Decision-making in Rangeland systems: an integrated Ecosystem-Agent-based Modeling Approach to Resilience and change (DREAMAR)

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Introduction

Rangelands comprise about 25% of the Earth's surface and these landscapes support more than 20 million people and most of the world's charismatic mega-fauna. Most of the people who live in these regions of the world herd domestic livestock and some do limited cultivation so they are dependent directly on the environment for most of their livelihoods. But change is rapidly altering the environments upon which these people depend through such factors as population pressures, land use and land tenure changes, climate variability, and policy changes which affect their ability to earn a living. This project is about understanding uncertainty and change in this linked human-environment system. Through an integrated modeling approach based on an appropriate theoretical framework that makes use of extensive empirical research we are addressing issues of societal resilience under change.

With work we have done in Mongolia, the northern U.S. Great Plains and in East Africa we are investigating how change affects the coupled human-ecological system. Figure 1 shows the relative strength of factors that affect household decision making in each of the sites. The data show a great deal of variability in the weight of factors that affect decision making which reflect the different states in which each site finds itself. Some of the factors inhibit decision making that make people resilient to changing environments while others facilitate it.

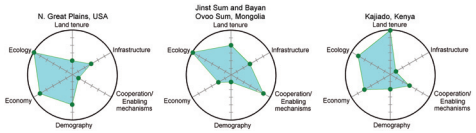

Figure 1. The relative strength of factors that affect household decision making in each of our study areas.

The factors were determined based on a synthesis of the data and expert knowledge and were used to develop the conceptual model of land use decision making (see Figure 2). The conceptual model makes clear that decisions livestock owners make are tightly tied to local ecosystem services. We use well-established and integrative computer models to represent ecosystems. To represent the importance of ecosystem services to livestock producing households and how their decisions may affect ecosystems, we use modeling. We are designing and constructing an agent-based model of livestock-owning households called DECUMA that incorporates ecosystem services.

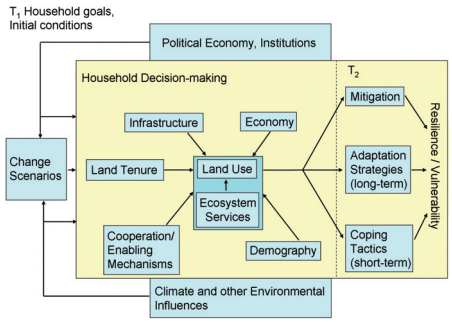

Figure 2. Conceptual model of factors influencing household decisions.

Designing DECUMA

DECUMA (DEcisions under Conditions of Uncertainty by Modeled Agents) models households as decision-making agents responding to the availability of ecosystem services and other opportunities and stressors. The DECUMA model is joined with the SAVANNA ecosystem model (Figure 3). and will be joined with DAYCENT. The SAVANNA ecosystem model is adept at modeling plant and animal productivity in rangelands in a spatially-explicit manner. The second model, DAYCENT, is adept at modeling trace gas fluxes and soil moisture dynamics in rangeland and agricultural systems. DECUMA will be tightly linked with both models, and the usefulness of the ecosystem models to represent household decision making and resiliency will be compared.

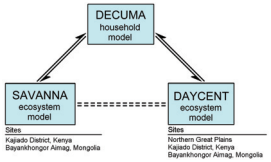

Figure 3. DECUMA will join with ecosystem models so services they provide affect decision making, which in turn affect ecosystems.

Agents in DECUMA will maintain essentially parallel models reflecting attributes of the agent and attributes of the environment the agent perceives, including attributes of other agents to which it is associated. Figure 4 summarizes the more important attributes and knowledge of the agents. Households will be associated with grid coordinates used in ecosystem modeling, and households may have both permanent and temporary homes, with temporary homes recording movements by pastoralists by month. Agents will also be characterized by their family size, livestock holdings by species, wage income, market information, and opportunities for diversification.

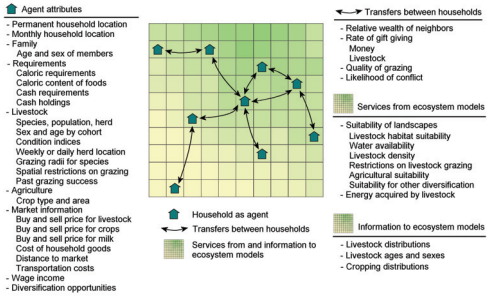

Figure 4. A spatial representation of DECUMA, with selected agent attributes and information transferred between agents and between DECUMA and the ecosystem models..

Households will have memory of the grazing success, in terms of energy acquired by livestock, in past grazing periods. This will provide agents with the opportunity to learn which grazing areas are best. Information will be shared in a realistic way between agents. Network connectivity between agents will approximate that known based on field work and surveys. Interacting agents will inform each other of the quality of grazing in their sites (a common past-time among pastoralists), and indices will reflect the likelihood agents may exchange gifts or be in conflict (Figure 5).

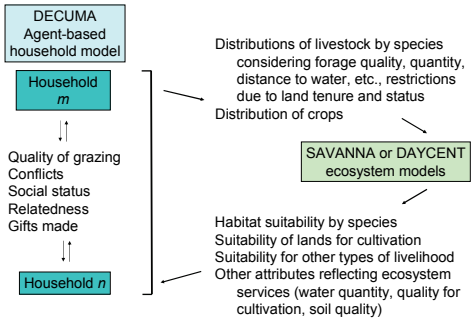

Figure 5. DECUMA program flow through one modeled time step.

Progress and Pathway Forward

DECUMA and SAVANNA are now tightly linked (Figure 6) and livestock populations that respond to forage quality and quantity are being modeled for each household. SAVANNA models wildlife species in Kajiado, Kenya appropriately, and DECUMA provides to SAVANNA the distribution of livestock. SAVANNA in-turn provides to DECUMA a measure of grazing success. After finalizing the infrastructure of the connected models, we will begin incorporating agent decision making modules that capture ecosystem and societal constraints on households.

When completed and validation of the model applications are complete, we will have modeled rangeland and cropland ecosystems inhabited by members of households whose decisions are influenced by – and in-turn influence – the a) ecosystem services available, b) infrastructure, land tenure, economy, etc., and c) information provided by other agents at multiple levels. The joined models will be able to represent human responses to ecosystem services at a level of detail not achieved before. We expect to be able to use our coupled models to answer questions relating to the links between social and ecological systems at the case study sites, particularly in relation to the nature of the linkages between social and ecological resilience/vulnerability.

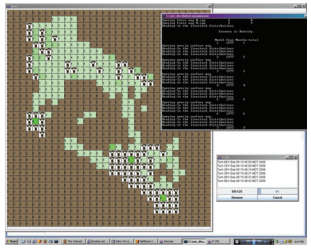

Figure 6. DECUMA and SAVANNA running a simulation in Kajiado District, Kenya. Households and their cattle are shown.

Broader Implications

Why is this important? Research that focuses on household and community behavior is important because it is at that level where fundamental decisions are made and it is here where resilience is manifested. The notion that recommendation domains can be identified for a broad set of people coping with change is becoming increasingly hard to believe, given the spatial and temporal heterogeneity of the systems we are looking at, and the complexity of the world we now live in. In the future we are going to have to be much smarter in the way that we match potential "clients" with potential policy or technical interventions. The only way the research community is going to make great progress in attaining objectives that do confer resilience (on social and ecological systems) is through much better targeting ability, a large part of which seem to be intimately entwined with understanding how households make decisions.

Acknowledgements

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For additional information, see the **DREAMAR Project**, http://www.nrel.colostate.edu/projects/dru/