets of phenomena for all domains which include the important behavioral aspects of the system. Furthermore, the information flows which connect and thereby control these phenomena can also be specified. This picture can be viewed as a qualitative overview of the system in some ways analogous to a road map. Figure 3 is an extremely schematic diagram. If all of the phenomena shown there were considered, and if all the information flows between all of them were shown, as in a flow chart, the resulting diagram would be so complicated as to impossibly confuse and frustrate even the most dedicated cartographer. Most of the phenomena are affected by several others, and the multiplicity of information pathways is exceedingly high. Fortunately, we do not need to draw flow charts of the entire system. The overall picture can be summarized quite adequately in an extremely compact way which allows a straightforward verbal description of the system as a set of functional relationships. We do not need to describe this procedure in detail at this point; it is described elsewhere (Clapham, in press, b). What is important is that the great complexity of the multidimensional system can be compressed into usable verbal form without needing to resort to the arcane and sometimes confusing representational tools of the systems analyst.

Going from the real world to a meaningful representation of a complex system is neither a simple nor an automatic task. It requires retaining sufficient complexity to understand the indirect effects of the dynamics of development without becoming confused by the complexity. The analyst must determine what is known about the system without foundering in a sea of detail or losing heart over the inscrutability of the patterns he is trying to represent. He must cast his net widely enough at first to enable him to be reasonably sure that the most important factors are included someplace within it. If his 'net' is a qualitative framework which helps to organize relationships without needing a lot of detail to do so, then this is a feasible task. Simplification and problem-definition can then proceed by eliminating relationships that are not important rather than by accretion of other problems that suddenly appear important.

Problem definition can be oriented toward the particular place and time rather than toward disciplinary framework. There is no insurance, of course, that the important paths will be identified, especially for the indirect effects which span disciplines and must be considered for situations which are not well understood. But analysis of any sort must be oriented toward answering questions, and it is not possible to answer a question which is not asked. Starting with a broad qualitative framework which attempts to include all of the relevant domains of the production sytem maximizes the likelihood that the questions which are most appropriate to a given development project will at least be asked.

Discussion and Conclusions

Throughout this paper, environmental problems of agriculture have been seen as phenomena which are closely associated with agricultural development. Their significance stems from their roles both in the agricultural production system and in the overall dynamic of the development process. They affect people, both as individual producers and as society. They are far more than amenity resources. Because development represents change within the agricultural system, the environmental and social factors comprising agriculture are closely tied to each other. Neither the implications nor the mechanism for control of ecological dysfunction is clear until the role of the environmental factor is seen clearly in the context of the system within which it exists. As a general rule, we do not need to describe environmental problems unless this helps us solve them. Solution to significant problems requires direction by policy makers, and it often requires changes in the behavior of individual producers which can bring about readjustments within the environmental domain. Only when the very close linkages of all three of these domains are seen, understood, and dealt with does it make much sense to talk about solutions.

It makes no sense to appeal to the long-term economic rationality of ecologically stable production if a farmer is so concerned with having enough to eat that his planning horizon cannot extend beyond the next harvest. It is not reasonable to talk about the provision of services by government or the dissemination of certain policy signals if the manpower base or the educational system of the country is not able to provide the services, or if the government believes that certain policies are against its own overall best interests. The significance of environmental problems of agriculture reaches far beyond ecological phenomena. Any practical analysis of the agricultural environment must explicitly recognize the cultural, economic, and policy bases of problems as well as their ecological base. It must furthermore recognize that solutions to this problem are equally culturally determined.

The identification, explication, and understanding of the higher-order phenomena which are most important for environmental problems of agriculture requires a high level of analytical sophistication. This does not mean that sophisticated mathematical models are necessary or even appropriate. Rather it means that the analyst must be extraordinarily careful to make sure that the questions being examined are the right questions and that the various tools that are available are optimally used. Without some kind of framework within which to build a comprehensive view of the agricultural production system, it is difficult or impossible to assess the interconnections between phenomena which are most important for system development. Because of this, it may not be possible to assess what data are needed or how to carry out the analysis for the most meaningful purposes. One may even ignore the roots of the problem or the keys to opportunities for solutions.

