MODELING THE HUMAN IMPACT ON RESOURCE SYSTEMS

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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 viewed as detrimental to the future utility of various resource systems. The many efforts around the world to change and improve the management of renewable resources attests to that.

Yet, we do not have any theoretical foundation for conclusions about the size of the causal impact on ecosystem characteristics of proposed changes, only beliefs about the probable direction. The knowlegde we have about the behaviour of ecosystems in response 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 coused by an indreasing 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 politically chosen course of action will work to improve the desireable qualities of an ecosystem.

A simple causal model of the human impact on the ecosystem

The problem we want to solve, sorting out the human impact on the ecosystems from the non-human impact, can be conceptualized by the following figure:

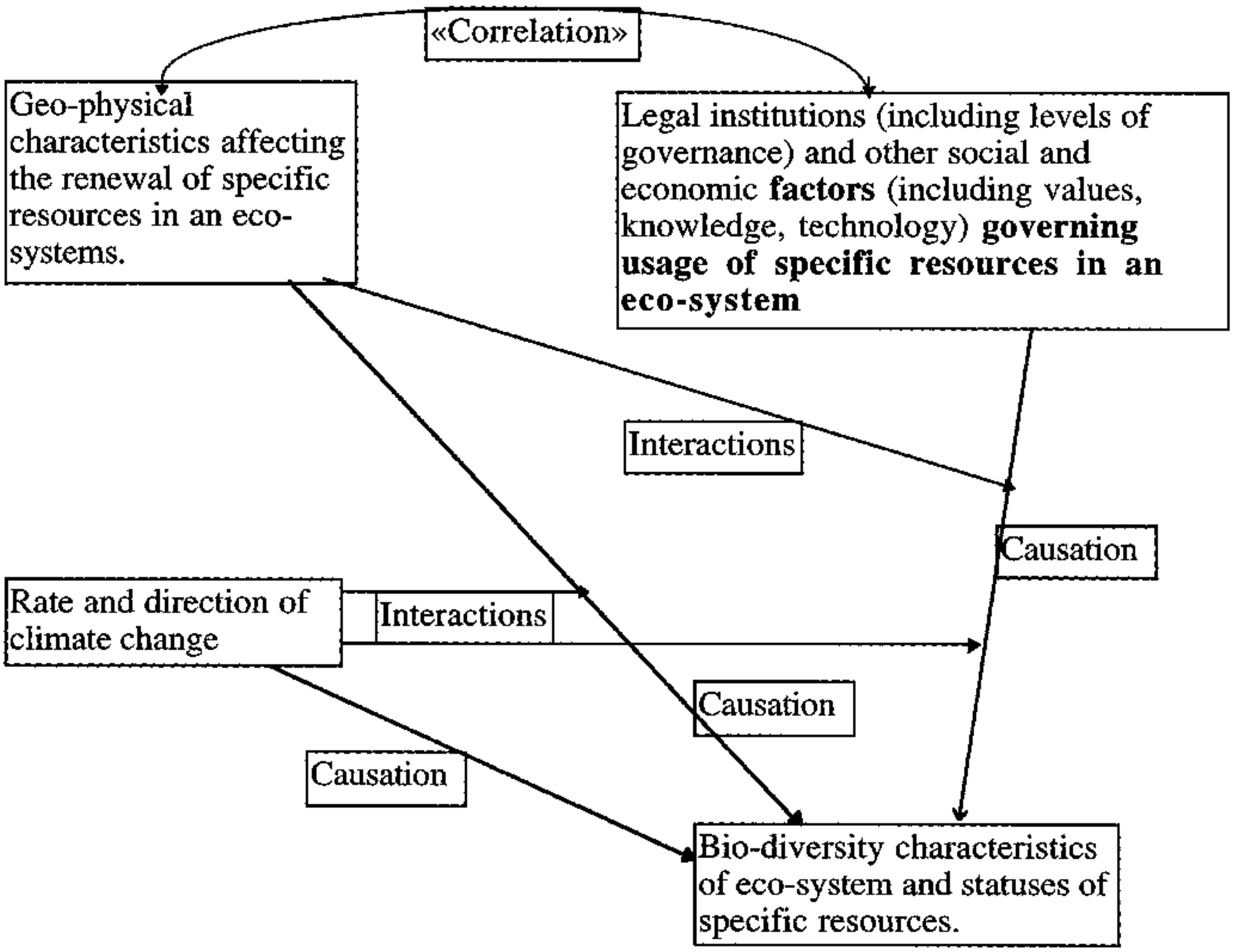

Figure 1 **Factors affecting the ecosystems**

To find quantitative estimates of the true impact of human activity we need to specify the correct model. This means we need to account for variation not only in social variables and resource system, but also in geo-physical characteristics, rate of change in climate, background correlations and interactions among causal factors.

