# ECOLOGICAL SYSTEMS AND MULTI-TIER HUMAN ORGANIZATION

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## Contents





## Summary

In order to study changes in the extent, composition, structure, and function of forest ecosystems, one needs to examine not only the ecological system, but also how socioeconomic factors affect human behavior and outcomes. Forest ecosystems are affected by many social, economic, and political factors. Human-induced causes of both deforestation and afforestation occur at multiple levels. Population growth can occur in one particular community or in a large region. Property rights may be well-defined in one region, but not in another. International trade affects the market price of many commodities, but the particular price received by farmers may also depend on government taxes and subsidies or the infrastructure provided in a specific community. Thus, adopting a multilevel approach is essential for understanding human impacts on forests. In this chapter, we present an initial effort to develop a multilevel theory of human action impacting over time on the extent and composition of forests and a strategy for such research.

## 1. Some Definitions and Assumptions

No single measure of forest health or value conveys full information about the condition or rate of change of any particular forest or set of forests. We use the term "forest conditions" to mean a suite of evaluative measures that together provide a composite picture of the current physical, biological, and economic value of a forest, as well as the rates of change in these values. Among the measures included in the concept of forest conditions are the density, biomass, basal area, diversity, species composition, economic and subsistence value, extent, shape, fragmentation, and rates of destruction, growth, removal, and regrowth of forests.

Forest conditions are dependent on both human decisions and on physical and biological processes. Human decisions directly and indirectly affect forest conditions. Direct actions result in an immediate impact on a particular forest. When a team working for a timber firm harvests a stand of timber, when a subsistence farmer clears a forest patch in order to plant manioc, or when a class of school children plant and protect tree seedlings, specific individuals are directly affecting the extent and shape of a particular forest, its rate of destruction or growth, and perhaps the species composition of that forest. These changes also may affect its economic and subsistence value. Indirect actions affecting forest conditions are mediated by other transactions between the person taking the indirect action and the person taking the related direct actions. The construction of dams, highways, and other types of physical infrastructure that directly affect forest conditions and their uses typically results in significant indirect effects. When individuals decide to build or purchase houses and furniture, to buy stock in certain multinational corporations, or even to buy coffee, bananas, or particular brands of ice cream, they indirectly affect conditions in forests that may be located nearby or across the globe from where they live. Changes in population density or its spatial distribution also indirectly affect forest conditions. Whether these changes affect forest conditions in a positive or negative manner depends on how the opportunities in a local setting and the choices of particular sets of individuals are mediated by institutions and demographic factors.

Forest conditions are simultaneously affected by physical factors such as solar radiation, temperature, precipitation, the chemical composition of the soil, and topography, as well as by a wide diversity of biological phenomena such as seed dispersal, competition, and herbivory. These physical and biological factors affect forest conditions at multiple spatial and temporal scales, as do anthropogenic changes.

In analyzing human decisions as they impact on forest conditions, we assume that:

1. Human decisions occur within tiers of decision-making units that extend from an individual to international organizations.
2. Within all tiers of decision making, fallible individuals make decisions that are intended to increase net benefits to themselves and potentially to others.
3. Individuals learn from their experiences and from culturally transmitted experiences.
4. Human decisions at all tiers are affected by the cultural values of the individuals, the resources they possess, the information they obtain, the incentives and disincentives they face, the internal learning and choice processes used, and the time horizon invoked.

5. Decisions at any one tier affect the information, incentives, and time horizon (and, perhaps the cultural values, resources, and internal choice processes) of others at that tier, at present and future time periods.
6. Decisions at any one tier frequently — but not necessarily — affect the cultural values, resources, information, incentives, internal choice processes, and time horizon invoked at other tiers. Thus, human choice is interdependent within tiers and across time and space. Impacts may be horizontal, upward, and downward.
7. Decisions at any one tier directly or indirectly affect forest conditions measured or aggregated at other tiers.
8. Physical and biological processes also affect the information, the incentives, and the time horizon that are used in human choice as well as being affected by human choice.

