Working Document No. **166**
July 1997

INTEGRATED CONCEPTUAL FRAMEWORK FOR TROPICAL AGROECOSYSTEM RESEARCH BASED ON COMPLEX SYSTEM THEORIES

A CIAT/University of Guelph Project

PROCEEDINGS OF THE FIRST INTERNAL WORKSHOP

(Held at CIAT, March 3, 1997)

Edited by Tamsyn Murray

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

Table of Contents

ANNOTATED AGENDA

I. The Project

08:00-08:30hs 1. Presentation of CIAT/University of Guelph Project. (Gilberto Gallopín) (30 min.)

History
Background and rationale
TAC request for new research model
Relevance of complex systems
The Project team
Choice of Pucallpa as initial case-study
Connection to Resilience Network

08:30-09:00 hs 2. The Canadian experience (David Waltner-Toews) (30 min.)

The Post Normal Science perspective in the project
The Canadian Agroecosystem Health Project.
Lessons from practical applications in Kenya and Nepal of the conceptual work already done on the Guelph/CIAT Project

09:00-09:30 hs 3. The Process (Tamsyn Murray) (30 min.)

What is the proposed process to develop the conceptual framework
Its implications for community and research involvement

09:30-09:40 hs 4. The Expected Outcomes (G. Gallopín/D. Waltner-Toews) (10 min.)

09:40-10:00 hs Coffee Break (20 minutes)

10:00-11:00 hs 5. General Discussion: needs and recommendations from researchers (all participants) (60 min.)

II. The Pucallpa Case-study

11:00-11:15 hs 6. Facts and Figures (Ernesto Raez-Luna) (15 min.)

11:15-11:30 hs 7. Explanation of process to follow to get the pieces together and identify gaps (G.Gallopín) (15 min.)

8. Getting the pieces together and identifying gaps (all participants)

11:30-12:00 hs • Identification of major issues (30 min.)

12:00-13:00 hs LUNCH (one hour)

13:00-13:20 hs
- Management goal(s) (20 min.)

13:20-13:50 hs
- Range of management objectives (30 min.)

13:50-14:30 hs
- Indicators to assess progress towards objectives (40 min.)

14:30-15:10 hs
- Range of management actions for consideration (40 min.)
- ◆ Identification of actions already being taken/considered by CIAT's research

15:10-15:30 hs Coffee break (20 minutes)

15:30-15:45 hs
- Time horizon and resolution (15 min.)

15:45-16:00 hs
- Spatial extent and disaggregation (15 min.)

16:00-16:30 hs
- System variables required to generate the indicators (30 min.)

16:30 hs End of workshop

Workshop Participants

Jacqueline Ashby, Director of Natural Resources, CIAT

Gilberto C. Gallopín, Land Management, CIAT

Peter Jones, Program Manager, Land Management, CIAT

Ron Knapp, Program Manager, Hillsides, CIAT

Carlos Lascano, Program Manager, Tropical Lowlands, CIAT

Tamsyn Murray, Land Management, CIAT

Ernesto Raez-Luna, Land Management, CIAT

Richard Thomas, Tropical Lowlands, CIAT

Erik Veneklaas, Land Management, CIAT

Raul Vera, Tropical Lowlands, CIAT

David Waltner-Toews, Department of Population Medicine, University of Guelph

Manual Winograd, Land Management, CIAT

Introduction

This workshop, held on March 3 1997, was the first of a series of workshops planned for the CIAT-University of Guelph Project. These workshops will extend over the next 2 years. In addition to them providing an integral part of the development of our theories and hypotheses, they present us with the opportunity to involve local stakeholders in the research process. The success of the Project depends in large part on the genuine inclusion of the multiple perspectives of those living in the agroecosystem in which we are applying the framework.

This first internal CIAT workshop served three main functions:

(i) We presented the concepts and research approach of the Project to other CIAT scientists, discussed our current and proposed research activities and invited their comments and recommendations.

(ii) Since the Project is attempting to develop an integrated conceptual framework, we wished to evaluate how other CIAT projects in the region may help in that process, and where for example their data and other research activities may potentially feed into and strengthen our framework.

(iii) In accordance with the logical sequence of the Project's research process, we conducted a short brainstorming session during which the CIAT scientists identified what they perceived to be the key problems and issues facing the region and the appropriate management goals and corresponding indicators. This provided a broader context in which to situate ongoing projects as well as making explicit some of the basic assumptions that are driving CIAT's research agenda.

Since the time of the workshop, CIAT has chosen to concentrate its efforts in the Ucayali region, increase project collaboration and make the region a benchmark site which can potentially provide important insights applicable to other forest margins areas in the tropics. The CIAT-University of Guelph Project, with its holistic and integrated approach, hopes to contribute to this end. The authors contributing to this report include; Gilberto Gallopín, Tamsyn Murray, Ernesto Raez-Luna, and David Waltner-Toews.

Presentation of the CIAT-university of Guelph Project: *Development and Application of an Integrated Conceptual Framework for Tropical Agroecosystem Research Based on Complex Systems Theories*

Gilberto C. Gallopín, Land Management, CIAT

Thank you for your participation in the First Internal Workshop of the CIAT/UG project. The purpose of this workshop is to build up, by using our collective knowledge and diverse viewpoints, a first-approximation conceptualization of the problematic of the Pucallpa area in the Peruvian Amazon, and to identify major gaps in understanding and additional expertise needed. This area has been selected as the first case-study of the project. The current workshop will draw mainly upon the insights coming from CIAT's scientists. A second workshop will be held at Pucallpa, to insure we include the concerns and knowledge of the social and institutional actors directly involved with the development of the whole agroecosystem. Later this year, the First International Workshop of the project will be held at CIAT, with the participation of CIATs scientists, representatives from the Pucallpa stakeholders, external experts for key areas not yet covered, and researchers on complex systems theories. It is expected that the product of that workshop will be a reasonably adequate conceptual model of the Pucallpa agroecosystem as a complex system, plus critical insights into the basic dynamical processes, in addition to a set of research priorities.

History of the CIAT/UG project

The origins of the project can be traced to June 1994, when Dr. David Waltner-Toews and myself met in a Workshop on Agroecosystem Health held in Ottawa. We quickly discovered we had common interests, particularly about looking for new ways of addressing agroecosystem sustainability and health. David was at that time starting a Canadian-wide project on Agroecosystem Health, and we realized that potential for cooperation was high. The similarities and differences between temperate and tropical agroecosystems have been discussed at that workshop, and we perceived the importance of including tropical agroecosystems in the analysis.

On the other hand, I had been involved in efforts to put together an international group of scientists working on different aspects of complex systems and sharing a common interest to explore the implications of complex systems theories for practical policy- and decision-making for sustainable development. David was a member of this informal group.

While we met in different occasions for workshops and discussions, the first opportunity for serious cooperation arose when we learned about the new CGIAR-CANADA Linkage Fund (CCLF) set up by CIDA. We made a proposal for the fund in 1996, and it was approved in the same year.

Project support and execution:

Supported by the CIDA CGIAR-CANADA Linkage Fund and executed by CIAT and the University of Guelph

Project Team:

Overall coordination: Dr. Gilberto C. Gallopín (CIAT).

Scientific coordinators and Principal Investigators of the project: David Waltner-Toews (University of

Guelph) and Gilberto C. Gallopín (CIAT).

Scientific Advisor: Dr. James Kay (University of Guelph)

Senior Scientist: Manuel Winograd
Research Associate: Tamsyn Murray
Research Associate: Ernesto Raez-Luna
Analyst: Hebert Montegranario

Other staff from CIAT and the University of Guelph participating contributing original data, specialized scientific advice, and critiques of the ongoing research:

CIAT:

Dr. Sam Fujisaka
Dr. Erik Veneklaas
Dr. Peter Jones
Other scientists (to be defined)
Scientists working in the selected sites (to be defined by the project)

University of Guelph:

Dr. Sally Humphries
Dr. Clarence Swanton

Project duration: three years

Project Rationale:

The problematic social, economic, environmental and productive issues facing agriculture and agricultural communities are part of a complex set of activities involving farmers, farm organizations, rural communities, and national, regional and international governments and institutions.

Environmental, social, and economic impacts have repercussions not only for individual farmers where they live, but for all actors at all hierarchical levels in the agroecosystem.

Constraints and opportunities occur at each level in this hierarchy; e.g., the nature and variety of markets, soil types and erosion, social structures and national policies.

Among many researchers and development experts there is an increasing sense of un-ease with traditional sectoral and disciplinary approaches, and a consensus that it is important to take a broad view when trying to solve agricultural problems.

It is increasingly obvious that the quest for sustainable agricultural development requires:

- *integration of* economic, social, cultural, political, and ecological factors
- *articulation* of the top-down approaches to development with the bottom-up or grassroots initiatives
- the simultaneous consideration of *the local and the global* dimensions and of the way they interact

- *broadening the space and time horizons* to accommodate the need for intergenerational as well as intragenerational equity.

The Technical Advisory Group (TAC) of the CGIAR has recognized the need for a new agricultural research model: "as yet, there is no accepted research model which embraces the physical, biological and human dimensions of long term (agricultural) sustainability. Developing such a model is a goal of truly international importance" (CGIAR. 1993. "The Ecoregional Approach to Research in the CGIAR". Report of the TAC/Centre Directors Working Group. CGIAR Mid-Term Meeting, Puerto Rico, May 1993, page 8.)

A *research model for sustainable agriculture* will certainly be more flexible and in some aspects at least, less easy to quantify than a research model for physics or chemistry. The CGIAR was referring to a new, interdisciplinary, multi-level, both site-specific and contextually meaningful, systemic approach to agricultural research, as opposed to the dominating "commodity model".

A research model in this sense includes essentially:

- a goal (sustainable agricultural production and development),
- a conceptual framework,
- a set of procedures,
- falsification criteria.

The development of a *holistic conceptual framework* for understanding and anticipating agroecosystem dynamics and behavior is an essential piece of a new research model.

Project Objectives

- To develop a conceptual framework for the holistic understanding of agroecosystems as hierarchical systems, using the new ideas being derived from Complex Systems theories.

- To apply this framework to concrete tropical agroecosystems in order to assess its applicability and usefulness for guiding research on agroecosystem sustainability.

- To perform comparative analysis of tropical and temperate agroecosystems in terms of systemic properties (on the basis of ongoing research on Canadian agroecosystem at the University of Guelph).

- Based on the research findings, to develop teaching materials on complex systems approaches to the study and sustainable care of agroecosystems. We expect that these materials will be used in Latin America, Canada and elsewhere.

- To train young scientists in the application of concepts and methodologies derived from complex systems theories to the study and evaluation of agroecosystems.

Relevance of Complex Systems

The rapidly developing field of complex systems theories is helping provide new insights on the properties and behavior of systems that are characterized by a high degree of complexity, a complexity that is characteristic of any socio-ecological system such as agroecosystems. Those new insights generate new relevant questions for research, and are beginning to provide new answers.

Complex systems are differentiated from simple systems, but also from what some call complicated systems. In very basic terms, the distinction between them can be stated as in Box 1.

Complex systems are characterized by the fact that *multiple* (and irreducible) *perspectives* are required in order to understand them; looking at them from only a single perspective fails to provide an understanding leading to successful resolution of problems. In the case of agroecosystems, including soil, water, plants, animals, and people, the fact that different social actors have different goals and perceptions is an essential feature contributing to the dynamics and behavior of the system. This implies that the inclusion of those features is important not only in terms of democracy and as part of the search for governance and technology transfer, but also as an epistemological necessity.

Other common property of complex systems is their hierarchical structure, including the operation of different levels of organization defining the division of the system into subsystems, of those into sub-subsystems, etc. In complex systems, this hierarchy constitutes what is sometimes called a "holarchy", a term used to emphasize that subsystems are holons, with holistic properties by themselves.

Complex systems exhibit the properties of self-organization, thereby changing their own structure and behavior in response to either internal changes or changes in their environment, and they may exhibit emergent properties, not predictable from a knowledge of the behavior and structure of their components. Those and other factors generate irreducible uncertainties about aspects of the behavior of complex systems, uncertainties that must be dealt with and that cannot be eliminated by gathering more data. Obviously, this has deep implications for agroecosystem management. Complex systems may be categorized as in Box 2.

One common characteristic of complex systems is that they have more than one stable state or condition to which the system will tend to go. If a system has only one stable state it is called

Box 1
A TAXONOMY OF SYSTEMS

SIMPLE. Can be adequately captured by using a single perspective or description and by a standard (often linear) model providing a solution through routine operations; e.g. idealized planetary motion.

COMPLICATED. Can be characterized by a single perspective; however, it is not satisfactorily captured by a standard model. Nevertheless, it is possible to get as close as desired to a "solution"; e.g., the three body problem

COMPLEX. In any complex system, there is no guarantee of a unique "solution", or indeed any. There are (at least) two classes of complexity; except for borderline cases, most complex systems exhibit both:

> **Epistemological complexity**: it requires a plurality of perspectives. Either complementary (e.g., light, quanta, policy) and/or hierarchical (organisms, organizations, within a broader system)
> **Functional complexity**: self-organization, emergent properties; e.g., Bémard cells.

Source: modified from http://inn.ingrm.it/compsys/index.htm

Box 2
TYPES OF COMPLEX SYSTEMS

COMPLEX PASSIVE. Changes in the system organization are basically determined by its environment.

COMPLEX ADAPTIVE. The system is able to change its "behavior" (changing the values of its variables) and "physiology" (moving between domains of attraction) to survive in a changing environment.

COMPLEX SELF-RENEWABLE. The system is able to cope with drastic change and structural collapse by regenerating itself with the same structure.

COMPLEX EVOLUTIONARY. The system is capable of changing its own structure leading to improvements in the system's performance in a changing environment. Structural changes may be progressive or punctuated; externally or internally driven.

