CATIE
CENTRO AGRONOMICO TROPICAL DE INVESTIGACION Y ENSEÑANZA
Annual Crops Program

INTEGRATIVE AGRICULTURAL SYSTEMS RESEARCH

Robert D. Hart

Antonio M. Pinchinat

Presented at the "Inter-Caribbean Seminar on Farming Systems Research Methodology", Pointe-a-Pitre, Guadeloupe, May 5-9, 1980.

Turrialba, Costa Rica
1980

INTEGRATIVE AGRICULTURAL SYSTEMS RESEARCH[1/]

Robert D. Hart[2/]

Antonio M. Pinchinat[3/]

Agricultural research has become more and more specialized as the study of agricultural production has been divided into smaller and smaller units. However subdividing and analyzing the components that form a phenomenon is not consistent with regional development objectives since agricultural development requires an understanding of whole agricultural processes. The recent interest in a systems approach to agricultural research undoubtedly reflects the realization that specialized knowledge alone cannot completely explain complex agricultural processes.

A system is an arrangement of components that function as a unit (Becht, 1974). An understanding of how a system functions requires more than a detailed description of its individual components; a study of how the system is structured (how the components are arranged) is also necessary. This may seem obvious, but Von Bertalanffy's General Systems Theory (Von Bertalanffy, 1968) introduced in 1930, produced a conceptual revolution

---

1/ Presented AT the "Inter-Caribbean Seminar on Farming Systems Research Methodology", Ponte-a-Pitre, Guadeoupe, May 5-9, 1980.

2/ Agricultural Ecologist, CATIE, Turrialba, Costa Rica.

3/ Agricultural Research Specialist, Zone 2, IICA, Santo Domingo, Dominican Republic.

in both the physical and biological services.

The systems approach has been applied to all biological disciplines, but is probably most associated with ecology. In 1935 Tansley proposed the term "Ecosystems" (Evans, 1956). The concept has been developed by many others, such as in the classic papers on trophic levels by Lindeman (1942), and on energy flow through ecosystems by H. T. Odum (1957).

As defined by E. P. Odum (1971), an ecosystem is "any unit that includes all the organisms in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity, and material cycles within the system". The biological community that interacts with the physical environment to form an ecosystem is composed of various populations. Populations can be subdivided into individual organisms that can be further subdivided into organs. These phenomenon are, at the same time, both components and therefore subsystems of larger systems as well as systems with their own components (subsystems). This hierarchical relationship between systems forms the conceptual framework for the science of ecology.

AGRICULTURAL SYSTEMS

If the ecological systems framework is applied to an agricultural production process, a set of hierarchically-related agricultural systems can be identified. Each level of the hierarchy is a set of systems with the outputs of some systems forming the inputs to others.

While it is possible to describe a global agricultural system, the geographic region is usually the largest unit of interest in agricultural development research. Figure 1, where one system from each hierarchical level was arbitraryly selected for closer inspection, shows a regional agricultural system with both agricultural and non-agricultural subsystems. Farms, agro-industries, and agricultural extension, research and education together form the regional agricultural sector. The region can ba analyzed as a system with energy, materials, capital, and information flowing into and out of the region and among the subsystems of the region.

Any one of the regional subsystems can be separated from the regional system and studies in detail. In Figure 1 a farm subsystem was selected. A farm system can ba viewed as a set of spatially-difined areas used for crops and/or animal production, and as a homestead area. The crop or animal production areas form agroecosystems, units analogous to the ecosystem unit in ecology. The economic transactions and management decisions on the farm can be combined to form a socioeconomic subsystem of the farm system. As in the case of the regional system, any subsystem of the farm can be selected for detailed study. In Figure 1 a crop agroecosystem was selected.

The agroecosystem can also be dissected into subsystems. As with natural ecosystems, it is composed of a biotic community of plants, animals and micro-organisms, and a physical environment with which it interacts. Soil, crops, weeds, plant diseases, and insects are prominent subsystems in crop-based agroecosystems. Energy flows between trophic levels and materials are cycled. An agroecosystem, however, differs from a natural ecosystem in that at least one plant or animal population must be of agricultural value and man plays a decisive management role. In the next hierarchical level presented in Figure 1, a crop subsystem was selected for closer inspection.