## 2. Human Choice

In the second, third, and fourth assumptions listed above, we self-consciously adopt a conception of human choice that views fallible humans as seeking goals perceived to be of net positive benefit to themselves, and potentially others, but limited in their success by the information they possess, the incentives they face, the time horizon they use, and their culturally constrained learning and choice-making processes. This conception is consistent with a large body of theoretical work in the bounded rationality and anthropological tradition. All individuals making choices are viewed as fallible learners — whether they are high-level officials with Ph.D. degrees and years of experience, or landless peasants with no education trying to eke out a subsistence for their families.

Whether fallible learners make good choices for themselves and for others depends not only on their values, but also on the information they possess and the internal learning and choice processes they have developed. Education and experience affect the levels and type of information and the heuristics and/or modes of analysis used in making decisions, in learning about the structure of the world, and in understanding how actions are linked to outcomes. Knowing who to trust, who is a group member, and who has shown group solidarity affects the strategies that individuals adopt, including positive or negative reciprocity. Rules related to information flow (e.g., who must be informed about actions taken and forest conditions) as well as to the payoffs received by participants, also affect what individuals learn about the situations they face. All individuals may or may not have the relevant information they need to make effective decisions in a particular setting. Officials may or may not have the relevant information and appropriate modes of analysis needed to determine sustainable development practices for all forest ecosystems present in many governmental jurisdictions. One would expect a higher probability of success when officials are making decisions that affect a limited range of forest ecosystems with which they are already deeply familiar as a result of years of prior experience. Similarly, a landless family may or may not have the relevant information and appropriate modes of learning and analysis needed to determine whether migration from one region to another would improve their life's chances.

Because it is extremely difficult to understand enough about particular decision makers that affect forest conditions through direct and indirect actions, we utilize a general conception of human behavior in our theoretical work. We can then draw on a variety of models of individual choice ranging from agents using very rough heuristics and having limited

access to relevant information, all the way to "hyper-rational" individuals who have complete information relevant to a situation and who have learned how to undertake analysis so as to maximize summed, quantitative goals. We view all of these models as potentially useful in an effort to understand human choice in complex, interdependent worlds. In modeling global change phenomena, however, it will frequently be necessary to use models that make many fewer assumptions about the internal knowledge and calculation capabilities of individuals.

In many instances, individual choices are aggregated within corporate bodies such as private firms, government agencies, local communities governed by elders, and nongovernmental organizations. A frequent technique to simplify analysis is to treat such corporate actors as if they were single decision makers. We adopt this convention in many of our analyses. We examine the internal incentive structures for some corporate actors so as to better understand the likely actions to be taken by such actors. In our efforts to measure the structure of situations in which individuals make decisions that impact on forest conditions, we focus on those aspects of structure which have repeatedly been shown to affect the type of decisions that individuals make. In the next section, we briefly describe the variables that we utilize to analyze a wide diversity of situations.

## 3. The Structure of Action Situations

When *individuals* make choices that either directly or indirectly affect forest conditions, they do so in the context of other individuals who are holding *positions* of various types (landowner, squatter, or governmental forest manager). Each individual in these positions has available to them an array of *actions* they may take (clear land, plant with selected species, harvest timber, sell or buy commodities, etc.) within a specified time period. In some cases, individuals must gain the agreement of others, and thus have less direct *control* over the actions they can take. These actions produce *outcomes,* such as the amount of forested land, nature and amount of commercial crop production, or conversion of forest to subsistence agriculture or pasture, etc. Individuals have diverse levels of *information* about their own actions and those of others (and, even who else is part of the interaction), about the perceived *benefits and costs* of different actions, and about how actions are *linked* to produce outcomes for participants. The italicized words are the universal elements that institutional analysts use in analyzing how the structure of these situations affects individual actions and how these actions jointly produce outcomes. In addition, one needs to know whether the participants in such situations are facing a decision that is unlikely to be repeated, such as migration from urban slums to the frontier, or will be repeated indefinitely, such as buying and selling commodities at a local farmers' market.

