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Stream: Theory

MODELING THE HUMAN IMPACT ON RESOURCE SYSTEMS

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Abstract
The paper argues that the biodiversity and sustainability measures characterizing an eco-system[1] are determined by three sets of variable characteristics. One set is the geo-physical parameters circumscribing the local eco-systems and its development. The second set is the longterm trends in climate change and other external long distance impacts such as acid rain and other kinds of fallout. The third set is the human usage of the eco-system and its resources.

Data must be collected on units permitting meaningful policy conclusions. It is argued that to get unbiased estimates of the size and direction of human impact on ecosystem characteristics data on all three types of causal variables are neccessary and the model must include the appropriate interaction terms.

The paper concludes with a plea for more long term projects, such as IFRI, collecting data on all factors affecting the status of an ecosystem.

Introduction
Loss of biodiversity, reduction of forests, and declining fish stocks in the oceans are examples of major problems facing the emerging global society. The scale and diversity of human activites cause large scale alterations in the various ecosystems. Many of the changes are unwanted and some are clearly detrimental to the future utility of various resource systems(Goudie 1981).

[1] Such as number of species, total biomass, Shannon-Wiener's and Simpson's diversity indeces, and other measures of composition, structure and function at the community-ecosystem level.

Yet, we do not have any theoretical foundation for conclusions about the size of causal impacts on ecosystem characteristics of proposed changes of conservation or management activites, only beliefs about the probable direction. Regressive impacts of public intervention as well as other types of "revenge" effects associated with changes in technology are rather more frequent than we usually want to admit[2] The knowlegde we have about the response of ecosystems to human activity is practical, gained through centuries of mutual adaptations between social system and ecosystem. Or it is presented in broad common sense terms such as the increased pressure on resources caused by an increasing number of people. As a basis for recommendations of policy this is not sufficient.

Among the forces affecting the development of an ecosystem, we need to distinguish causal factors which can be manipulated by political decisions from other human impacts and from the various natural forces affecting the ecosystem. We need to know why, and under which conditions, a certain course of action will work to improve the desireable qualities of an ecosystem.

The unit of analysis

In a "review of what we know from macro- and micro-level studies about the effect of human choices on levels of deforestation and biodiversity", Ostrom (1995b) concludes that "The problem in analysing and measuring social, political, and economic variables as these impact on forest conditions is to find the right scale for measurement and analysis. Regions within countries where macro-level statistics report extremely worrisome changes over time, vary substantially in regard to these same statistics. Variables that are stastistically significant in cross-sectional studies are not statistically significant in panel studies in the same countries."

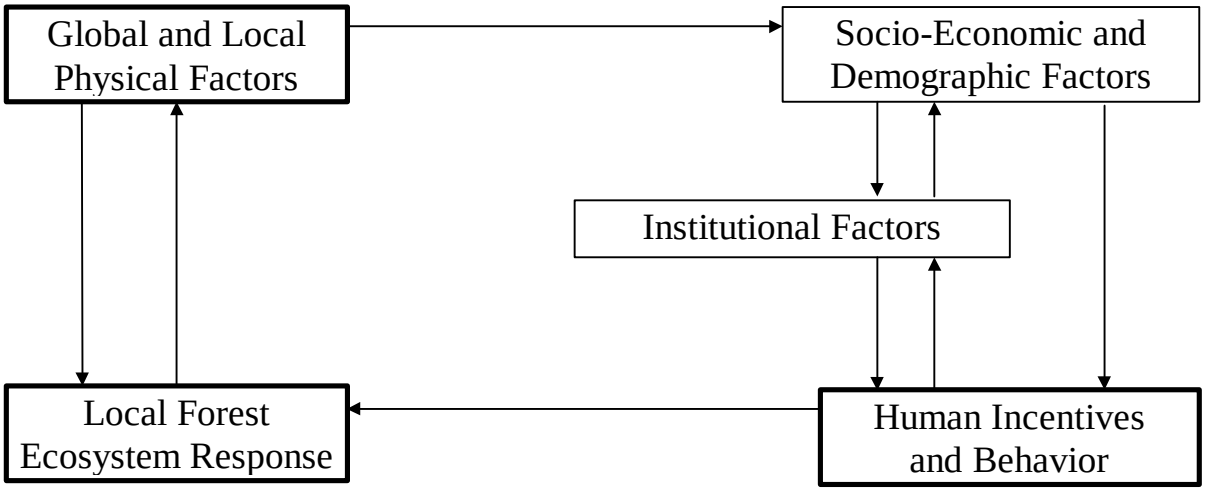
The problem of scale can be restated as a question of what the meaningful unit of analysis ought to be. With "levels of deforestation and biodiversity" of a forest as the dependent variable the only possible unit of analysis is "a forest". But that does not take us far. How do we define a forest for a study of the causal impact of human activites on forest conditions? The unit must join a forest community ecosystem to a community of human users, and the unit must be small enough to permit meaningful inferences about politically relevant variables. With the kind of dependent variables suggested, the outer boundaries of such a unit are the local ecosystem. But within that we need to look at the area over which the selected indicators can be assumed uniform and the delineation of politically relevant units. Of the more obvious variables for use in defining a forest would be the geophysical characteristics of the setting, such as