COMPLEX SELF-AWARE. The system is able to observe itself and its own evolution thereby opening new repertoires of responses and connections. Among these are empathy , imagination and perspective of the other; and the ability to modulate responses exploring new situations and alternative visions without loss of identity.

globally stable; in that case, if the system is moved away from the stable state, it will tend to return to it, no matter how far away or in what direction it has been displaced. This means that all perturbations are reversible; the only concern is how long will the system take to go back to its equilibrium. Only simple systems can be globally stable.

If a system has more than one stable state (or set of states) then it is no longer guaranteed that it will come back to the original stable state if displaced away from it; it might go to another stable state, depending not only on the size of the perturbation but more importantly on how near the system state is to the boundary separating the "basin of attraction" of each stable state. This can be illustrated graphically for the case of a system whose state is defined by the values of only two variables, x and y. A state of the system at a given point in time is completely defined by a point in the two-dimensional space (x,y). The case shown in the figure represents a system with two stable sets: one is a stable state (a point) and the other is a stable orbit (representing a periodic oscillation in the values of x and y). If the state of the system is originally within the domain of attraction of the stable state (or the stable orbit) it will tend to go to the corresponding state (or orbit). However, if the system is perturbed in such a way that its state crosses the boundary separating the two domains of attraction, it may "fall" into the other domain, and exhibit a sudden, qualitative, change in its mode of behavior. The system is not globally stable. This is the basis of the notion of **resilience**, which refers to the capacity of the system to remain in its original domain of attraction in the face of perturbations. It has been shown in a number of empirical cases and also through modeling, that many natural resource systems have the property of having more than one stable state or set of states. The implications for management are very deep.

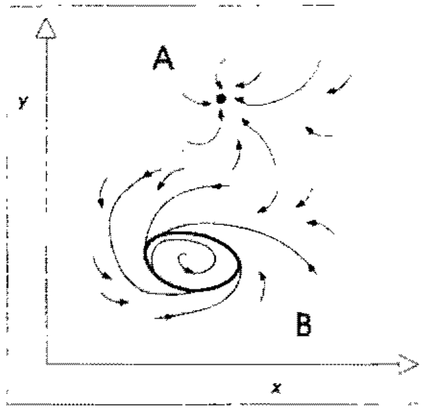


Figure 3

Choice of Pucallpa/Ucayali as case-study

The Ucayali region of the Peruvian Amazon has been chosen as the first case-study for the development and testing of the conceptual framework because of the following reasons:

1. The case is certainly complex enough to require an integrated framework. The process of development in Ucayali involves economic, social, ecological, agricultural, and technological dimensions.

2. A number of projects are already going on. This includes CIAT's projects as well as projects developed by other international, national, and local institutions. The project will benefit from the information and data gathered by those other projects; conversely, the project could help the integrations of those activities.

3. Research in the region is in an active state; new research and development activities are being planned. This means that some of the critical research questions identified by the project might be answered through those activities. The project may also help to set research priorities for the area.

Pucallpa land-use model

The goal of the project is to develop an integrated conceptual framework including the major factors and dimensions determining the behavior of the agroecosystem (including both human and non-human elements). Some of these factors (such as land erosion, agricultural yields, population growth) are amenable to quantification, but other factors of no lesser importance, cannot be quantified (or are trivialized if quantification is forced on them). This includes many cultural, social and political factors. Moreover, the laws or rules giving rise to many of those factors are unknown. Still, insofar as these factors are considered important in determining the behavior of the system, they must be included in the conceptual framework.

For the subsets of factors that can be quantified, the use of simulation models may be very effective in developing understanding and exploring alternative hypothesis. In a very basic sense, a simulation model is an articulated set of hypothesis under the form of variables and relations between variables, usually unfolding in time. The project is developing a dynamic mathematical simulation model of land use in the Pucallpa area, which is still at the exploratory stage. A flow diagram of the first cut model is shown in Figure 2. Despite its preliminary nature, the process of building the model has already helped to identify critical gaps in knowledge, gaps that must be filled in order to anticipate the future trajectories of land use in the region.

The model is run in the M environment, a modeling and visual interface developed by the National Institute of Public Health and Environmental Protection (RIVM) of the Netherlands. M is available freely to CIAT as a consequence of previous cooperation agreements, and it runs under Unix and under Windows 95 and NT. A sample output of the model appears in Figure 3.

Connection to the Resilience Network

The Pucallpa case study is also linked to an international research project called the Resilience Network, a joint innovative research project by the Beijer International Institute for Ecological Economics and the University of Florida, through my participation as a member of the Network. The Pucallpa case has been accepted as a case study of the Resilience Network; this will add new dimensions to the project.

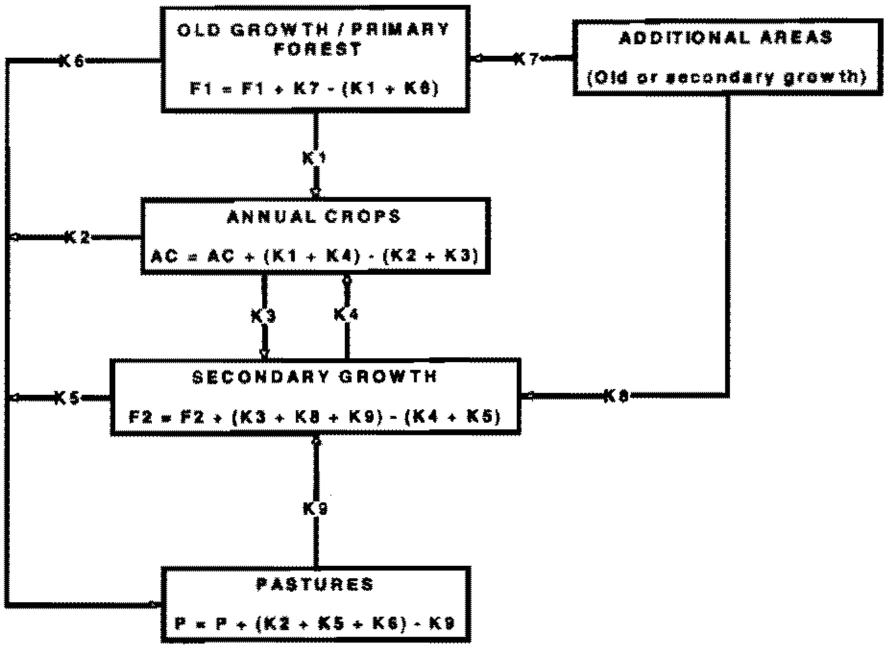


Figure 3. Flow diagram of land use in a farm (Pucallpa)

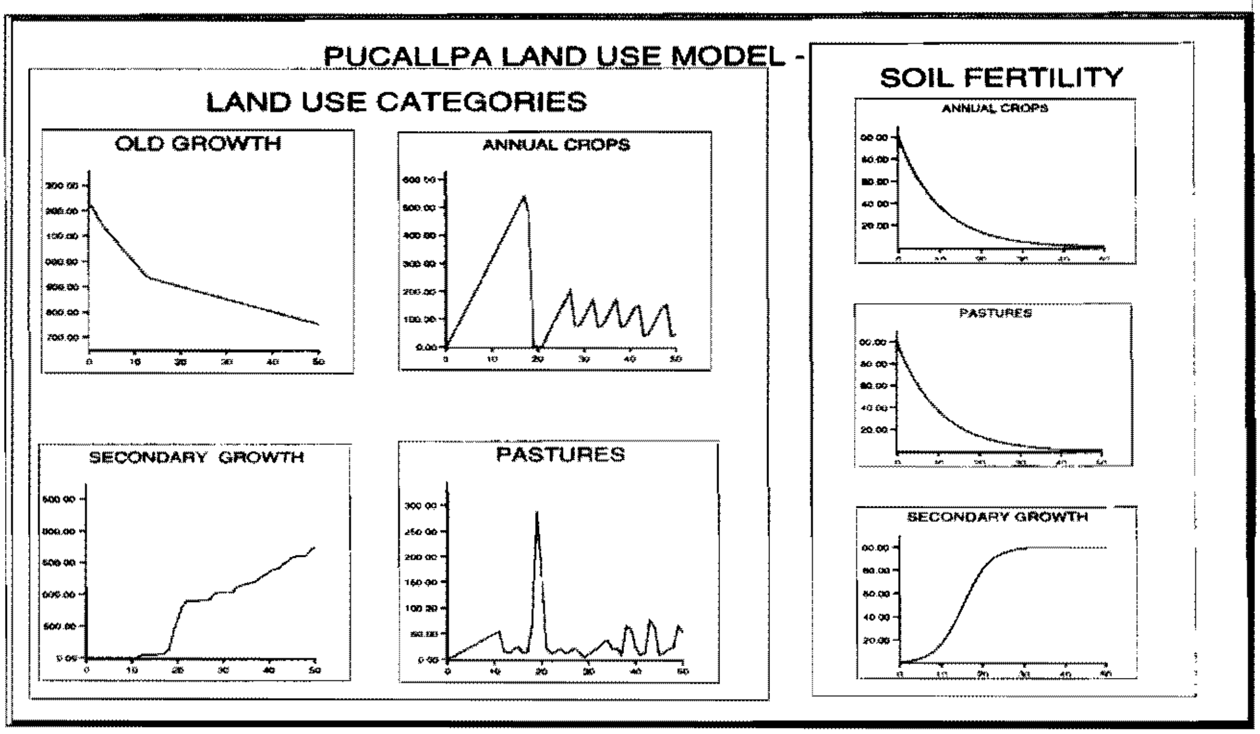


Figure 4. A simulation run of the model

Agroecosystem Health: a Canadian experience in understanding complexity in agricultural sustainability

David Waltner-Toews,
Department of Population Medicine,
University of Guelph

In 1993, a group of researchers at the University of Guelph received $1.35 million (CDN) from the EcoResearch Program of the Tri-Council, an ad hoc research council comprising the Medical, Social Sciences and Humanities, and Natural Sciences and Engineering Research Councils of Canada. Over the course of three years, the research team included some 23 researchers from a dozen disciplines covering the full range from qualitative sociology to economics and health sciences to various natural sciences. The team also included nine post-doctoral research associates, 18 graduate students, eight assistants and four staff.

For me, as a Principal Investigator, this research grew out of an increasing sense that environmental, socio-economic and public health policies and management decisions in agriculture are often developed and implemented as if they applied to independent, parallel universes. While management and political policy decision-makers were sometimes forced to integrate these dimensions and/or to articulate trade-offs, university discipline-based research has done little to provide a basis for integrated action.

The goal of the Agroecosystem Health (AESH) Project was to develop a framework for evaluating and improving the health of (Canadian) agroecosystems. Nevertheless, as a PI, my interest was much broader; indeed, it seems to me that the need for this research was even greater throughout the tropics than within Canada. For this reason, I have sought partners in various developing countries to build on the Canadian work and extend it both intellectually and practically - including this CIAT-Guelph project. In this presentation, I do not intend to put forward any of the many detailed studies that were done within the umbrella of the larger AESH project. It seems to me, however, that it is useful to ask what we learned in the last three years that can help us in the current research into tropical agroecosystems.

The objectives of the AESH project seem simple enough. They were

1) To develop generic classes of indicators which can be used to characterize the health of agroecosystems.

2) To understand the dynamic relationships of AESH indicators over space and time a) among dimensions (biophysical, socio-economic and community health) and b) in response to external stressors, particularly policy.

Our proposed research strategy was to combine an ecosystems approach with an evaluative framework. This seemed, at the time, to be a relatively straightforward and simple approach. Before delving into what that meant in practice, it is worth identifying some assumptions that we made which, at the time we started, were not well articulated or understood.

These were that:

1) a single systems description of agricultural landscapes and activities is possible;
2) measurable indicators of system status can be identified; and
3) professional investigative expertise is probably sufficient to address the issues.

The first and third of these assumptions are most surely false. The second is only partly true.

The ecosystem approach to solving complex problems involves consideration of the following, which I list in no special order:

1) Ecosystems (particularly agroecosystems) include people, and thus have socio-cultural and economic as well as biophysical dimensions to them.

2) Ecosystems can be viewed as nested hierarchies which self-organize around attractors (such nested hierarchies are termed holarchies, with each "self-contained unit" within the hierarchy being a holon).

3) General patterns of ecosystem behaviour can be discerned, but exact causal pathways are often uncertain and may resist analysis.

Two problematic issues immediately become apparent.

Issue #1 (see Table 1). Agricultural activities can be seen to be nested in at least two different ways - a social hierarchy from individuals to families and on up to a global society, and an ecological hierarchy, starting at fields or plots and on up through farms and watersheds to the biosphere. One could spent a lifetime trying to find ways to merge these hierarchies. In fact, for practical purpose, no such exact merging is required. It is possible to think of layers that more or less overlap, particularly at the farm/ family level, and the ecodistrict or sub-watershed level and the community (Table 2).

Issue #2 (Table 2). Given some kind of workable merging of holarchies, we are still left with the problem of multiple perspectives. A minimum set would include one that is grounded in ecology and one that is grounded in human society, but the possibilities are almost endless. Our project began with a set of three perspectives, one primarily economic, one primarily environmental, and one primarily rooted in community health. Two things become apparent from this:

1) we are back to our independent parallel universes and
2) we can begin to create at least conceptual models of the systems we are talking about.

Although we did not come up with any fully integrated conceptual models at this stage, it was possible to use some models heuristically across perspectives. Thus Holling's figure eight (Figure 1) (Holling 1986) can be viewed at various scales. It is in fact the kind of model farmers use: they enter certain kinds of information (desirable seeds and genetic information) and suppress other kinds (pests and weeds); they harvest the produce that accumulates during what in a natural system would be called succession; and then re-organize their farm activities around new sets of information. One can see this also in economic terms, and use it as a basis both for genetic biodiversity (to keep open the options for future development), economic diversity (to keep open market options, etc) and social diversity (to keep open a range of ideas/ options/ ways of doing things, that will allow the farm or community to adapt to changing times. Drawing analogies across perspectives is interesting and useful, but it does not address the fundamental problem of a socio-economic system being viewed as separate from the ecological system. This is still not the "real world" where these are closely interconnected. Nevertheless, it is a beginning, and several researchers on the Project developed other heuristically useful models.

