The paper by Christiansen and Altaweel addresses a fundamental problem confronted by modern society, namely: what are the potential impacts of environmental change on human society? In this era of global warming it is (again) becoming necessary to understand how societies relate and respond to global environmental change. I say "again" because this was a popular field in the 19th and early 20th century when figures such as Ellsworth Huntingdon outlined bold and rather oversimplified relationships between human society and climate. The problem is that in the past both the theoretical framework as well as the techniques available were insufficient to tackle the full complexities of the interactions that might be expected. Now, techniques of agent-based modeling allow researches to demonstrate how human communities might respond to variations in key variables. In addition, these models also illustrate the rich range of response mechanisms that are employed as well as the varied outcomes. Christiansen and Altaweel outline the technical framework employed by the MASS[1] team, and successfully summarize the basic methods used. As a member of the MASS team I am hardly an objective commentator, but at least I can point out some of the ramifications of the simulations.

As the authors state, it is a difficult challenge to represent all of the processes and interactions required. That this is not simply a matter of adding more processes to the mix is illustrated by how one envisages the utility of some of the input data. For example, one problem that results from the use of cuneiform texts (in the form of Sumerian or Akkadian tablets) to supply input data is that they can lead to a form of uncertainty rule. In other words when cuneiform texts are discovered on an archaeological site they provide a wealth of new information on that site as well as on the ways of life that were practiced. However, the presence of texts at a site usually corresponds with a more "open" economic and political system, often with the site in question being part of a larger political economy than might be the case for a small subsistence village that possessed no texts. In other words, a larger information base is equally associated with a larger and more complex socio-economic system, which itself is more difficult to model because of the greater uncertainty involved. This is not to criticize the use of texts—they are a crucial part of the MASS input data—but simply to caution the modeler that novel forms of data come with their own limitations. Currently the MASS model under discussion is only being deployed around a single small settlement, but the next generation of simulations is under construction to incorporate systems of settlements together with interacting nomadic pastoral communities.

Certainly the models capture more reality than an earlier generation of processual models, and as the authors' state:

> "The cognitive powers given to the agents allowed them to evaluate different behavioral options before choosing what they believed to be their best option, such as seeking a one-way gift exchange from a kin member rather than borrowing grain from unrelated agents."

This assumes that agents / community members take rational decisions and that those decisions are embedded in a social context rather than assuming a homogenous social environment. There is also the potential for a certain amount of serendipity to be injected into the decision-making process. It must of course be emphasized that even

[1] MASS = Modeling Ancient Settlement Systems

these complex models are much simpler than "reality" (whatever that may be), but they take us another step along the road to appreciating that human societies do not simply respond in a simple linear way to external stresses. This is something that has been long known to social scientists, but there is an urgent need for the generation of empirically-based models that can be used to bridge the gap between social and environmental disciplines.

Christiansen and Altaweel conclude as follows:

> "…this brief overview of the ENKIMDU engine and its enabling technologies makes it clear that researchers have the ability to create complex agent-based simulations that can test varied theoretical approaches and address the numerous needs of researchers."

In other words these simulations can enable researchers to stipulate, for example, that "under these circumstances, there are the following outcomes."

An illuminating point illustrated by the household diaries is that even over brief simulation runs of 100 years we are seeing the appearance of social differentiation, so that some households become relatively rich in resources whereas others become impoverished. Whether this constitutes "social evolution" or not is a matter for debate but it is clear that often as a result of positive feedback processes we are seeing (in certain circumstances) the rich getting richer and the poor getting poorer. The operation of such processes is hardly going to surprise experts on complexity theory (nor my grandmother for that matter), but it is fascinating to see that counter-intuitive outcomes often emerge, so that societies faced by stress often overcome those stresses as a result of creative new solutions. For example, one emerging outcome of the simulations is that during periods of stress arising from, let us say, a run of drought years, there is an increase in exchange activity, specifically with animals being traded for badly-needed grain. In other words an event in the environmental sphere has an impact within the economic sphere mediated through a social matrix. Because such outcomes may, in part, result from the finite range of activities incorporated into the model, it is probably necessary to increase the complexity of the models still further. One of the great advantages of the ENKIMDU simulation system is that it is fully capable of handling such increased levels of complexity.