[2] See e.g. Ostrom 1995a, Sieber 1981, and Tenner 1996,

type of soil, steepness and geographical orientation of terrain, predominant wind direction, and amount of precipitation. On top of we put the divisions of properties and jurisdictions (either formal or informal). Only by matching ecological and socio-economic characteristics will a meaningful unit be defined.

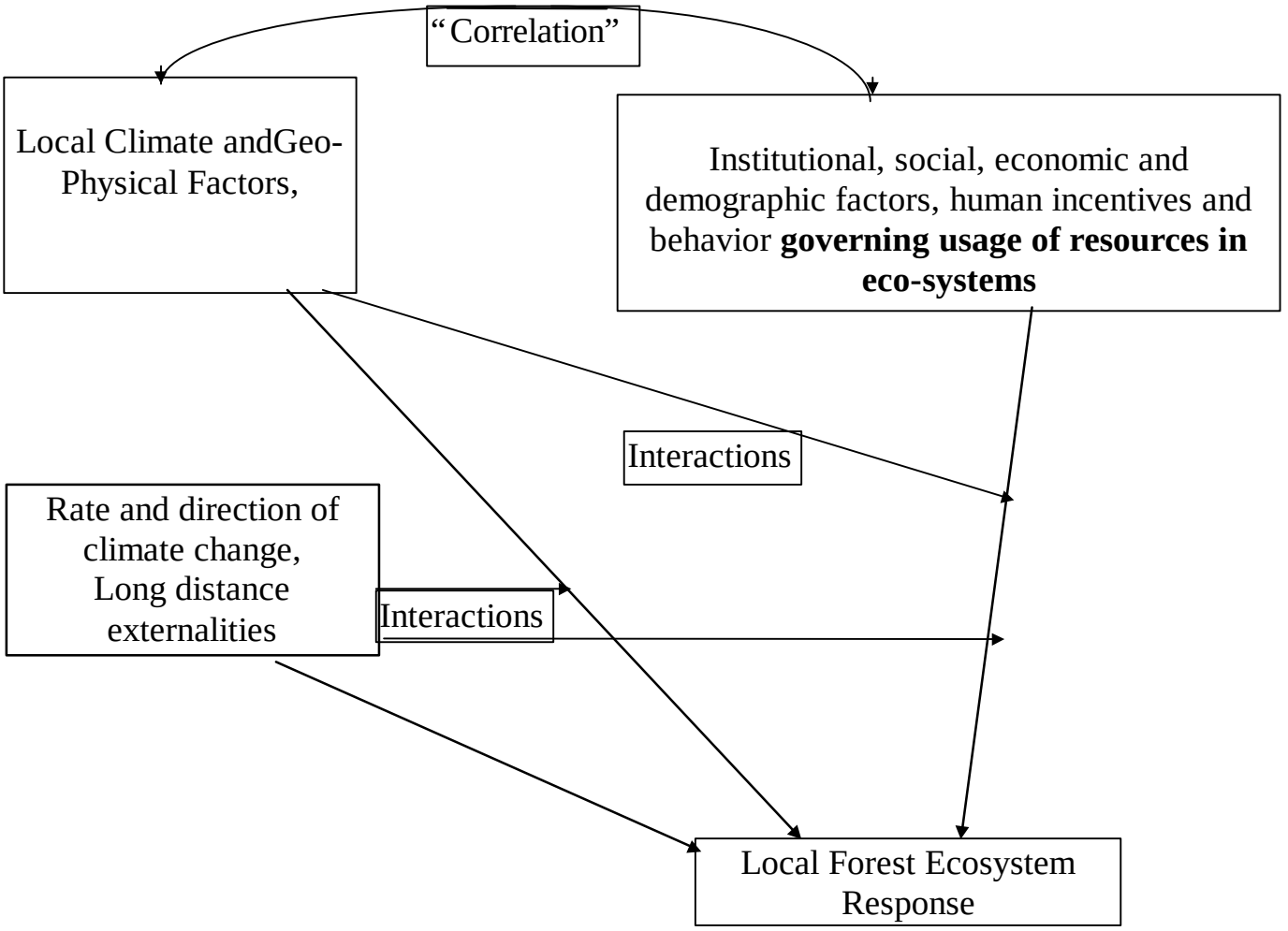
Getting the model right

The first and foremost problem in estimating any causal impact is to get the model right. After reviewing some of the macrolevel statistical of socio-economic impacts on environment and deforestation, Ostrom (1995b) concluds that micro level studies are necessary to be able to model how human action accumulates to impact on rates of deforestation and biodiversity loss at regional and national scales. But she also finds that micro-level studies are too diverse. Their cumulative results do not lend themselves to statistical analysis. To remedy this situation the International Forest Rersources and Institutions (IFRI) project was initiated. This project is guided by the following conceptual model (figure 7 page 19):



To discuss some of the technical problems of modelling the causal impact of human agency the model can be simplifies as shown in Figure 1

Figure 1 **Factors affecting the ecosystems**



Compared to IFRI's model above, the Socio-Economic, Institutional and Human Incentives and Behavior Factors have been put together into one box, while global physical factors such as climate change and other external long distance factors, have been pulled out as a separate group from the "Global and Local Physical Factors".

The causal factors

The figure defines a simple causal structure. The hypothesis is that the biodiversity and sustainability measures characterizing an eco-system[3] are

[3] Such as number of species, total biomass, Shannon-Wiener's and Simpson's diversity indeces, and other measures of composition, structure and function at the community-ecosystem level.

determined by three sets of variable characteristics. One set is the geo-physical parameters circumscribing the local eco-systems and its development. The second set is the longterm trends in climate change and other external long distance impacts such as acid rain and other kinds of fallout. The third set is the human usage of the eco-system and its resources.

It is well documented that human activity has had a large impact on forest conditions throughout the world (see e.g. Goudie 1990). Without the human impact local geo-physical characteristics such as length of season, variation in temperature, soil type, amount of precipitation, orientation and inclination of habitat, elevation above sea, and local characteristics of natural disturbances together with the long term trends in climate change will