Situational analysis is at the core of explanations offered by analysts for the actions and outcomes observed in diverse settings. One tries first to identify the structure of a situation — its participants in positions who choose actions that are linked to outcomes in light of the information they possess and the likely costs and benefits they face. When the structure of the situation is such that everyone can be better off if they select some strategies rather than others — a pure coordination problem — it is challenging to explain why some groups achieve better outcomes than others. Most of the relevant problems related to human uses of forests are not this benign. Many of the situations of interest will involve some aspects of "social dilemmas" and "collective action problems." Social dilemmas exist when

substantial gains could be achieved for a group, but each individual has an opportunity to seek a private gain at a cost to the group achieving a higher outcome. The collective action problem involved is how to overcome these temptations that undermine the achievement of higher returns for the group.

Having identified the structure of a situation, the analyst next tries to understand how this structure is affected by physical and biological variables, by the structure of the surrounding community and economy, and by the specific rules in use. The expected benefits of planting tree crops or harvesting mature trees, for example, depend on (1) the soils, climate, and location of the decision maker; (2) the resulting topography, climate, and soils; (3) the shared values held by those considered to be part of the decision-maker's community; and (4) the rules in use specifying what may or may not be planted or harvested. Because the variables that affect the structure of a situation are scale dependent, as one moves across levels of action, the relevant physical and biological world, human community, and set of relevant rules changes.

While situations are normally analyzed separately, they are linked together in complex chains in the ongoing world. The linkages among diverse situations are particularly important to understand when studying processes of deforestation or reforestation, because the outcomes of one situation tend to spill out or spill in to many other situations. Consequently, it is essential to understand how they are linked across space and within particular time frames as well as across spatial and temporal scales.

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**Biographical Sketches**

**Professor Moran**'s research currently combines remote-sensing methods, and field methods of data gathering and analysis, in the study of secondary succession in the Amazon Basin. Landsat TM satellite digital data are combined in Geographic Information Systems (GIS) with soils, vegetation, land use histories, yield, and carbon cycling to arrive at a detailed understanding of the processes responsible for accelerated or retarded rates of regrowth following deforestation. This work has been funded by the National Science Foundation, NOAA, NASA, and the Midwestern Center of the National Institutes for Global Environmental Change in the past. Current support includes NSF, the population program at the National Institutes of Health, and the National Aeronautics and Space Administration (NASA). Students working with him have the opportunity to

develop their own research or take part in ongoing projects that examine deforestation and afforestation processes in temperate and tropical forest ecosystems in the Western Hemisphere. Moran is the author of 6 books, 9 edited volumes and over 100 articles.

**Professor Ostrom** is interested in exploring how institutional rules affect the structure of action situations within which individuals face incentives, make choices, and jointly affect each other. Problems involving collective goods and common-pool resource systems, and how various types of institutions enhance or detract from the capabilities of individuals to achieve equitable, workable, efficient solutions are a central theoretical concern. In urban settings she has been interested in the problems of collective action where citizens face problems of crime, poor education, and deteriorating environmental conditions. She is also interested in the same problems as they relate to resource problems in the Third World, particularly problems of collective action related to forests, fisheries, grazing areas, agricultural lands, and water systems. A major study of institutions and forests is being initiated as part of an effort to study the interrelationships between local and global commons. Professor Ostrom is currently working with colleagues in several tropical countries to investigate the impacts of diverse institutional arrangements on forest conditions and on global environmental change. The Workshop in Political Theory and Policy Analysis emphasizes theory and its application to policy-related research. Research focuses on the effect of institutional arrangements upon the incentives that people face and consequently upon individuals' behavior. Both micro and macro analyses of institutions in diverse countries are conducted by Research Associates, Visiting Scholars, and Indiana University students.

**Dr. Randolph** is a forest ecologist. He teaches courses in forest ecology, global environmental change, and applications of geographic information systems and remote sensing in natural resources management. His research interests focus upon ecological aspects of global environmental change with particular interests in forestry and agriculture. Other research interests include carbon dynamics of temperate and tropical forests and physiological ecology of woody plants and small mammals. He has had fieldwork experience in Indiana, Tennessee, eastern Canada, eastern Brazil, Venezuela, Costa Rica, Guatemala, and Honduras.
Dr. Randolph is director of the Ph.D. in Environmental Science program. Since 1990 he has been Director of the Midwestern Regional Center of the National Institute for Global Environmental Change (NIGEC), sponsored by the Department of Energy.