A crop system is an arrangement of crop populations that process energy (solar radiation) and material inputs (soil nutrients, water, etc.) to produce energy and material outputs (biomass, water, and heat). The crop populations can be arranged both spacially (planting distance) and chronologically (date of planting) to form "cropping patterns".

The individual crop species and their varieties are subsystems of the crop system and make up the next hierarchical level under the crop system. Each individual crop can be subdivided into hierarchically lower subsystems such as its genetic or reproductive subsystem.

TRADITIONAL AGRICULTURAL RESEARCH APPROACH

In general agricultural researchers have studied the phenomenon included in the above hierarchy as separate units. There seems to be two important weaknesses to this traditional approach: (1) the units are studied in isolation; any interaction between the unit and other systems is often ignored, and (2) the lower-level systems (the agroecosystem components) have received more attention than agroecosystems, farms, or regional systems.

In too many cases, agricultural specialists have studied the systems within a region as if they were isolated phenomena. Soil scientists measure fertilizer responses, agronomists breed "better" varieties, crop protection specialists identify "better" pesticides, and agricultural economists analyze sigle-product marketing systems. The technology generated by isolated agricultural research is expected to somehow produce agricultural development.

The "green revolution" approach, a highly specialized form of traditional agricultural research, is based on the assumption that the availability of "better" crop varieties will produce regional development. The varieties are often developed and evaluated in isolation from the systems in which they function as components. For the green revolution approach to work, the farmer must integrate the new variety into his crop system, the modified crop system into his agroecosystem, and the modified agroecosystem into his farm system. It is assumed that the combined impact of such modified farm systems in a specific geographic region will result in regional development. This type of approach may work in a one-crop region, with a one-crop farm system, with a one-crop agroecosystem, with a one-crop system; however, in complex regions with complex farms, complex agroecosystems and complex crop systems, as is common in the third-world tropics, its chances for success are minimal.

AN INTEGRATIVE APPROACH TO AGRICULTURAL SYSTEMS RESEARCH

If the immediate objective of agricultural research is to provide information in support of rational regional development, as is usually the case in third-world countries, it is obvious that the relationships among the agricultural systems within a region must be defined and studied through an integrative approach. The experience gained by institutions involved in crop systems research combined with systems analysis principles may be used as a basis for an integrative approach to agricultural systems research.

Three-level-minimum principle

In order to analyze agricultural systems as a set of hierarchically-integrated systems, at least three hierarchical levels must be examined. To understand how a system works, i.e. to relate its structure to its function, the components of the system, their arrangement, and the inputs and outputs of the system must be identified and described. The system itself functions as a subsystem of a larger system; this larger system must be described in order to identify and describe the inputs and outputs of the system of interest. In order to modify or design new systems, the components of the system must also be studied. The system of interest, its components, and the system in which it functions as a component are the three hierarchical levels that must be examined in any agricultural research project.

Applying the three-level-minimum principle to a project for improving farms systems, for example, means that information on regional systems, farm system and agroecosystems must be studied and integrated. Similarly, to develop better crop systems, research must be carried out on agroecosystems, crop systems and individual crops.

A research strategy for regional development

While three hierarchical levels must be studied in order to analyze a specific agricultural system, if the objective is regional development, the entire hierarchy from the regional system down to individual crops and animals must be considered. A research strategy with the different activities to be carried out at each level is summarized in Figure 2.

The strategy is designed for research to be carried out within a 3 to 4 year period. In some cases, as when a region is very large or heterogeneous, more time will be required. The strategy can be divided into the following 11 basic steps:

1. Preliminary characterization of the regional system. The objective is to produce a general qualitative model of the region that includes primary (agriculture, silviculture, mining, etc.), secondary (processing of primary products), and tertiary (services) activities and the most important inputs and outputs of the region. Another objective of this phase is the identification of important farm system types.

2. Preliminary characterization of important farm systems. The objective is to produce a general qualitative model of the important farm systems within the region. The model should include the agroecosystems and inputs and outputs of the farm system.