shape the local forest conditions. For the purposes here the impact on forest conditions from the rate and direction of global changes in climate (see Walker and Steffen 1997) and other long range external impacts are treated as a separate type of causal factor for 2 reasons. Firstly, in developing policies to conserve biodiversity it will be important to consider mitigating their impact, and secondly, since we mostly will be without direct data on how they vary we need to consider explicitly how that will affect our estimates of the other variables.

Ostrom (1995b)´s model contains a feedback effect from the local ecosystem to the global. Modelling the impact of these three types of variables by means of cross-sectional data makes the feedbak from local ecosystem to global conditions insignificant. This link we can disregard.

Local environmental adaptations.

The figure includes a correlation between social and geo-physical characteristics. This has been a basic theme in studies of human ecology[4]. The adaptations of cultures to their environments show up in several ways. Decisions on e.g. management rules are not taken without a view to the broad characteristics of the area they are intended to apply to. Through historical adaptations the geo-physical characteristics of the area will shape the world view of people living there, their values and perceptions of resources. This affects local choices of institutional solutions in governing resource usage (compare Folke and Berkes 1995). It would seem that indigenous knowledge of local resources, the ability to describe and utilise the local environment for maintaining a community, would be a good index of adaptation to the same environment. With "modernisation", in particular integration into a market system and large scale division of labor, the adaptation to a local environemnt tends to deteriorate. Knowledge of other resources than those who can be traded

[4] for a recent survey see Bates, Daniel G., and Fred Plog 1991, also Bennett 1976, Vayda(ed.) 1968, and Forde 1934 surveys the same theme.

on the market are lost, and the total quality of the environment will be irrelevant to the survival of the local community. This means there will be a systematic variation in the correlation of environmental and community characteristics according to degree of modernisation. These observations has two implications for our model building.

First: The basic consequence of any correlation between geo-physical variables and societal variables is that it is impossible to estimate unbiased effects from one set of variables alone. We need to include both kinds in our model. Second: The basic consequence of the systematic variation in correlations of environment and the caracteristics of the local community is to introduce an element of autocorrelation in the model.