Having described the system in one or more ways, we were still left with the problem of evaluation. It's all very well to describe the state of a system, but to make decisions regarding management, we need to have some way to judge whether things are getting better or worse. This evaluation, it turns out, cannot be done without referring to goals.

Figure 2 displays a cube, in which we now have scale accounted for, and dimension, but to which we have now added a third dimension which we called health. Health is at one and the same time a simple concept for which most people have some intuitive sense, and a difficult concept which cannot be defined in any exact way. For all practical purposes, it come down to something we might call integrity or structure, which make a thing recognizable something (an animal vs a road-kill for instance) and something called effectiveness, which refers to what we want the system to do.

Among the many controversies which this raises is the question of who the "we" is in "what we want the system to do". Scientists have not developed a good language, nor widely accepted research methodologies, with which to study systems with people inside them. For one thing, normal science assumes that anyone should be able to replicate an experiment; if people are inside, then we must exclude them, since in experimenting on themselves, they will change the dynamics of the system. Thus, a fundamental tenet of science is violated. In the second place, we general assume that natural systems evolve over time through a combination of coded historical information (DNA, culture) and changing environments. People, however, also respond to perceived possible futures, and will change their behaviour, and the physical and socio-economic dimensions of the system in which they live, in response to an environment which does not yet exist, and may never exist. For this reason, I once suggested that the way to sustainable agriculture might more likely lie through better poetry than through better tractors. How do we get around this?

Funtowicz and Ravetz (1994) have proposed that, in addition to basic science, which is a narrowly focused, self-directed activity to discover the "truth" about nature, we can talk about applied science and professional consultancies, where success is determined not just by scientific peers who replicated your experiments, but by clients who judge whether or not you have solved their problems. They have no particular interest in complex systems. They may want to know if their livestock will survive. Furthermore, when we move into the realm of such things as environmental and public health and agricultural policy and management, we are faced with multiple perspectives, multiple competing goals, and multiple stakeholders. The science necessary to deal with this complex, uncertain situation has been called post normal, interactive or second order science (Figure 3).

Normal science, as described by Thomas Kuhn in his book The Structure of Scientific Revolutions, involves puzzle solving based on an unquestioned set of assumptions, which he called a paradigm. Proof in normal science is by formal deduction and values are unspoken. Furthermore, each discipline may have its own paradigm, which requires scientific specialists to truncate their view of the world so that, for instance, soil physicists can only say things about soil structure, microbiologists study microbes, and economists study economic activities. We are here in the world of multiple parallel universes.

Post normal science, on the other hand, involves the resolution of problematic situations based on "communicative rationality" a term used by the philosopher Habermas, who described three kinds of rationality: instrumental rationality was used by normal science with the idea that we wish to control nature through technology; strategic rationality has been used to describe evolutionary biology and economic activities, where winning is the aim of the game; and communicative rationality, in which negotiation, consensus-building and complex problem solving are the goals.

Ellen Wall, a post doctoral researcher, worked with me on considering how one might talk about community health issues using a post normal approach (Waltner-Toews & Wall 1997). The central question we came up with, it turns out, can be used for many kinds of complex evaluation issues related to sustainability, including health, environmental and agriculture. The question is: Are the quality and quantity of internal and external resources sufficient, and is their organization appropriate, for the system to meet its goals?

What is quickly apparent is that, in order to answer the question, we not only need to define and measure resources and their organization - activities which can be carried out by normal scientists - but that this is done in relation to agreed-upon, scale dependent goals. In this setting, participatory research methods become central for goal definition, and scientific activity is in relation to those goals. This is a reversal of what we have come to expect in the applied scientists, where the experts most often define the goals. These goals, which are another way of talking about effectiveness, can be thought of in more specific terms as efficiency, adaptability, equity, aesthetics and the like. Some of these goals are in competition with each other (eg efficiency & adaptability), a situation which is resolved through negotiation between both internal and external stakeholders at various scales. Post normal science, then, puts communication and negotiation at the centre of a process which includes the best scientific and indigenous knowledge available. In a sense, politics becomes political science, and open to the same scrutiny, evaluation and peer-review as another scientific activity.

Some lessons Learned from the AESH Project

There is a clear need for considerably more *transdisciplinary* research into the interactions among environmental change, agricultural practice, economic policies and public health. Such research should include both empirical, community-based studies and further development of the theoretical and scholarly framework for such investigations. Based on the work of the past three years, the Project concludes the following:

1) The combination of agroecosystems approaches for describing the complex reality of agriculture with the evaluative concepts provided by health was demonstrated to be useful both in terms of stimulating innovative and important transdisciplinary research questions and for formulating the pursuit of knowledge and its outcomes in ways that are useful for decision-makers at all levels.

2) Given a view of reality which includes nested hierarchies and multiple perspectives, it is unlikely that any single model will capture a full description of agroecosystems, and that an openness to multiple systems, each created for different purposes, is necessary, at least at this early stage in the research, and perhaps, on first principles, for the foreseeable future.

3) While general attributes of health can be elucidated such as integrity and effectiveness, or resilience and capacity for renewal, the indicators required to measure them may be context-specific, and some of them can only be determined in consultation with stakeholders in the system.

4) The issues of scale, both spatial and temporal, are fundamental to any consideration of agroecosystem health. Any definition of an agroecosystem, beyond the most general theoretical one, requires specification of spatial scale and extent. The Project recommends that agroecosystems be studied at scales from the field plot to large regional ecozones, as well as globally, while recognizing the nested hierarchical structure implicit in such scale definitions. It is necessary to assess the consistency (or otherwise) in health evaluations from one scale to another, not just simply declare that any piece of work on agroecosystem health applies only to the spatial scale at which it was undertaken.

5) While much of the analysis has potential application for policy development and implementation, researchers are still far from having a sufficient scholarly basis for recommending policy initiatives relative to agroecosystem health. Indeed, it is likely that many policies need to be developed in the context of interactive research with stakeholders, and may be only partially amenable to external, expert-driven evaluations and prescriptions. That is, resolutions to agroecosystem health problems need to be negotiated, not prescribed. This would be in keeping with the health approach, where internally-derived values are combined with external measurements to arrive at decisions for management. In the shorter term, a

practical course of action might be to assess potential policy initiatives, including the deregulation underway in response to deficit concerns and trade agreements, against some of the more robust indicators of agroecosystem health developed in the Project.

New approaches to understanding the world can be understood as going through a general cycle, from concrete experience to new ideas and hypotheses, to new conceptual maps, and finally, to the generation of new solutions. For the past several years, there has been considerable effort expended on generating new ideas and concepts. For many of us, these concepts and even the models derived from them are insufficiently tested; what do they mean for decision-making? How do they contribute to making a more congenial, sustainable world - not just to understand its difficulties? What is required is not only the synthesis of the natural and social sciences and the humanities, but a synthesis of action research with more conventional expert-dominated research.

In keeping with this move from theory to praxis, I have expended considerable effort over the past several months building on the work in Canada to create a global network of community-based ecosystem health projects. The purpose of this network would be to expand the practice and theory necessary for creating and sustaining liveable human communities on earth. To date, activities in this area have lead to the following:

Sites	Partners with U of Guelph
Pucallpa, Peru	CIAT
Kiambu District, Kenya	U of Nairobi
Kathmandu, Nepal	National Zoonoses and Food Hygiene Research Centre

The CIAT project has CIDA funding and we are seeking additional funds from other sources. The Kenya project has been funded by IDRC. IDRC has also funded the preparatory/ pilot studies for the Nepal project. Other projects are also being explored in Uganda (a community with an AIDS-socio-ecological breakdown mess); Tanzania (a community with the highest rate of plague in the world as the result of a combination of international agricultural markets and local socio-ecological changes); Ontario (a community with parasitic water contamination); and perhaps southern Africa (in partnership with universities in S. Africa and Sweden. Ultimately, I would like to see representatives of these communities learn from each other, facilitated by system scientists but not dictated to by them.

Table 1: Issue 1: Scale: Temporal and Spatial Cross-level Effects

Social and Ecosystem Hierarchies/Holarchies

Individual	Field
Family	Farm
Community	L.R.A (Land Resource Area)
State	Watershed
Nation	Ecoregion
International Organization	Ecozone
United Nations	Biosphere

Table 2: Issue 2: Pespective : The Problem of "Parallel Worlds"

Matrix for Goals and Indicators

Scale	Biophysical	Social	Economic
Field/Individual			
Farm/Family			
Ecodistrict/Community			
Watershed/State			
Region/Nation			
Ecozone/International			
Biosphere/United Nations			

Heuristic models - synthesis by analogy - scale issue

At each scale (farm region) the consequences of collapse increase in *magnitude* and the *risk* of collapse increases as dependence on single sources of information (genetic, social, economic) increases

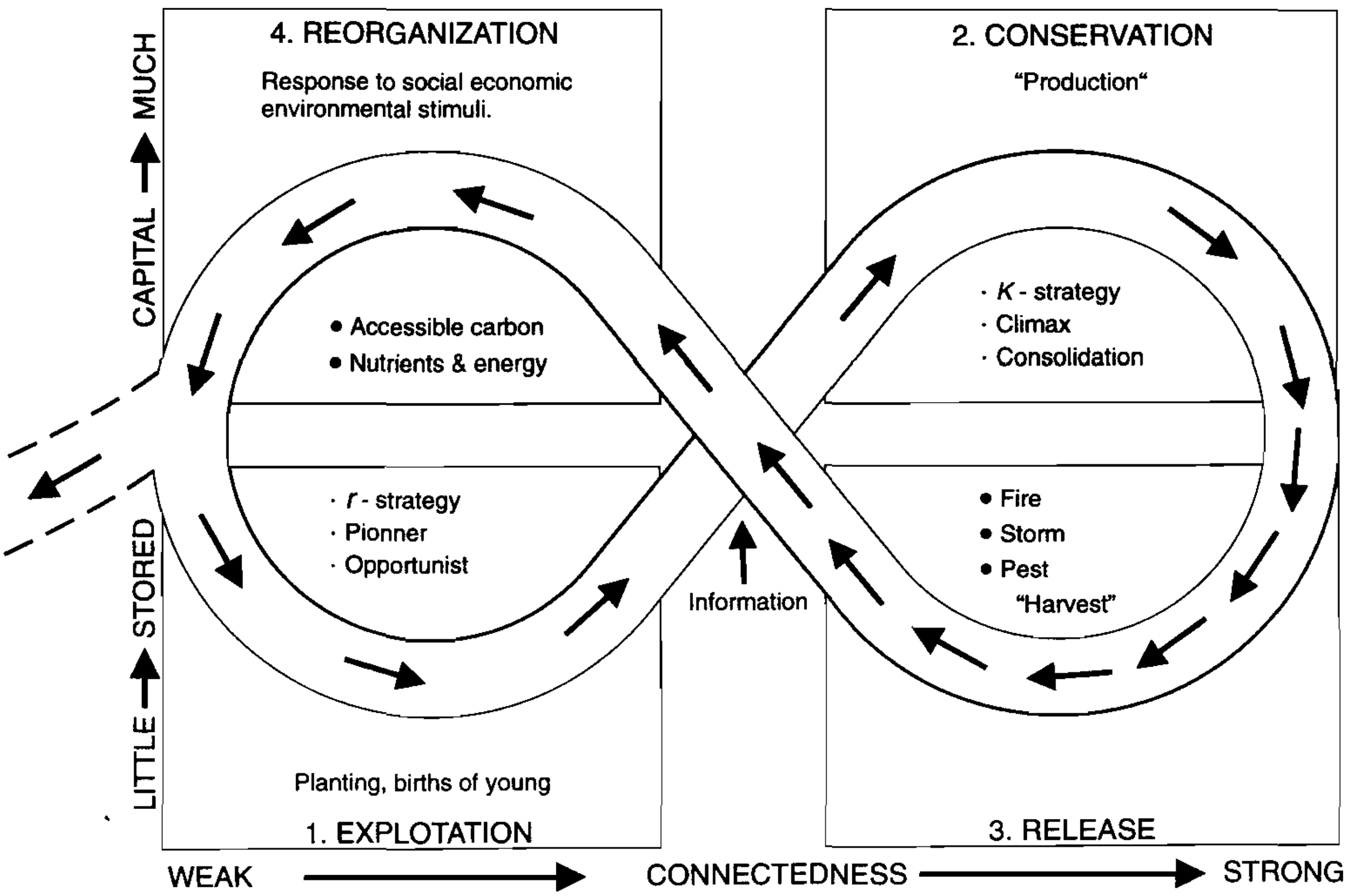


Figure 1. Externalized sources of Information (less sustainable) vs. Internalized (more sustainable).

Source: C.S. Holling, 1992.