3. Preliminary characterization of important agroecosystems. As in the case of the regional and farm system characterizations, the objective of this phase is to produce a qualitative model. If possible, some quantitative estimates of inputs and outputs should be obtained.

4. Regional studies. Using the static qualitative model produced during phase 1, climate, soils, marketing, and credit studies can be carried out over a two-year period. It is important that this information be avial-

able as input ot the alternative-design stage (see step 9).

5. Farm register studies of representative farm systems. Using the static, qualitative model of the farm system produced during phase 2, farm register studies of representive farms that include the agroecosystems being analized experimentally (steps 6-8) should be undertaken at the same time as the regional studies and experiments. The analysis of the farm systems is also an important input to the alternative-design stage.

6. Exploratory experiments with agroecosystems. Experiments that include many factors at few levels should be conducted with the objective of identifying: (a) promising research areas and (b) components that strongly interact and must be analyzed as a unit (an example might be soil fertility and weed management) and components that can be studied separetely.

7. Analytical experiments with agroecosystems. Exploratory experiments and experiments with components of the agroecosystems (step 8) will usually point to aspects that need more analysis. These experiments will usually include many levels of one or two factors; for example multiple fertilizer-input levels in order to define the output of the system as a function of nutrient input.

8. Component research. The experiments carried out during this phase will be very similar to the traditional research with crop varieties, weed control, etc.

9. Design of alternatives. This is essentially a model-building phase. At the end of two years of research, including regional and farm system studies and exploratory and analytical experiments, it should be possible to build quantitative models of the agroecosystems selected for study. It should be

possible to use this model as the basis for the design of alternatives. These alternatives can be different management recommendations for the original agroecosystems or completely new systems.

10. Evaluation of alternatives. This phase is both a validation of the model designed in step 9 and, since it is carried out on representative farms, and a preliminary evaluation of the potential adaptability of the alternative technology that has been produced. If the model is not valid or the technology not acceptable, it will be necessary to return to the alternative-design phase. If the alternative is acceptable, the technology transfer phase can begin.

11. Technology transfer. The alternative agroecosystem that has been evaluated on representative farms can now be transfered on a regional basis.

Interdisciplinary integration of research activities

Implicit in the system approach to agricultural research is the inter-disciplinary integration of research activities (Pinchinat et al. 1976). An agronomist doing crop system research must communicate with crop specialists in order to find better crop components, as well as with agroecosystem specialists in order to understand the physical and biological environments in which his crops system must function. Agroecosystem specialists can not design alternatives without the direct input from scientists working with systems that are both higher and lower on the hierarchical scale.

CONCLUSION

There are strong arguments for putting aside the naive assumption that complex regional agricultural processes can be improved by independently breeding better crops, setting up more fertilizer experiments, or carrying out another marketing study. This reductionist approach should be replaced by a systems approach in which the relationships among agricultural systems receive at least as much attention as the study of the isolated phenomena. The systems approach requires the integration of an interdisciplinary team of agricultural research specialists. The research strategy followed by the team should include regional and farm system studies and experiments with agroecosystems and the biological and physical components that form the agroecosystems.

LITERATURE CITED

1. BECHT, G. 1974. Systems theory, the key to holism and reductionism. Bioscience 24(10):579-596.

2. EVANS, F. C. 1956. Ecosystems as the basic unit in ecology. Science 123:1127-1128.

3. LINDEMAN, R. L. 1942. The trophic-dynamic aspect of ecology. Ecology 23:399-418.

4. ODUM, E. P. 1971. Fundamentals of ecology. Saunders, Washington, D. C. 574 p.

5. ODUM, H. T. 1957. Trophic structure and productivity of Silver Springs, Florida. Ecological Monographs 27:55-112.

6. PINCHINAT, A. M., SORIA, J. and BAZAN, R. 1976. Multiple cropping in Tropical America. In Multiple Cropping: Amer. Soc. Agron. Madison. Special Pub. 22:57-61.

7. VON BERTALANFFY, L. 1968. General systems theory. George Braziller, Inc. New York. 295 p.

RH/AP/ph
FITO

FIGURE LEGENDS

Figure 1. The hierarchical relationship between regions, farms, agroecosystems and crops.