To avoid the problems of autocorrelation we must find the mising variable explaining the correlation. Integration into a large scale market society with extensive division of labor will cause a local forest to be in a particular condition for example because the local community is affluent enough to leave it alone, not because of the exemplary management of it. To control for the variation in dependence on local resources one must include in the model both the potential market price of the resources of the local forest and the market price of what they actually produce.

Interaction effects.
The concepts of sensitivity and resilience as used by Blakie and Brookfiled (1987) suggets that the responses of ecosystems to human agency is not uniform. The impact of a given action will be different in areas of high sensitivity and low resilience compared to areas of low sensitivity and high resilience. We can capture such conditional effects by introducing interaction terms in the model. The impact of some particular social, economic or political variable may depend on the value of some geo-physical or climate characteristic. The figure suggest three interaction:

- that the impact of social, economic or political variables depend on the geo-physical variables of the environment
- that the impact of social, economic or political variables depend on the rate and direction of change in climate, and
- that the impact of geo-physical variables will depend on the rate and direction of change in climate

The first interaction, the stipulation that the impact of human activities will depend on the geo-physical characteristics of the local environment, can for example be illustrated by the different impacts of clear cutting in different soils and altitudes.

The second interaction stipulated is between human activity and changes in climate. This can be illustrated by the variable impact of forest fires according to temperature and precipitation.
The third interaction, between changes in climate and local geophysical characteristics, is seen in the impact on the local forest conditions of changes in the amount of rain, average temperatures and length of season.

The impact of acid rain depend on the type of rock and the amount of lime in the earth. Other long range factors may include radioactive fall out, industrial smoke or other human made substances. Some of these may contain fertilisers affecting the local growth rates.

Variables describing institutional, social, economic and demographic factors, human incentives and behavior governing usage of resources in eco-systems
The first subdivsion of these variables must be between policy relevant variables and the rest of them.

The human impact on the eco-system can be divided into
1. policy-relevant variables
   such as
   - politically determined characteristics of resource management institutions
   - level and distributions of taxes and subsidies related to ecosystem usage
   - restrictions on locations and standards of emission of local manufacturing
   - .....

2. other variables
   such as
   - population size and density
   - technology
   - level of economic development
   - relative prices of local resources and products
   - cultural aspects of resource management institutions
   - .....

From exisiting studies of local communities it seems to be the case that there in durable systems usually will be a certain measure of congruence between the cultural foundation and the politically designed characteristics of the resource management institutions. Without this minimum of congruence one might

expect the impact of policy decisions at best to be zero and often counterproductive, leading to erratic fluctuations of impacts.

If policy relevant variables correlate with other variables, leaving out other variables will bias the estimates of the impact of policy relevant variables.

Interaction effects among social, economic and political variables
Will policy variables have the same impact regardless of the value of other variables? The answer is not obvious, and current state of theory does not give much guidance. It would for example seem to be a reasonable hypothesis that the impact of a certain level of taxation will depend on the level of economic development. Also the experience from other areas of society suggest we need to take account of interactions and correlations also among socio-economic variables.

Conclusions
The human impact on the forest is caused by people who use and harvest from the forest and its resources. But their actions are governed by a complex web of choices and conditions ranging from their personal values to the established rules of a local community and the legislation, taxation and subsidisation of the national government. But the consequeces of their actiosn are shaped and tempered by local and global geo-physical forces.

The consequences of national efforts to protect nature, or optimise some specific forest resource use, are sometimes counterproductive. In other cases the consequences are as intended. Today not enough is known on how to fashion policies and actions which can support sustainable development of forest resources (Ostrom 1995a, b). To understand how the national “rules of the game” affect the choices and actions of the users of a forest we need variation in the policy relevant variables to go together with the simultaneous recording of forest conditions and human activity.

If we disregard for a moment the problems of measurement for legal institutions and other relevant social and economic characteristics as well as eco-system and resource characteristics, the problem of sorting out the human impact from the impact of other factors, could be solved by collecting data on the four sets of variables of figure 1 for “enough cases” from “enough samples”. Multivariate studies of correlations will, with enough replications, help us sort out the politically relevant variables which make a difference in sustainability of a resource from those who do not.

A first preliminary conclusion must be that we need several long term projects such as IFRI collecting data on all factors affecting the status of an ecosystem. As the number of available cases increase more complex models can be tested.

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