The figure defines a simple causal structure. The hypothesis is that the biodiversity and sustainability measures characterizing an eco-system and its resources are determined by three sets of variable characteristics. One set is the geo-physical parameters circumscribing the eco-systems and its development. The second set is the human usage of the eco-system and its resources. The third set is the longterm trend in climate change.

The figure depicts two complicating features. One is the possibility of correlations between social and geo-physical characteristics. 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. And even more important, the geo-physical characteristics of the area will through historical adaptations 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).

The other complication is the possibility of interactions between geo-physical characteristics (and/ or the rate of change in these) and the impact of social variables. The consequences of some particular institutional variable may depend on the value of some geo-physical characteristic. For example, clear cutting a forest may not affect the ecosystem the same way independent of elevation above sea level. The response of the ecosystem to some human disturbance my be affected by the direction and rate of change in climate.

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 could be solved by collecting data on the four sets of variables 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.

Sample size

The level of detail in current theory is not sufficient to define the relevant measurement procedures directly either for dependent variables or for legal and socio-economic variables. The situation for geo-physical factors is better. But in exploring the social impact on ecosystems, one has to start with broad exploratory studies. The number of variables will easily be counted in hundreds. The number of cases needed to detect regression coefficients of size b_k at significance level **a** in a model with p variables will be
$n = p + 1 + (t_a / b_k)*(RSS/RSS_k)$ where t_a is the critical value at significance level **a** in the t-distribution with appropriate deegees of freedom.

If one wants to detect b_k's of true size 0,1 at significance level 0,05, the number of cases needed will be in the order of $n=p+400*(RSS/RSS_k)$, meaning the number of cases will depend on how good the model is and the correlations among the explanatory variables. Better models and uncorrelated x-variables need fewer cases.

Even in the best of circumstances it seems probable that it will be a long time before the simultaneous collection of socio-economic, eco-system and geo-physical data has been done for enough cases to estimate the true effects of human activity on ecosystems. During this period we will have problems with more variables than cases.

Can we reduce the number of variables in any way?

The need for geo-physical variables

In the study of the human impact on ecosystem characteristics one cannot leave out geo-physical variables. Legal institutions as well as many other social and economic characteristics will correlate with geo-physical characteristics. Leaving them out will give biased estimates of the impact of legal and socio-economic variables. Thus there is no way of comparing the actual biodiversity characteristics of two areas with different institutions without controlling for the geophysical parameteres.

Few cases of simultaneous measurements of socio-economic characteristics and bio-diversity characteristics implies that we need to collect data for both types of variables at the same time.

The many data sets which have been collected have usually been either only biological data or only socio-economic data. Geo-physical data will usually be missing. But it will often be possible to reconstruct these.

Circumventing the need for geo-physical variables in the measurement of the human impact

If one for a given study area could estimate the various biodiversity characteristics which would prevail in the absence of human activity in the area, the actual observed characteristics could be made relative to this «standard biodiversity». The deviance from 1 would measure the compund human impact.

Conceivably this could be approximated by using a reference area. A reference area will in this case be an area similar to the study area in geo-physical characteristics, but without human impact or at least with a regime of constant human impact (measured on an appropriate time scale). Making the ecosystem characteristics of the study area relative to this reference area, will control some of the variation in geo-physical characteristics of a study area.

However, the selection of reference area is problematic, and comparisons of data across cases with different reference areas will in principle be as untenable as the first order problem.

A second, more sophisticated strategy will be to go through the data collected by biologists and/or foresters on «virgin» forests and estimate «standard» biodiversity tables, for example in the form of regression equations linking the geo-physical parameters (including trends in climate) to a standard biodiversity index for an area with a given set of parameter values. Observed values should then be made relative to this, thus giving a measure of deviation in current ecosystem characteristics which presumably could be attributed to human activity.

The ecosystem characteristics will then be standardized according to the best estimate of an «untouch» ecosystem with the exact geo-physical characteristics of the area where socio-economic variables have been collected. The deviation between theoretical and observed index variables can then be attributed to the human impact.

However, this standardisation will not remove the problem of background correlations between geo-physical variables and socio-economic variables and it vill be impossible to estimate the interactions. In the model without geo-physical variables and using the standardised measures of the ecosystem characteristics, the effect of the geo-physical variables will be indirect and the interaction effects missing. Both the missing correlations and the missing interactions will bias the estimates of the policy relevant variables

For policy purposes the knowledge about both the background correlations and the size of interaction effects will be needed.

Policy relevant variables

Can social and cultural variables other than the directly policy relevant variables be left out from a study?

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
   -

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

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

From exisiting studies 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.

Interaction effects

Experience from other areas of society suggest we need to take account of interactions and correlations also among socio-economic 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.

Concentrating on policy relevant variables only, can not be recommended.

Conclusions

A first preliminary conclusion must be that we need a long term project collecting data on all factors affecting the status of an ecosystem. As the number of available cases increase, more complex models can be tested. But for a long time there will be problems with more variables than cases.