Figure 2. Eleven steps in an integrative research strategy that includes the analysis of a series of hierarchical agricultural system and the generation of alternative agroecosystems.

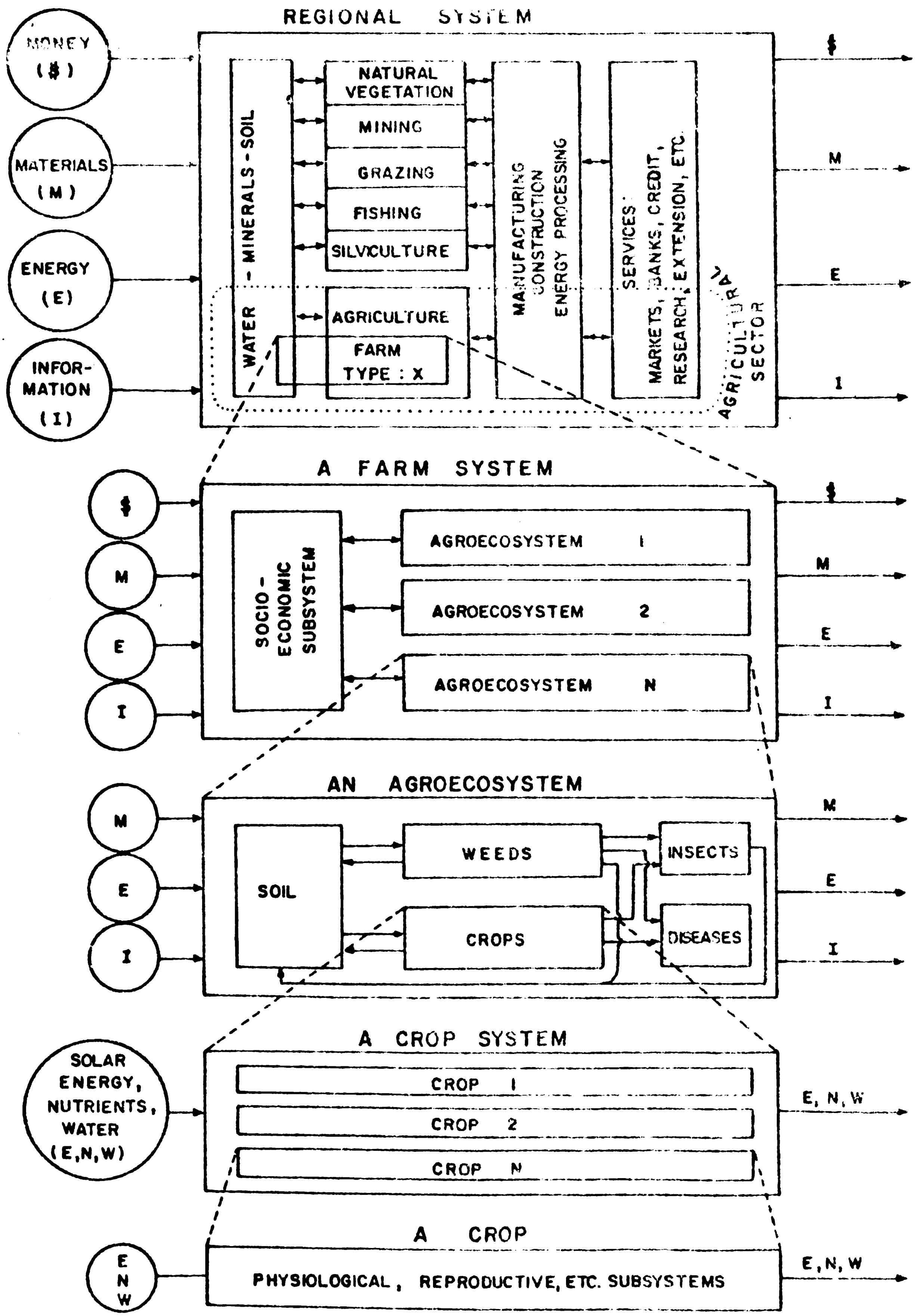

Figure 1. The hierarchical relationship between regions, farms, agroecosystems and crops.