Figure 2

A Conceptual Framework for Agroecosystem Health Management

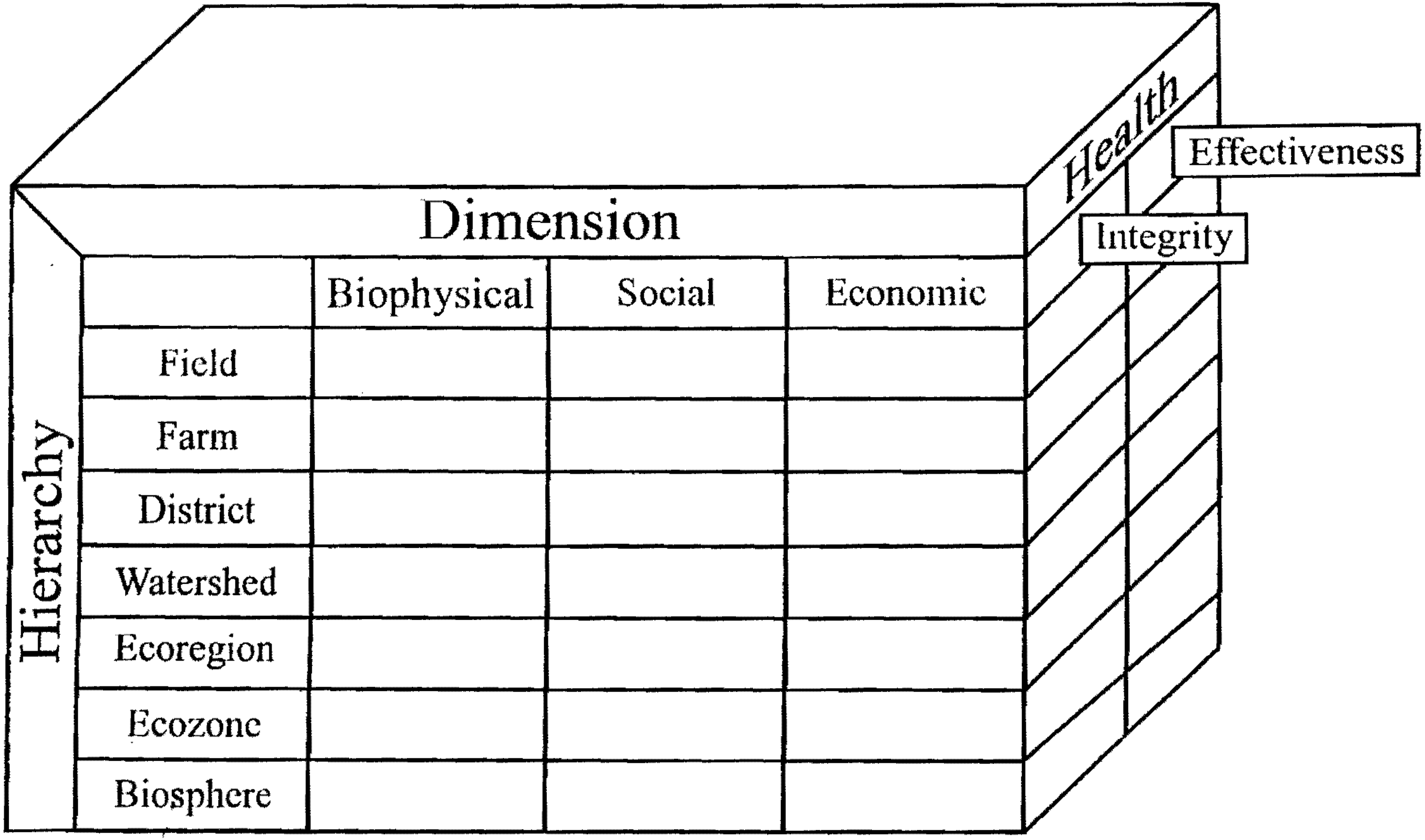
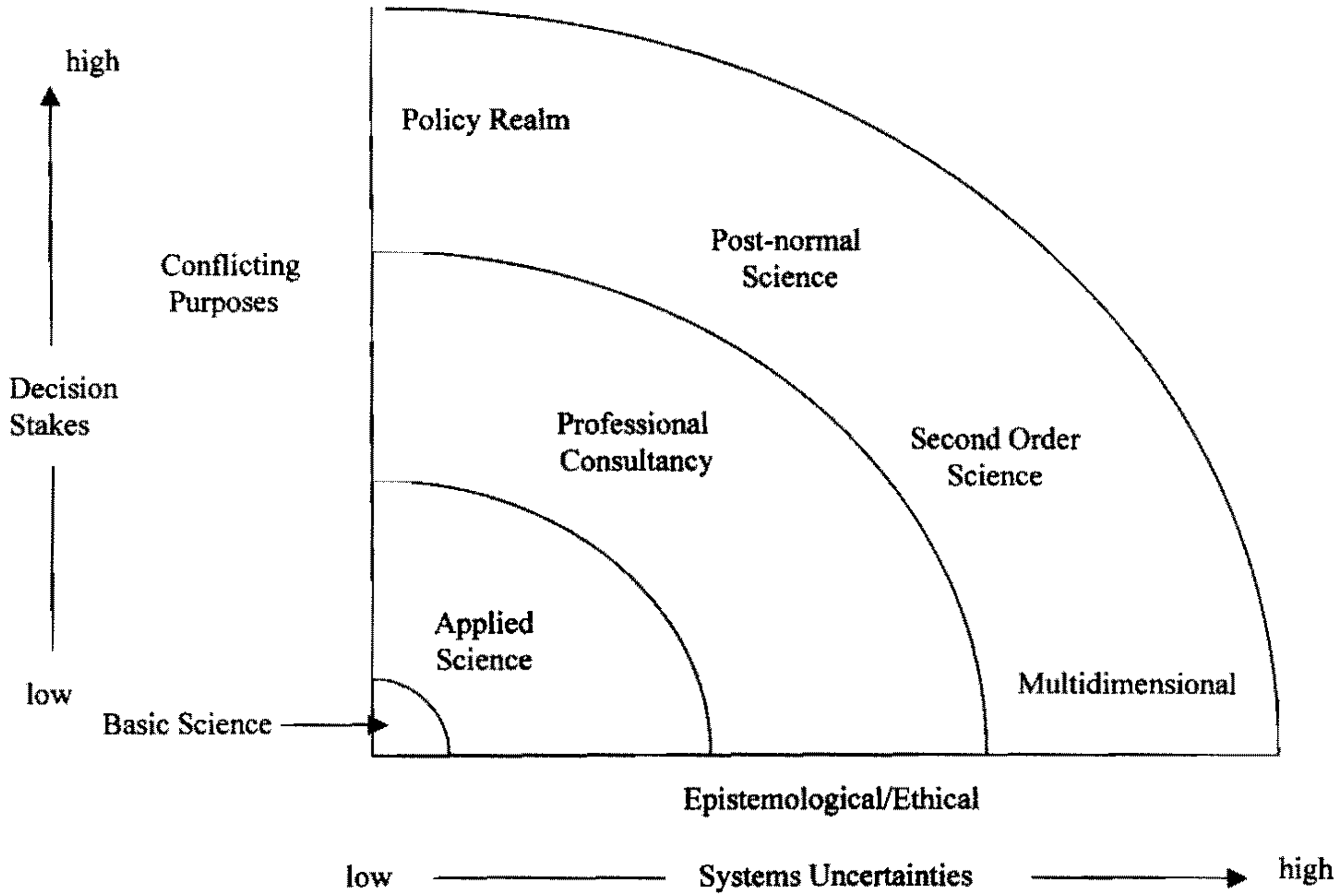


Figure 3: Issue #3 Whose ecosystem is this anyway? - Knowledge, Power and Expertise



Source: Funtowicz and Ravetz (1994)

References

Funtowicz, S. & Ravetz, J. (1994) Emergent complex systems. *Futures* **26(6)**, 568-582.

Waltner-Toews, D. & Wall, E. (1997) Emergent perplexity: In search of post-normal questions for agroecosystem health. *Social Science and Medicine* (in press).

Holling, C.S. (1986) The resilience of terrestrial ecosystems: local surprise and global change. In *Sustainable Development of the Biosphere*, eds. Clark, W. and Mann, R.E. Oxford University Press, London. 292- 320 pp.

The Research Process

Tamsyn Murray, Land Management, CIAT

The primary goal of this project is to develop a framework that can guide agricultural research. Therefore we not only wish to provide new concepts and forms of analysis to better understand agroecosystems, but also develop a research process, a method, that will outline for future researchers the necessary steps to be taken to achieve a more complete understanding of the system. Figure 1 represents the first draft of such a proposed research method. We have identified a series a steps through which both researchers and stakeholders progress. Although there is a particular sequence to the process, the whole process is iterative. As new information is discovered past stages are revisited and modified. The differing roles and responsibilities of the scientists and stakeholders must be explicit.

Despite the fact that the project draws primarily on complex systems theory, there are a number of other approaches, ones that emphasize non-linearity, multiple steady states, hierarchy, and emergence, that have influenced the conceptual basis of the Project. They include: the ecosystem approach (Kay 1994; Slocombe 1993; Allen *et al.* 1993a); soft-systems methodology (Checkland 1981; 1990); adaptive environmental assessment (Holling 1978; Walters 1986); hierarchy theory (Allen *et al.* 1984; 1993b); post-normal science (Funtowicz & Ravetz 1994) and ecosystem/agroecosystem health (Rapport 1989; Costanza *et al.* 1992; Waltner-Toews & Wall 1997; Waltner-Toews & Nielsen 1995; Gallopín 1995).

The following section includes brief descriptions of the different steps identified:

Scaling

There are two parts to this process. First the system of interest is defined and delimited, as not all aspects of the system can be included. The boundaries both in time and space are identified, ie. what is the extent of the system and over what time period are we concerned. In addition we need to identify what type of system it is, eg. agricultural, fisheries, or forestry system. This defines our perspective, clarifies what is of interest to the observer (trees, food, income). Second, the system is situated within a nested hierarchy and the key contextual relationships with higher and lower systems in this hierarchy are identified. In scaling we are able to begin to highlight the cross-scale interactions and the level at which important emergent properties become evident.

Historical Reconstruction

In order to discover the dynamics of the system, repeating patterns, critical processes and cause-effect relationships, the history of the system needs to be reconstructed. In this project we separated key developments into ecological, economic, demographic, political and cultural dimensions. In addition we focused on changes in the pattern of organization ie. the configuration of relationships among the system's components that determines the system's essential characteristics, changes in structure and process.

Problem(s) Analysis

During this step the critical management goals and objectives are identified. This helps to highlight the key issues or problems that are of interest to the stakeholders. Once the objectives are defined, the indicators that allow one to assess the performance of such objectives are identified.

Subsystem Models

Problem(s) analysis leads naturally on to the description of various subsystems models that detail the different system variables on interest. Focussing on subsystems allows simplification of different processes across time and space, and allows one to clarify the key interactions and influences in the system.

Re-Examination of the System

At this step complex systems theories are applied. The application of complex systems theories should provide us with a different understanding of system behaviour. The following figures show in one way how CST provides an alternate interpretation. Figure 2 shows how an ecosystem develops along a thermodynamic branch, a path in its state space, until it reaches an optimum operating point. At this point the disorganizing forces in the external environment and the organizing thermodynamic forces are balanced. This point is temporary as the external environment is constantly changing. Figure 3 shows what may happen when there is a perturbation in the environment. For example an ecosystem subject to stress will shift to a lower optimium operating point. Maple forests subjected to acid rain are seen to shift to a state of lower productivity and lower biomass. However in this case if the external environmental conditions return to their previous state, so will the optimum operating point shift back. In Figure 4 the system is perturbed to the point where it follows a new thermodynamic path. In this case some new structures are added and some disappear. New pathways for energy flow may connect new components, however the ecosystem's organization will not be very different from the original. Such a change was observed in a marsh gut ecosystem in Florida that had been stressed by warm water affluent. This resulted in an increase in the temperature of the water and the loss of two top predators, two lower predators, the addition of three lower predators and herbivore species. There was also a change in the foodweb in terms of cycling and trophic positions. In Figure 5 the system moves to a different thermodynamic branch. In this case the system is so reorganized that it is clearly recognized as being different from the original system. Even if the original external conditions return the system has no possibility of returning to its original optimum operating point. A classic example of this is when savannah ecosystems are irreversibly changed into woody vegetation through overgrazing.

Thus we may look at the agroecosystems in Ucayali in light of these different stable states that at certain points are stressed and altered either reversibly or irreversibly. What is key is the conditions or characteristics of the system that allow it to recover or instead flip into a different and more degraded steady state.

In the initial examination of the case study site, Pucallpa, it was hypothesized that there may exist the condition in which certain degraded pastures do not renew themselves and do not return to secondary growth. Rather they stay in a permanently degraded condition, one that requires intervention, ie. inputs or mechanized cultivation, to move it from this steady state. Complex system theory may be able to provide insight into this process whereby the system bifurcates or flips into a different state. We can begin by looking at the conditions that result in this different state, identify triggers and see whether we can monitor them. Such conditions and triggers may include both ecological and socio-economic factors. The possible determinants may be grazing (timing and intensity are key) which in turn causes compaction, reduced infiltration rates and weed invasion. There may be a break in critical cycles that reduce the availability of nutrients or a decline in the availability of sources of renewal, such as seeds or dispersors.

Another important aspect of CST is understanding the "human activity system", providing insight into the core purpose of human activities in the system. Checkland (1981) outlines a methodology that attempts to encapsulate the fundamental nature of the human goals and intentions. It exposes the viewpoint and rationale of those defining and addressing the perceived problems. Checkland describes six root definitions (CATWOE) that allow us to understand that rationale. They include "C" - client of the system and analysis, for whom the system works; "A" - actors in the system, those who do "T"; "T" - the transformation process, the measured change in state, conversion of input to output; "W" - weltanschauung, world view that make "T" meaningful; "O" - owners, those who can stop "T"; and "E" - the environment. Table 3 gives an example of how this approach could be applied to the different human activity systems with the Ucayali region. Once all the root definitions are described, we have a better understanding of the power structures and relations as well as the socio-political context of the system.

Table 3: Soft Systems Description of the Human Activity System

Type of System	Cattle/ Pasture	Forest/ Agroforestry	Fisheries
"C" Clients	farmers	forestry companies	fishermen
"A" Actors	farmers cattle	foresters	fishermen fish
"T" Transformation Process	degraded to improved land	harvesting wood	harvesting fish
"W" Weltanschuuang	cattle provide income	trees provide income	fish provide food
"O" Owners	government	government	government
"E" Environment	cleared land and surrounding secondary growth	primary growth	aquatic ecosystem - Ucayali watershed

Comparisons

These interpretations, both the subsystem models and the CST applications, are brought into the real world and set against the perceptions of what exists there. This could be done either in collaboration with stakeholders or with other tools such as GIS and remote sensing. The purpose of the comparison is in part to generate a debate with concerned people in the region which will later aid in defining possible changes which are both desirable and feasible.

Change, Action and Monitoring

These later steps are driven primarily by the stakeholders. Once they are complete the problems and critical issues need to be reassessed.