Creating a qualitative picture of the interrelationships among phenomena provides a usable perspective from which to judge the likely significance of the phenomena and the state of our knowledge about them. This perspective can help identify needs for additional knowledge and data and then help justify the data collection. It can also help identify pressure points to which the system may be sensitive, as well as structural constraints on possible problem solutions. Its usefulness in understanding the broad dimensions of environmental problems of agriculture is shown in the two examples given earlier in the paper, and Clapham (in press, a) shows how it can even suggest some solutions to important problems.

Summary

Environmental problems of agriculture constitute some of the most complex and significant problems of modern times. They are found in all countries, but they are most prominent -- and most serious -- in developing countries located in ecologically vulnerable areas. Their roots commonly lie in the culture of the population, the farmers' behavior, or the economy of the area. In order to assess patterns of agricultural development in general, or to assess the implications of development projects, we must include the environmental, behavioral, and policy dimensions of the agricultural production system into a single framework, so that we can understand both the problems as narrowly defined and the measures which must be taken in order to solve them. One way of doing this is through a comprehensive, but qualitative overview of the system. This provides a general framework for the analysis, and it can be simplified so that a particular problem can be treated in a meaningful and adequate fashion.

References

Biswas, A.K., in press. Climate and Economic and Agricultural Development. Science.

Brown, C.H., 1955. Egyptian Cotton. London: Leonard Hill, xi+174.

Clapham, W. B., Jr., 1976. An approach to quantifying the exploitability of human ecosystems. Human Ecology 4: 1-30.

Clapham, W.B., Jr., in press, a. Agricultural system structure and the Egyptian cotton leafworm. Submitted for publication.

Clapham, W.B., Jr., in press, b. An Integrated View of Environmental Problems of Agriculture. I.I.A.S.A. Research Report.

Clapham, W.B., Jr., and Pestel, R.F., 1978a. A Common Framework for Integrating the Economic and Ecologic Dimensions of Human Ecosystems; I: General Considerations. IIASA Research Memorandum RM-78-29: v+27;

Clapham, W.B., Jr., and Pestel, R.F., 1978b. A Common Framework for Integrating the Economic and Ecologic Dimensions of Human Ecosystems; II: Processes and Problem Chains within the Natural Stratum. IIASA Research Memorandum RM-78-30: v+52;

Clapham, W.B., Jr., and Pestel, R.F., 1978c. A Common Framework for Integrating the Economic and Ecologic Dimensions of Human Ecosystems; III: Policy, Uncertainty, and Analysis. IIASA Research Memorandum RM-78-31: v+23.

Colorado State University, 1977. Issue paper on the Agricultural Sector.

El-Tobgy, H.A., 1976. Contemporary Egyptian Agriculture, 2nd ed. Beirut: The Ford Foundation, x+228.

Geertz, C., 1963. Agricultural Involution: the Process of Ecological Change in Indonesia. Berkeley: University of California Press, xx+176.

Golubev, G.N., Shvytov, I.A., and Vasiliev, O.F., 1978. Environmental Problems of Agriculture; I: Water-Related Environmental Impacts off Agriculture at the Field Level. IIASA Research Memorandum RM-78-32: v+24.

Hanson, A.J., and Koesoebiono, 1977. Settling coastal swamplands in Sumatra: a case study for integrated resource management. Pusat Studi Pengelolaan Sumberdaya dan Lingkungan Research Report No. 4: 1-46.

Holling, C.C., ed., 1978. Adaptive Environmental Assessment and Management New York: John Wiley & Sons, xviv+377.

Picardi, A.C., and Seifert, W.W., 1977. A tragedy of the commons in the Sahel. Ekistics 258: 297-304.

Rapoport, R.A., 1968. Pigs for the Ancestors: Ritual in the Ecology of a New Guinea People. New Haven: Yale University Press.

Webb, H.R., 1978. Various reports of the agricultural attache to the U.S. Embassy in Cairo to the U.S. Department of Agriculture, Washington.