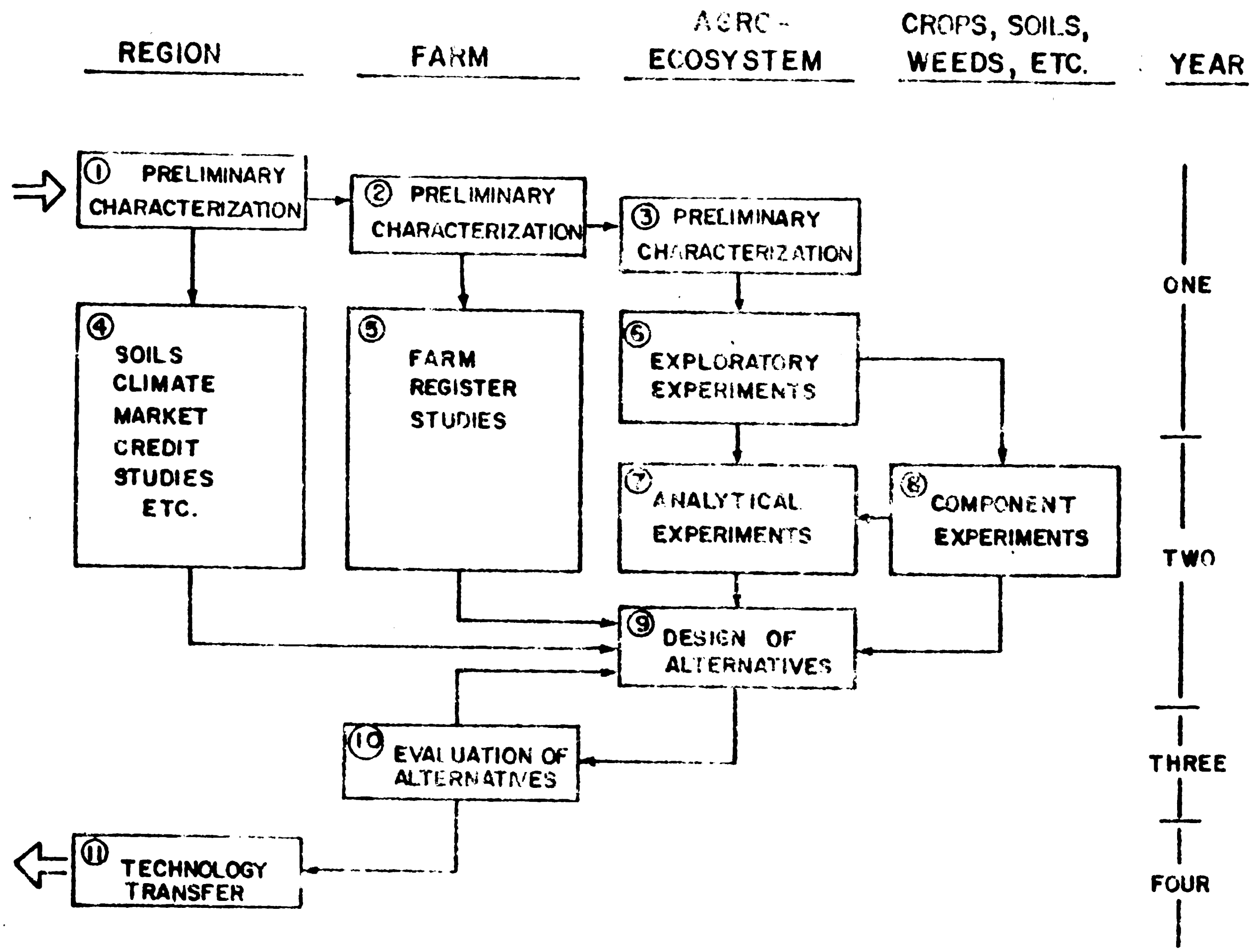

Figure 2. Eleven steps in an integrative research strategy that includes the analysis of a series of hierarchical agricultural system and the generation of alternative agroecosystems.