If one wished to think of these steps in terms of researcher- community interaction, we might suggest that the scaling and historical reconstruction is best done by CIAT researchers alone; problem analysis and subsystem models by CIAT researchers in consultation with stakeholder groups; re-examination using complex systems theory is done mainly by scientists, the comparison of developed models with reality and previous models is done by both scientists and stakeholders, whereas the last few stages, from identifying possible changes, instituting and then monitoring them are mainly stakeholder driven, with facilitation and advice from scientists.

An equally important outcome of this process relates to the ability of the created or modified stakeholder institutions to sustain the process in addressing new problems. Participation in this process should be more than a "one-time" thing. We wish to create institutions in which people can, and do, continue to participate in solving their own problems long after the researchers are gone. This is the ultimate sign of success.

Finally, we emphasize that this process can be used to address many types of problems; it is both iterative and multi-faceted. There is no clear endpoint because agricultural sustainability, in an ever-changing global situation, involves not just environmental conservation and economic viability, but the creation of agricultural institutions and management practices which are responsive, adaptable, and can "learn" as they go.

Figure 1:Different Stages in the Research Process

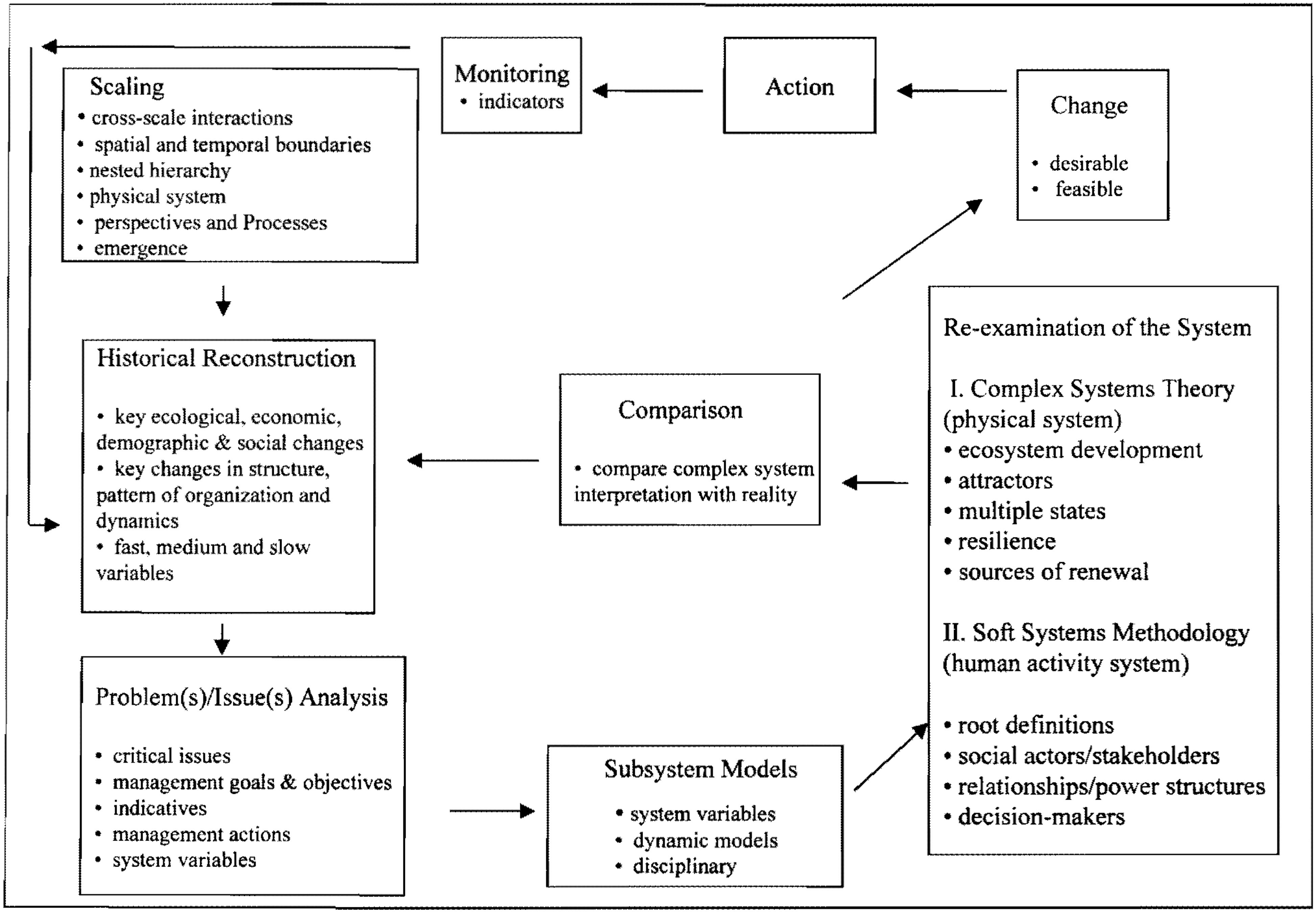


Figure 2

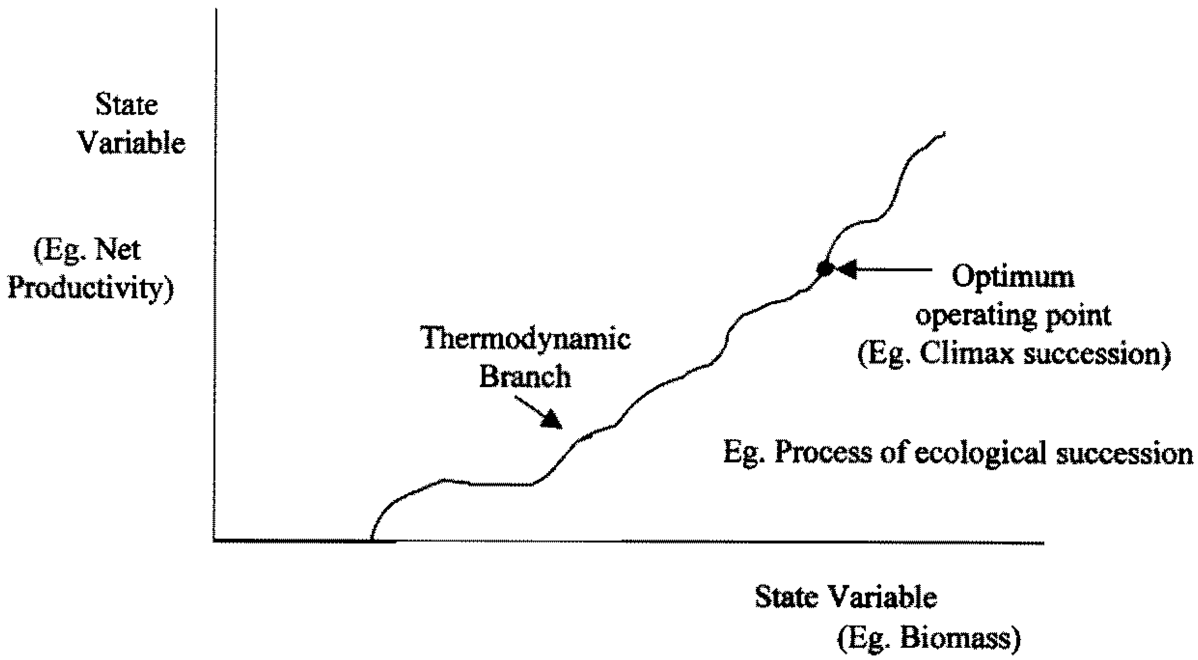
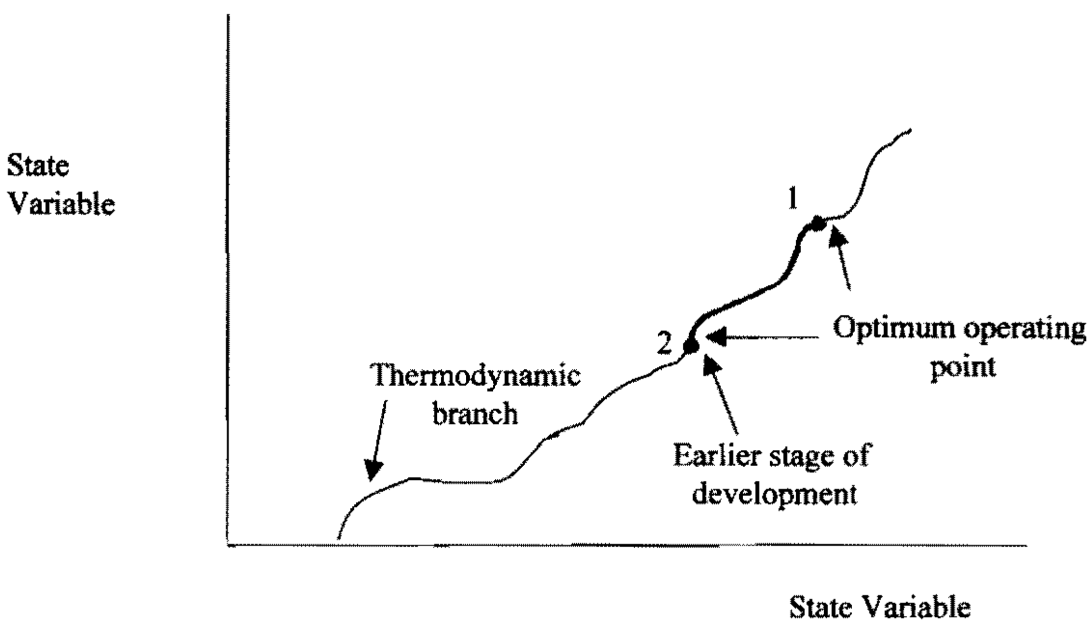


Figure 3



Adapted from James Kay (1994)

Figure 4

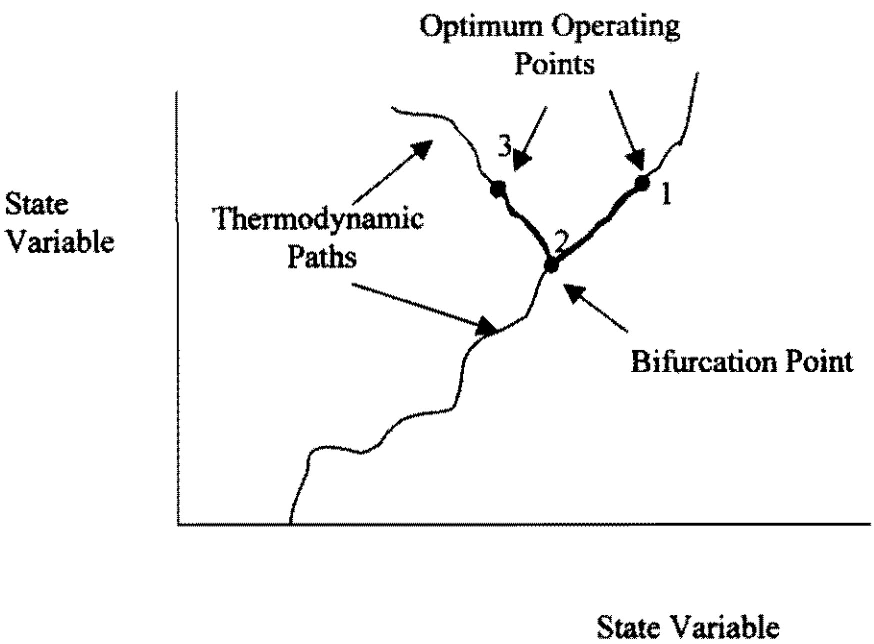
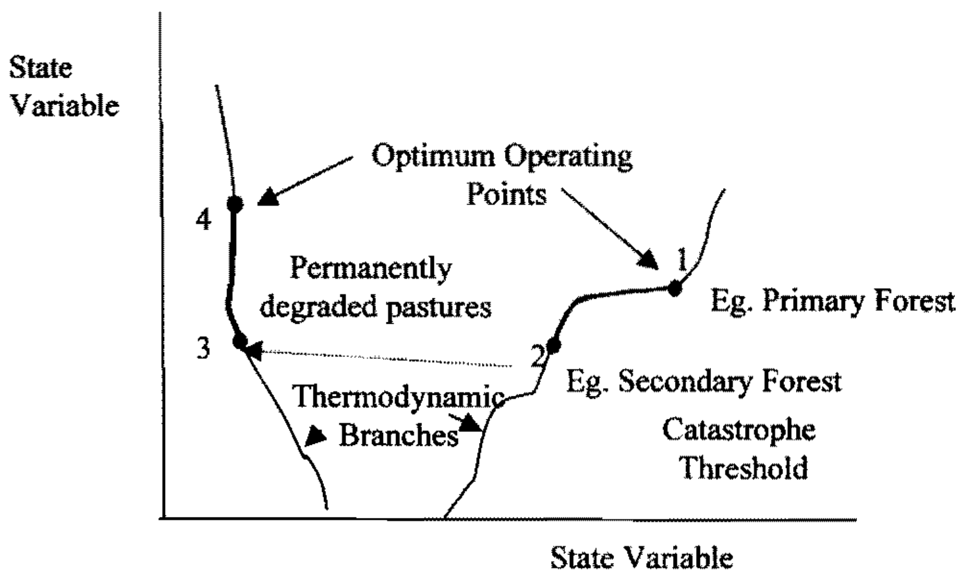


Figure 5



Adapted from James Kay (1994)

References

Allen, T.F., Bandurski, B.L., King, A.W. (1993a). *The Ecosystem Approach: Theory and Ecological Integrity*. Report to the Great Lakes Science Advisory Board

Allen, T.F., King, A.W., Milne, B., Johnson, A., Turner, S. (1993b) The Problem of Scaling. *Evolutionary Trends in Plants* **7(1)**: 3-8.

Allen, T.F., O'Neill, R.V., Hoekstra, T.W. (1984) *Interlevel relations in ecological research and management. Some working principles from hierarchy theory.* USDA Forest Service General Technical Report RM-110. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO, 11pp.