Figure Captions

Figure 1. Schematic diagram of environmental production problems as functions of the sources and influences of the phenomena involved. Scale in arbitrary units.
Three groups are identified. I-environmental phenomena integral to the production process; II-Environmental phenomena are external to the production process, but have their primary effect on agricultural production; III-Source of the phenomenon is within agriculture, but the primary effect is external.
15 environmental phenomena are shown: 1-Weather fluctuation; 2-Earthquakes; 3-Other natural disasters; 4-Floods; 5-Waterlogging and salinization; 6-Pesticide resistance; 7-Agricultural chemical residues in soil; 8-Soil fertility; 9-Soil erosion; 10-Pest and weed attack; 11-Soil compaction; 12-Genetic vulnerability of crops; 13-Human disease; 14-Agriculture-related eutrophication; 15-Agricultural chemical runoff.

Figure 2. Schematic diagram of a typical 3-year crop rotation in Egypt.

Figure 3. Schematic representation of agricultural production systems.

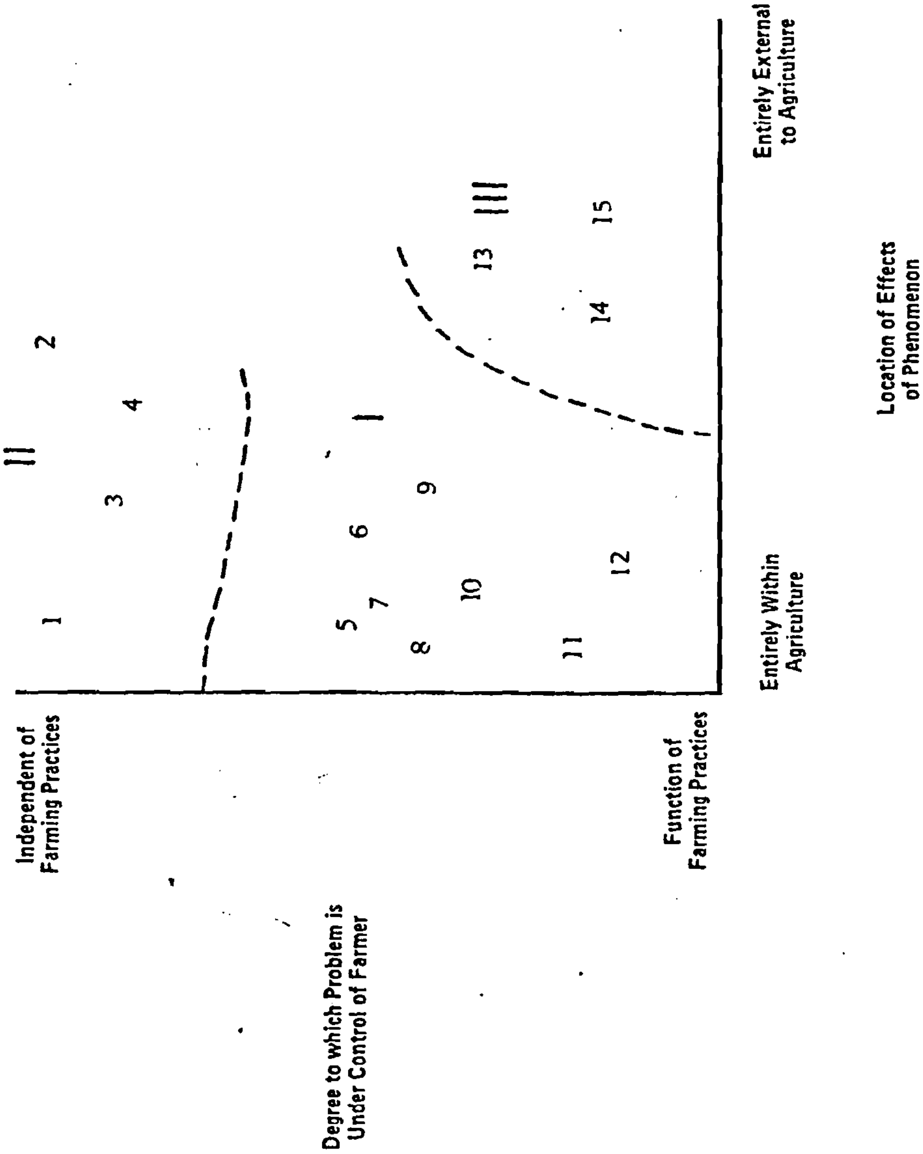
Independent of Farming Practices
Function of Farming Practices
Degree to which Problem is Under Control of Farmer
Entirely Within Agriculture
Entirely External to Agriculture
Location of Effects of Phenomenon
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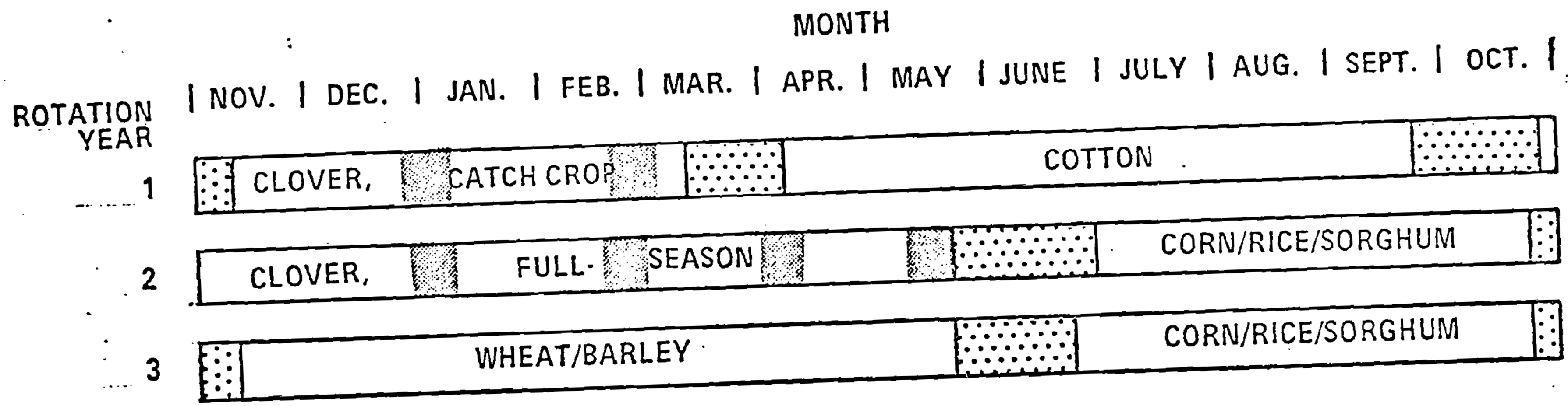
Figure 1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MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
ROTATION YEAR
1
CLOVER,
CATCH CROP
COTTON
2
CLOVER,
FULL-
SEASON
CORN/RICE/SORGHUM
3
WHEAT/BARLEY
CORN/RICE/SORGHUM