Checkland, P. (1981) *Systems Thinking, Systems Practice*. John Wiley & Sons Ltd. Chichester, 330pp.

Checkland, P. (1990) *Soft Systems Methodology in Action*. Wiley, Chichester, 329 pp.

Costanza, R., Funtowicz, S. , Ravetz, J. (1992) Assessing and communicating data quality in policy-relevant research. *Environmental Management* **16(1)**, 121-131.

Funtowicz, S. & Ravetz, J. (1994) Emergent complex systems. *Futures* **26(6)**, 568-582.

Gallopín, G.C. (1995). The potential of agroecosystem health as a guiding concept for agricultural research. *Ecosystem Health* **1(3)** pp.129-140.

Holling, C.S (1978) *Adaptive Environmental Assessment and Management*. John Wiley & Sons Ltd., Chichester, 337 pp.

Kay, J.J. (1994) *The Ecosystem Approach, Ecosystems as Complex Systems*. University of Waterloo, Waterloo.

Rapport, D.J. (1989) What constitutes ecosystem health. *Perspectives in Biology and Medicine* **33(11)**, 121-132.

Slocombe, D.S. (1993) Environmental planning, ecosystem science and ecosystem approaches for integrating environment and development. *Environmental Management* **17(3)**, pp 289-303.

Walters, C. (1986) *Adaptive Management of Renewable Resources*. MacMillan Publishing Company, New York, 374 pp.

Waltner-Toews, D. & Wall, E. (1997) Emergent perplexity: In search of post-normal questions for agroecosystem health. *Social Science and Medicine* (in press).

Waltner-Toews, D. & Nielsen, O. (1995) *Assessing agroecosystem health*. Discussion Paper # 23, Agroecosystem Health project, University of Guelph.

AN OVERVIEW OF THE PUCALLPA-UCAYALI REGION, PERU

Case Study Site

Ernesto F. Ráez-Luna and Tamsyn Rowley
May, 1997

CIDA-funded Special Project "Development and Application of an Integrated Conceptual Framework for Tropical Agroecosystem Research based on Complex Systems Theories" // PE-4 (formerly P22): "Sustainability and Land Use Dynamics in Latin America" Project.

This section provides a summary introduction to the project's case study site. Basic descriptive data related to sustainability and agriculture in Pucallpa-Ucayali are presented here in the form of a slide show.

PLAN OF THE OVERVIEW

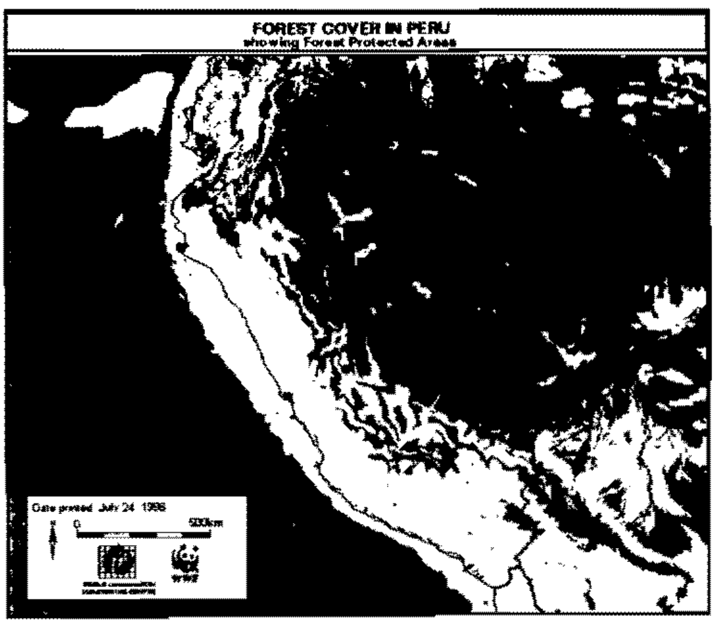
- Context
- Description
- Social Actors
- R&D Background
- Summary Diagnostics

The following slides offer a geographic CONTEXT for the study site.

Perú

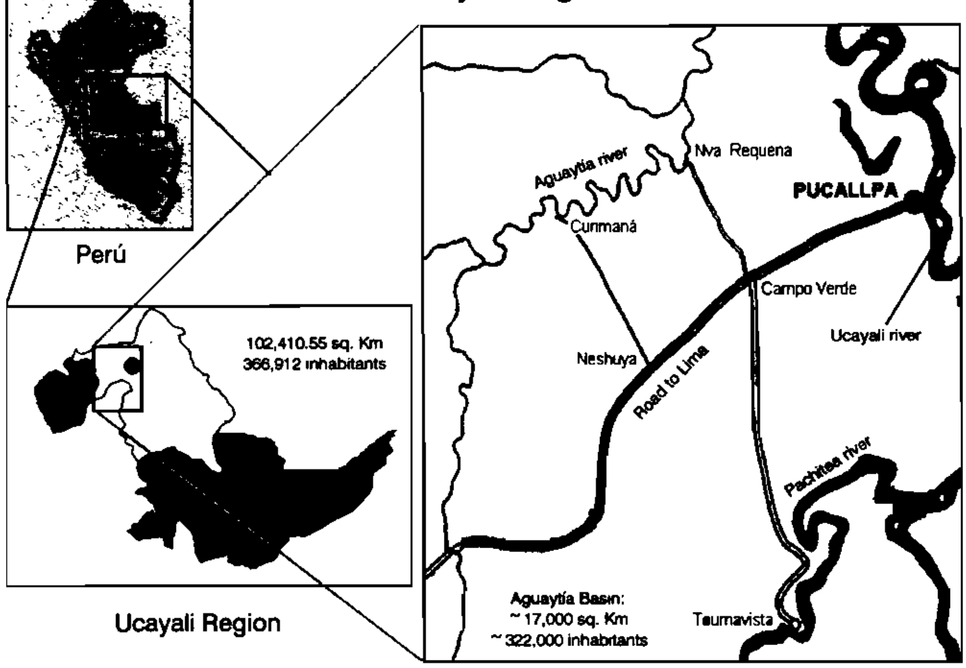
Source: Magellan Geographix

Peruvian Amazonia



Source: World Conservation Monitoring Centre / World Wide Fund for Nature, 1996.

The Ucayali Region



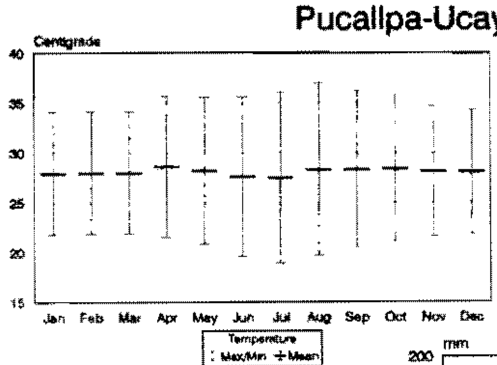
The following slides offer an ecological and economic DESCRIPTION of the study site.

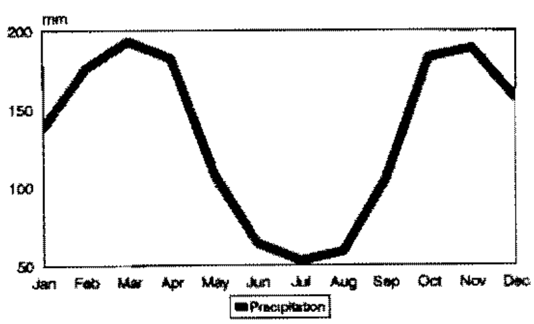
Natural Landscape

- Lowland neotropical rainforest
  - Meandering rivers, oxbow lakes, swamps.
  - Floodplains: Along Ucayali river and tributaries. Entisols.
  - "Restingas" (occasionally flooded terrain). Mixed soils, entisols.
  - Upland terraces: <u>Most of the study area</u>. Ultisols.

Source: Veneklaas 1997.

Pucallpa-Ucayali Climate





Source: Temperature: IVITA (1976-1981 averages). Precipitation: CIAT (25-year averages).

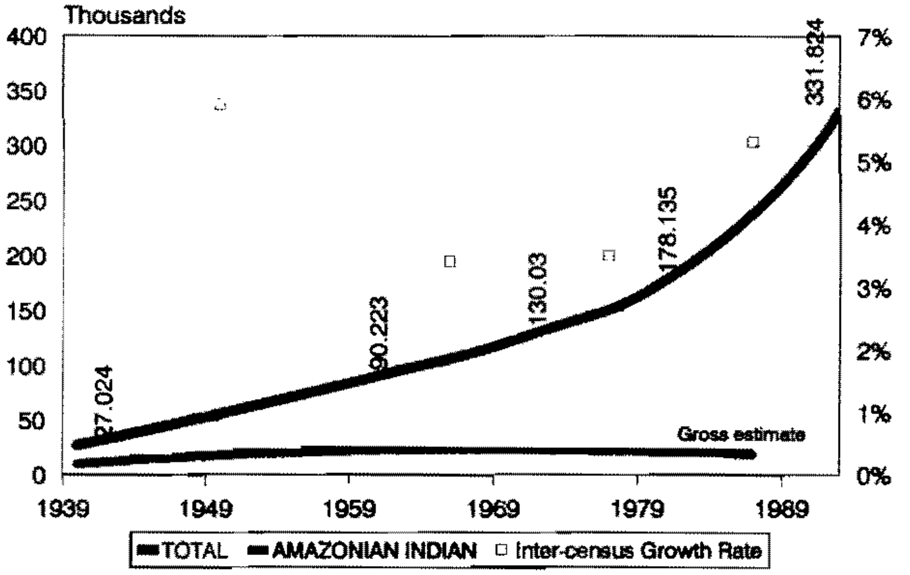
Biodiversity

- Not assessed. Thought to be very high:
  - Perú contains 23% of the known Neotropical plant diversity (9% worldwide), concentrated in the Amazon lowlands.
  - Perú contains 44% of the known Neotropical bird diversity (18% worldwide).
  - The study area lies nearby three claimed Pleistocene refuges.
- E and S of Pucallpa considered of highest conservation priority based on species richness and endemism (CI 1991)

Summary History of Ucayali

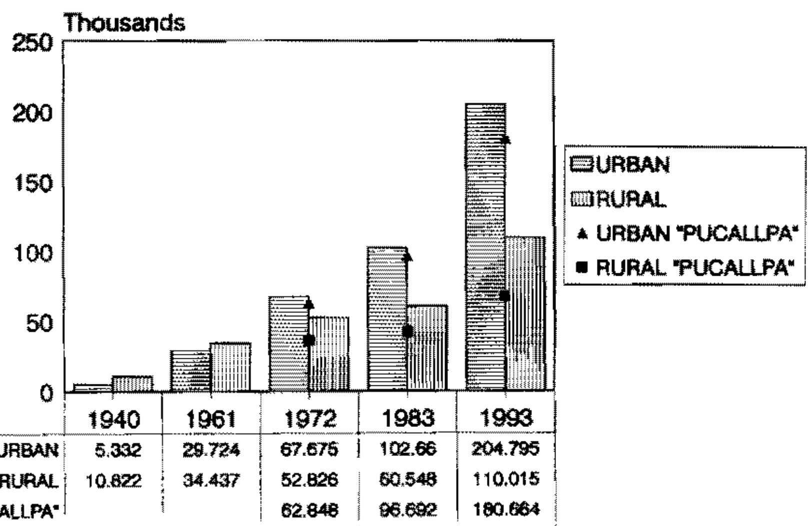
- Since ~5,000 YBP: Amazonian cultures. Hunting-gathering and low-intensity shifting agriculture. Occasional contacts with Andean civilizations and Spanish conquerors.
- 1880s - 1930s: Rubber boom. Foundation of Pucallpa (1888).
- 1940s: Road Lima-Pucallpa (1943). Spontaneous colonization from the highlands.
- 1950s: Timber extraction stimulates colonist encroachment. Improvement of road to Lima. Major colonization waves by the end of the period.
- 1960s - 1970s: Agro-silvan economy develops. Subsidy from nature. Cattle numbers increase.
  - 1965 - 1975: Peruvian Amazon: Fur and live animal trade.
  - 1970 - 1972: Peru: Nationalist military government re-distributes land.
- 1980s: Coca boom. Nation-level economic crisis (hyperinflation) and terrorist guerrillas. Generalized abandonment of lands (cattle numbers decrease).
- 1990s: Control of economic crisis and terrorism. Land re-privatization. Declines in coca production (?). Reclamation of abandoned farms (?)

Ucayali: Demography



Source: INEI, 1994. Departamento de Ucayali: Perfil Socio-demográfico. Lima. (c. 1.1 & 1.2).

Ucayali: Demography

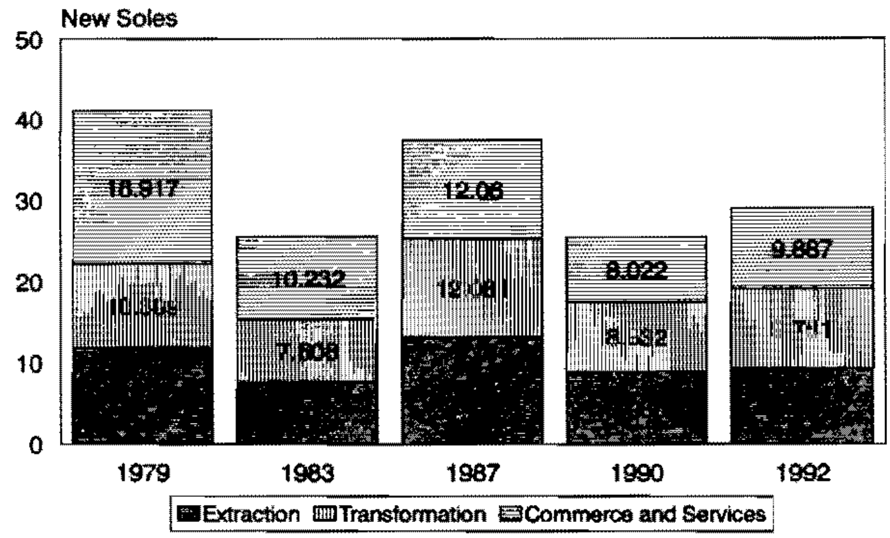


	1940	1961	1972	1983	1993
URBAN	5.332	29.724	67.675	102.66	204.795
RURAL	10.822	34.437	52.826	60.548	110.015
URBAN "PUCALLPA"			62.848	96.692	180.664
RURAL "PUCALLPA"			36.107	42.097	67.786

Source: INEI, 1994. Departamento de Ucayali: Perfil Socio-demográfico. Lima. (c. 1.6 & 1.7).