Figure 2

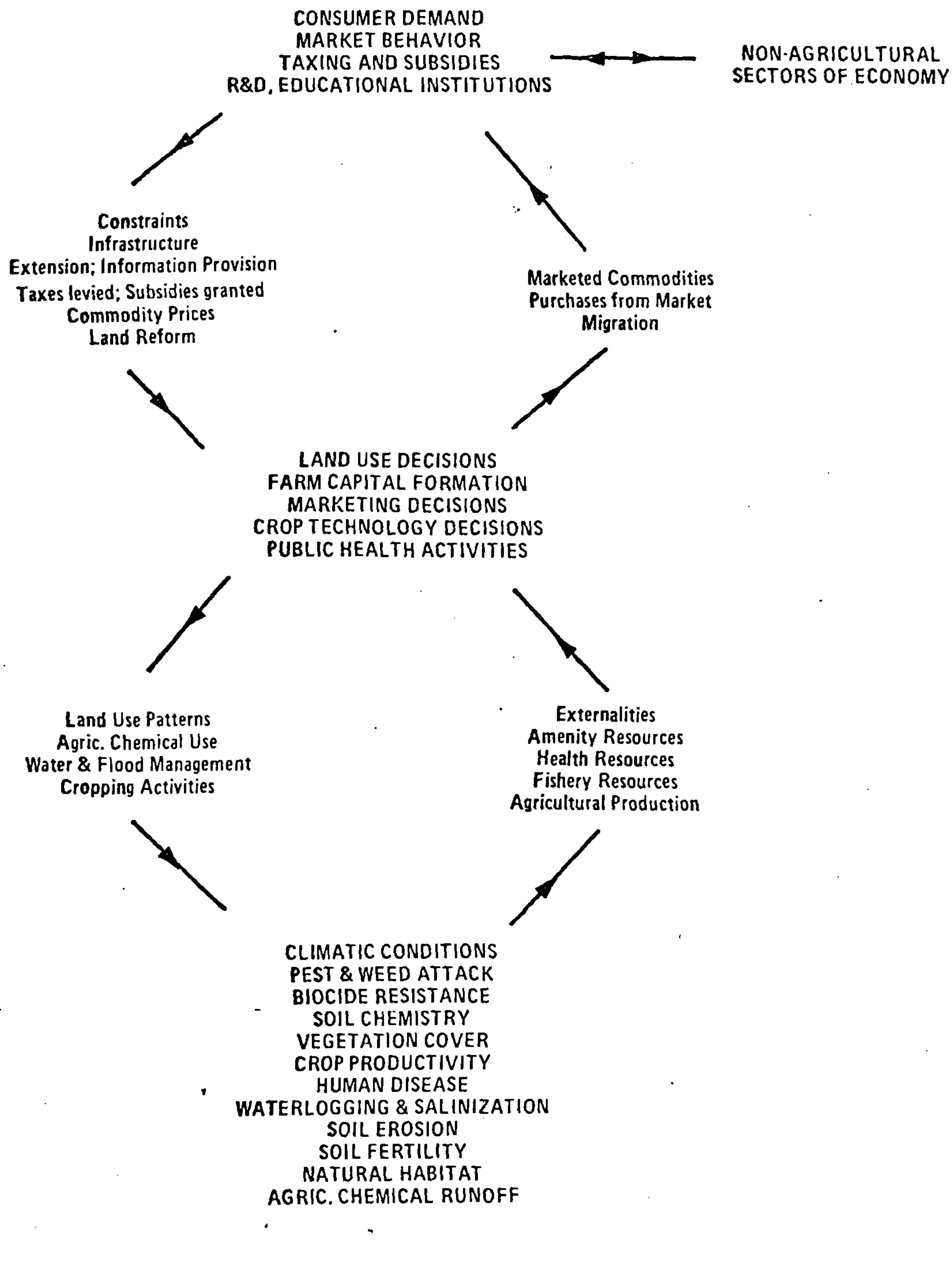
CONSUMER DEMAND
MARKET BEHAVIOR
TAXING AND SUBSIDIES
R&D, EDUCATIONAL INSTITUTIONS
NON-AGRICULTURAL SECTORS OF ECONOMY
Constraints
Infrastructure
Extension; Information Provision
Taxes levied; Subsidies granted
Commodity Prices
Land Reform
Marketed Commodities
Purchases from Market
Migration
LAND USE DECISIONS
FARM CAPITAL FORMATION
MARKETING DECISIONS
CROP TECHNOLOGY DECISIONS
PUBLIC HEALTH ACTIVITIES
Land Use Patterns
Agric. Chemical Use
Water & Flood Management
Cropping Activities
Externalities
Amenity Resources
Health Resources
Fishery Resources
Agricultural Production
CLIMATIC CONDITIONS
PEST & WEED ATTACK
BIOCIDE RESISTANCE
SOIL CHEMISTRY
VEGETATION COVER
CROP PRODUCTIVITY
HUMAN DISEASE
WATERLOGGING & SALINIZATION
SOIL EROSION
SOIL FERTILITY
NATURAL HABITAT
AGRIC. CHEMICAL RUNOFF

Figure 3

Table 1 Domains of agricultural production systems

	Environmental	Individual Management	Policy Making
Representative Actors or Phenomena	Soil, water Crops & Livestock Pests & Weeds Nutrients	Farmers Herders Fishermen	Governments; International Organizations
Characteristics	Phenomena obey laws of natural ecosystems	Decisions directed internally to affect own actions	Decisions directed externally to affect others

Table 2 Approaches to domains of agricultural production systems

	Environmental	Individual Management	Policy Making
Phenomena	Crop Growth; Nutrient movement Hydrology Soil movement	Cropping planning Land Use decisions Farm capital Formation Market decisions	Taxation, Subsidies Coordination of Different Sectors Market Management Education Policy R&D, Extension Policy
Disciplines or Background of Practitioners	Ecology, Agronomy, Soil Science, Hydrology	Microeconomics Rural Sociology	Macroeconomics Business, Law Policy