Ucayali: Economy

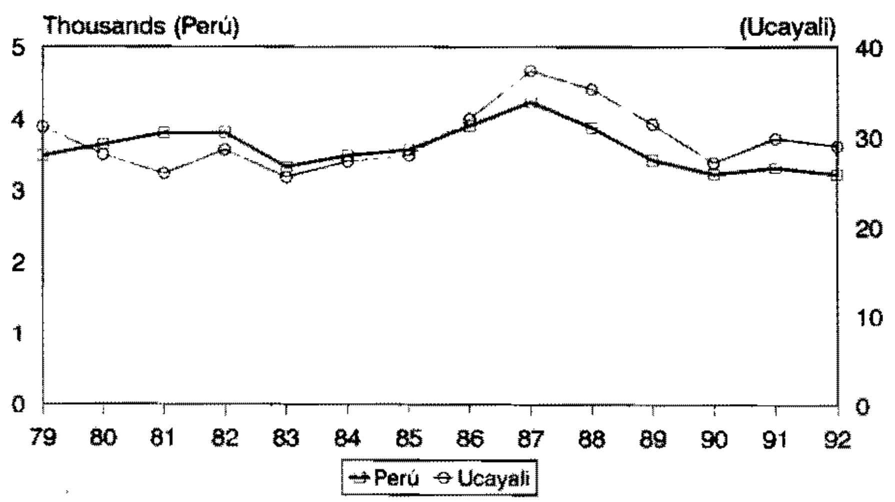
GDP (1979 Constant Prices)

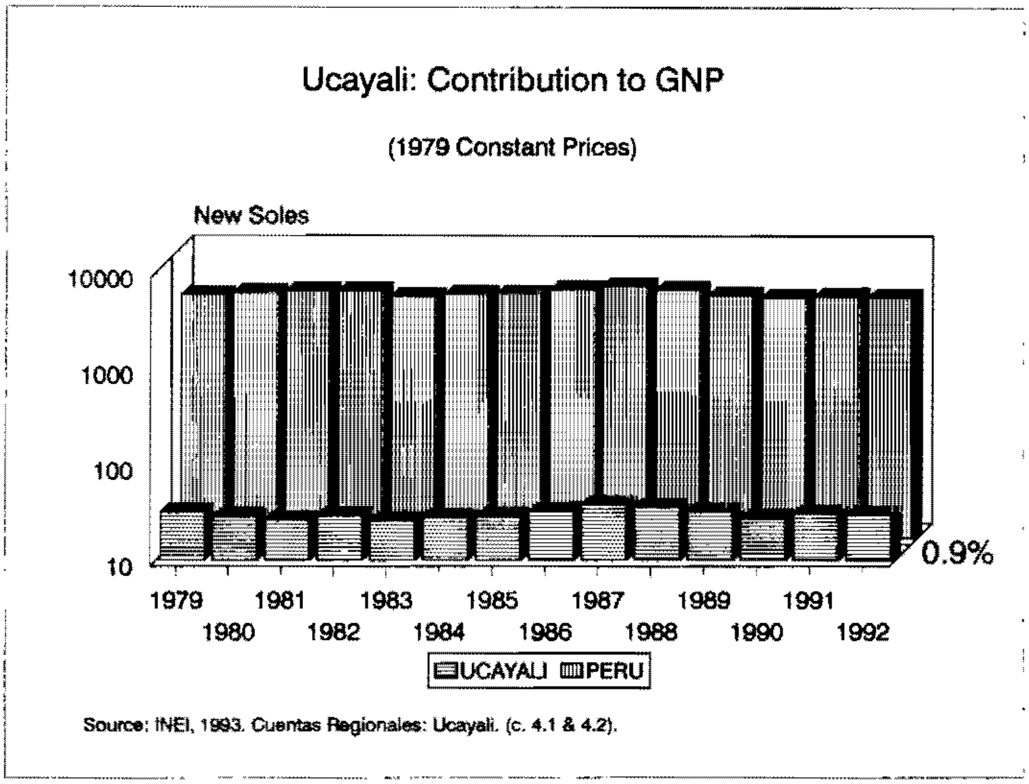


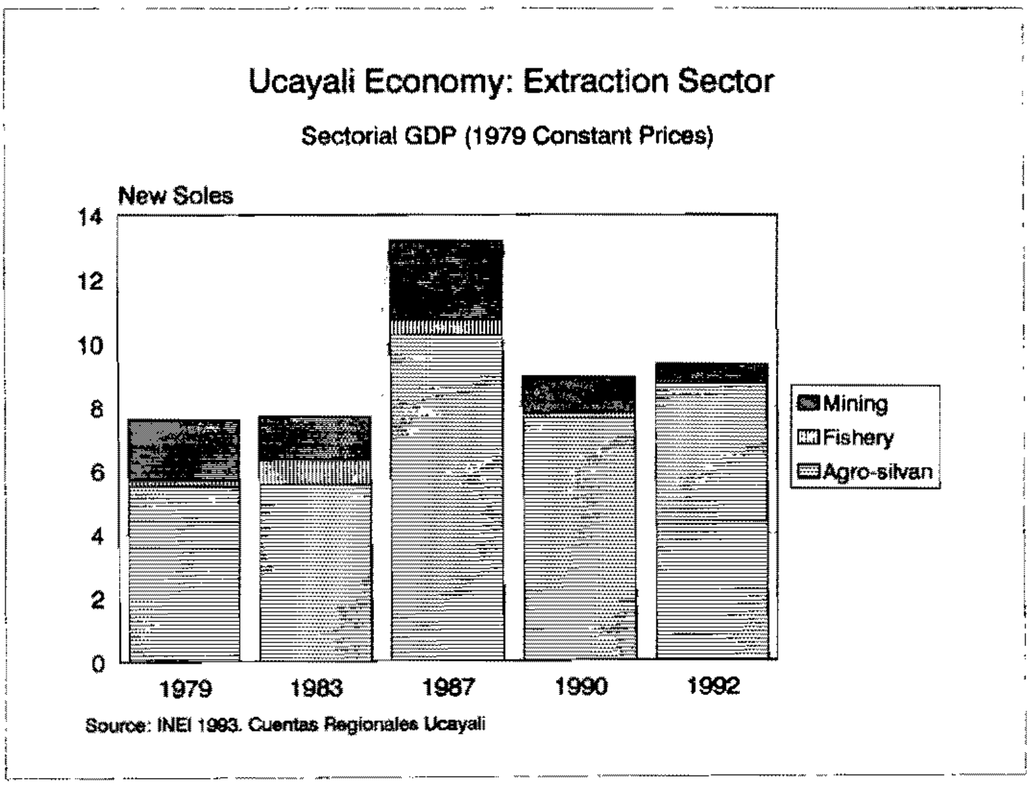
Source: INEI. 1993. Cuentas Regionales Ucayali.

Dynamics: GNP vs. Ucayali's GDP

(1979 Constant Prices)

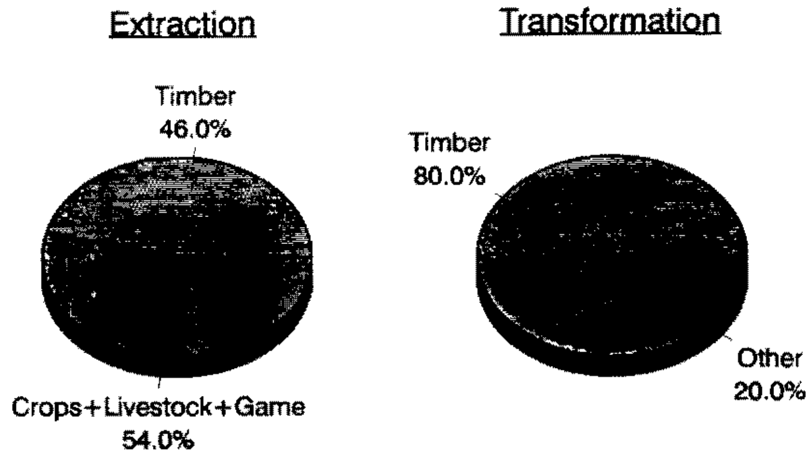



Ucayali: Contribution to GNP
(1979 Constant Prices)
New Soles
10000
1000
100
10
0.9%
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
UCAYALI
PERU
Source: INEI, 1993. Cuentas Regionales: Ucayali. (c. 4.1 & 4.2).


Ucayali Economy: Extraction Sector
Sectorial GDP (1979 Constant Prices)
New Soles
14
12
10
8
6
4
2
0
1979
1983
1987
1990
1992
Mining
Fishery
Agro-silvan
Source: INEI 1993. Cuentas Regionales Ucayali

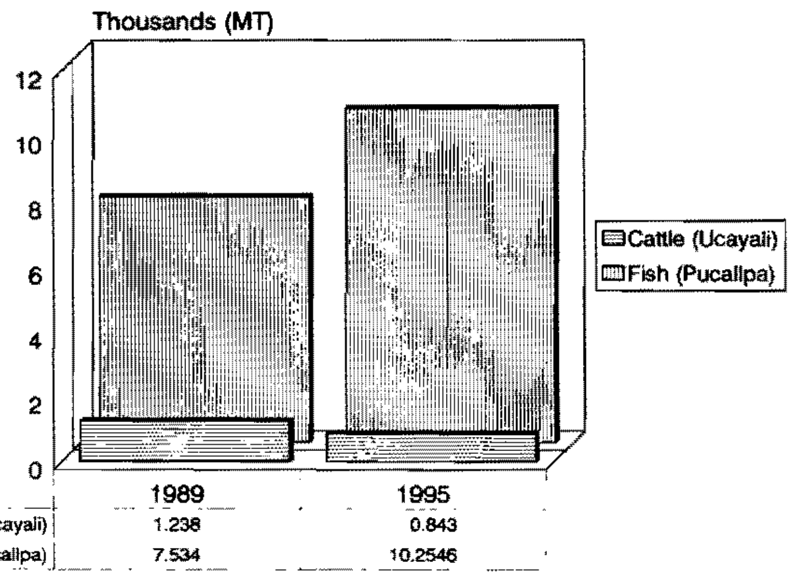
Ucayali Economy: Importance of Timber

Contribution to 1982's Sectorial GDPs



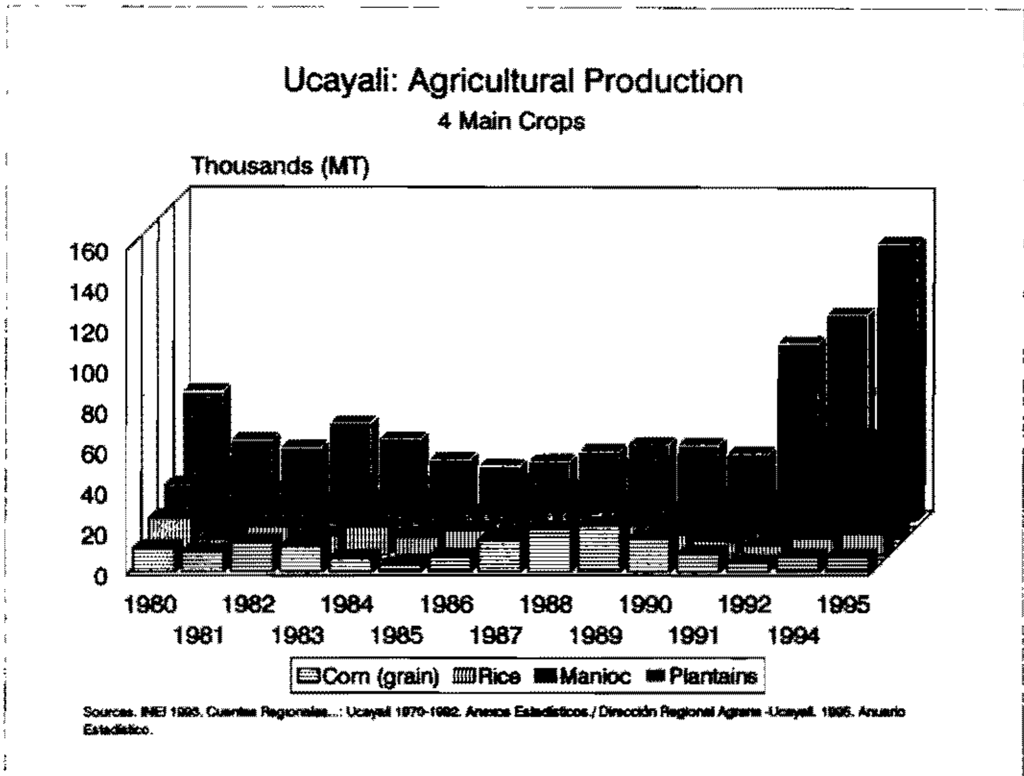
Source: INFOR. 1986. Diagnóstico de la Actividad Forestal del Departamento de Ucayali.

Ucayali: Animal Protein Production

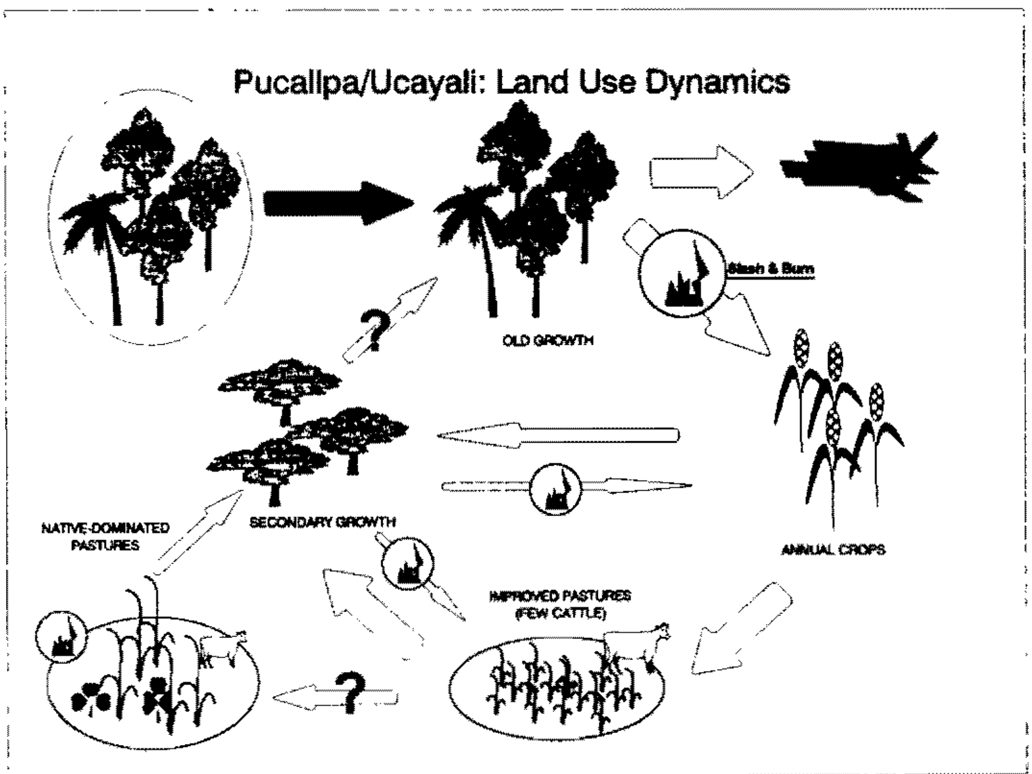


	1989	1995
Cattle (Ucayali)	1.238	0.843
Fish (Pucallpa)	7.534	10.2546

Sources: Proyecto de Capacitación, Extensión y Divulgación Forestal, 1991 Temas Forestales No 11 / Dirección Regional Agraria - Ucayali 1995 Anuario Estadístico./ Saavedra, 1996 (MS). Diagnóstico de la act. pesquera en la región Ucayali



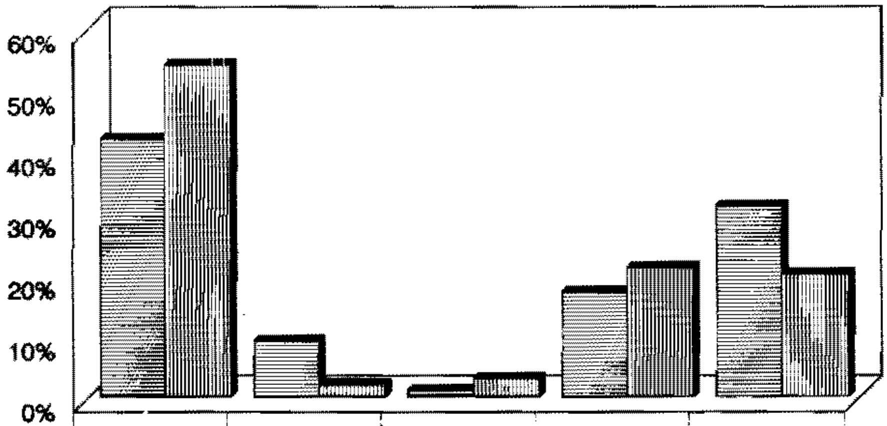
Ucayali: Agricultural Production
4 Main Crops
Thousands (MT)
160
140
120
100
80
60
40
20
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1994
1995
Corn (grain)
Rice
Manioc
Plantains



Pucallpa/Ucayali: Land Use Dynamics
Slash & Burn
OLD GROWTH
?
ANNUAL CROPS
SECONDARY GROWTH
NATIVE-DOMINATED PASTURES
IMPROVED PASTURES (FEW CATTLE)
?

Pucallpa: Land use pattern

Land Use (% of area) in Cattle Farms, 1982 vs. 1996



	Pastures	Annual Crops	Permt. Crops	Secondary	Old Growth
1982	42%	9%	1%	17%	31%
1996	54%	2%	3%	21%	20%

Source: Zaldivar 1989. (n = 70: farm size = 59.2 +/- 45.7 Ha); Fujisaka 1997 Unpublished data (n = 23, farm size = 67 Ha).

SOCIAL ACTORS

- Government
  - Central (Lima-based top policy makers and technical staff)
  - Regional (centrally-elected bureaucrats and technical staff)
  - Municipal (democratically-elected public officers)
- Citizenship
  - Timber: extractors (small / large), industrials, middlemen; CNF
  - Agricultural producers (incl. coca producers)
  - Merchants
  - Artisanal fishermen
  - Drug dealers
  - Urban dwellers (incl. displaced population in Pucallpa shantytowns)
- Civil organizations
  - NGOs and grassroots organizations
  - Education and research organizations (University, research institutions)

R&D IN PUCALLPA-UCAYALI

- Institutions
- Available Technology
- Traditional Approach to R&D

R&D Institutions in Ucayali

- NARs
  - IVITA: Cattle production (since ~ 1983, small producers)
  - INIA: Cattle production, agroforestry, silviculture
  - IIAP: Research in natural resources, aquaculture, and agroforestry
  - University of Ucayali: Agronomy and Forestry.
- IARDS
  - CIAT: Cattle production: forages, degraded pastures (small to medium producers)
  - ICRAF: Agroforestry
  - CIFOR: Carbon sequestration markets, management of secondary forests.
- Development Agencies
  - IDRC / CIID: Agricultural research; institutional development
  - UNDP: Oil palm (alternative development)
  - IICA-GTZ: Alternative development
  - USAID: Control of coca production

Agricultural and NN. RR. Technology in Ucayali

- Improved grass-legume pastures for double-purpose cattle
  - CIAT / IVITA
- Agroforestry: Reforestation with timber and industrial species, alley cropping (experimental)
  - ICRAF - INIA, IIAP, Reforestation Committee, Oil Palm Grower Asso.
- Integrated Organic Farming (earthworm-compost horticulture, aquaculture, small farm animals)
  - IIAP
- Sustainable logging and Silviculture
  - INIA - INRENA - ITTO
  - CNF - Netherlands (secondary and "residual" forest)
- Region-level Sustainable Land Use Plans
  - Regional government (?)
  - Swiss cooperation / CDC-Perú
  - IIAP and other

R&D Traditional Approach

(National and International)

- Top-down
  - Farmer knowledge / rationality underestimated
- Gender-biased toward males
- Oriented to product maximization
  - Farmers' and regional priorities overlooked
- Sectored, oligo-disciplinary
  - Economic evaluation often missing
  - Ecological evaluation always missing
  - Context (national / global) missing
- Environmental issues not addressed

SYNTHESIS

- Socioeconomics
- Ecology

Pucallpa-Ucayali: Socioeconomic Synthesis

- Agricultural frontier in the Andean (Western) Amazon
  - Colonist majority, unrooted and marginal. Native cultures decimated: "Ecological blindness" (?)
  - Uncertain / Risk-prone environment (terrorism!): Risk aversion.
  - Subsidy & Boom-oriented economy (coca!): Opportunism.
    - Subsidy from nature: timber, fish, game.
  - Diversified and uncertain production. (Increasing agricultural prod.?)
  - Low institutional development. Particularly at grassroots.
  - Low market development. Extra-regional dependency (?)
  - Extractive, extensive, low-technology production.
  - Labor and capital scarcity (?)
  - High relative poverty, urban-concentrated; although livelihood better than in highlands and larger cities.
- Perú: Macro-economic bonanza. Neo-liberal policies. Latent social violence.
- World: New attitudes and possibilities for holistic R&D and sustainability.

Pucallpa-Ucayali Ecological Synthesis

- Extensively exploited old-growth forests, defaunated and wood-impoverished (genetically eroded).
- Slowly increasing deforestation (carbon emissions).
- Encroaching secondary growth and low-productivity pastures in most densely human-populated area.
- Extensive loss of productive capacity and economic value of land.
- Increasing uncontrolled fresh-water fisheries. Severe risk of over-exploitation.
- The only region in the Peruvian Amazon without protected areas. Three areas in Ucayali considered of highest conservation priority (FANPE 1996).
- Pucallpa area considered environmentally critical based on deforestation, top soil erosion and water pollution (UNCED 1992).

Sources: Gonzales 1995 in Hajek. / FANPE, 1996. Biodiversidad Biológica del Perú.

METHODOLOGICAL SEQUENCE

Gilberto C. Gallopín, Land Management, CIAT

The proposed process to follow in this workshop in order to organize our collective knowledge implies starting with the identification of the major issues (which could be problems but also opportunities) for the Pucallpa area. Those will help to identify the major management goals and objectives. Indicators capable of showing decision-makers the degree to which the goals/objectives are being approached are defined next. The whole sequence is presented below, although it is not expected we will cover all of it in the limited time available. We need to cover the first steps, because they are the ones that will define what to include or exclude in the characterization of the system. Note that this procedure implies defining the variables and factors to be investigated insofar as they are important for addressing the issues, goals or objectives defined for the case. Those may or may not be the variables or factors traditionally considered important within each of the involved discipline; as a matter of fact, it often happens that some of the critical variables (systemwise) are overlooked by the disciplinary studies. The complete sequence is:

- Identification of major issues
- Management goal(s)
- Range of management objectives
- Indicators to assess progress towards objectives
- Range of management actions for consideration
    - Identification of actions already being taken/considered by CIAT's research
- Time horizon and resolution
- Spatial extent and disaggregation
- System variables required to generate the indicators
- Identification of the relevant subsystems
- Analysis of the system

MAJOR ISSUES FOR THE PUCALLPA AGROECOSYSTEM

Workshop Participants

The following list of issues and relevant indicators are the result of a brainstorming session during which the CIAT scientists working in Pucallpa identified the most critical and key factors acting shaping the agroecosystem.

WHOLE SYSTEM:

- Perverse resilience (contagious unsustainability?)
- Road system as organizing principle
- River system as organizing principle

AGRICULTURAL:

- Degraded pastures
- Increased monocropping
- Efficiency of agricultural inputs
- Low cattle inventory
- Low genetic potential
- Lack of agricultural machinery
- Seed supplies
- Utilization of non-traditional crops and agroindustries (e.g. Uña de gato, camu-camu - potential uses of biodiversity)
- Weeds
- Irreversible loss of soil/land productivity

ECOLOGICAL:

- Deforestation
- Alterations in fish populations
- Increased fragmentation
- Increased percentage of secondary growth
- Impacts of coca on biodiversity
- River pollution
- Impacts of selective logging
- Pollution of breeding fish grounds
- Lack of inventory or information on biodiversity
- Impacts of activities in floodplain on rivers

ECONOMIC:

- Transport costs
- Labour and capital scarcity
- Sudden foreign investment and inflow (e.g., DEA)
- No extension services
- Coca - economic impacts
- Unreliable markets, price fluctuations
- Extractive and absentee forestry system - little reinvestment in local economy

- Net economic outflow from region.
- Undervalued land prices (because of guerilla, etc.)

HEALTH:

- Human health problems (?)
- Water quality
- Urban air pollution
- Lack of sewerage facilities
- Medical uses of biodiversity

SOCIAL AND DEMOGRAPHIC:

- Coca - social impacts (e.g. coca cities)
- Urban unemployment
- Rural to urban migration - social problems (e.g. outmigration of youth to Pucallca)
- Urban poverty (no clear problem of rural poverty)

INSTITUTIONAL:

- Institutional instability
- Lack of policy continuity
- No land monitoring agency

POLITICAL:

- Power structure (e.g. concentrated power of timber industry)
- Geopolitical context - Amazon seen as important source of development for nation

MANAGEMENT GOALS

1. Enhance productive capacity
2. Increase human welfare
3. Increase food production for nation
4. Environmental protection
5. Sustainable management of biodiversity
6. Empowerment of local institutions

INDICATORS FOR EACH MANAGEMENT GOAL

1. Enhance Productive Capacity

- Total factor productivity
- Yield per factor of production - Land, Labour, Technology, Capital and Human Capacity
- Ratio of land in production versus abandoned land - Actual Production Ratio (APR)
- Diversity of agricultural activities
- Fisheries:
    - catch effort
    - recruitment rate

- fish value
- species composition

2. Increase Human Welfare

- Child mortality
- Average income
- Unemployment
- Income distribution
- Poverty level
- Capital accumulation
- Literacy
- Morbidity - diarrheal; respiratory
- Satisfaction - suicide rates
- Crime
- Social support networks - community health

3. Increased Food Production for the Nation

- Total regional food production
- Ratio of regional food production to national food production

4. Environmental Quality

- Proportion of vegetation in native state
- Rate of deforestation/ratio to reforestation
- Protected areas - within specific ecological niches
- Change in indicator species
- Mismatch between actual land use and optimal land use - land use conflicts
- Water pollution
- (Need indicators of aquatic ecosystem health)
- Greenhouse gases emissions
- Proportion of degraded land

5. Sustainable Management of Biodiversity

- Proportion of native species with market value
- Income generated from non-timber products
- Number of non-traditional species being utilized
- Habitat loss of wild species
- (need indicators of management)

6. Empowerment of local institutions

- Proportion of agricultural product (?) prices determined by local markets versus proportion set by the central government
- Proportion of credit from local banks versus proportion from national banks
- Percentage of public services paid for by the local government
- Percentage of businesses owned locally versus by outsiders
- Change in membership numbers in local institutions