Agent-Based Modelling of Vulnerable Food Systems

Agent-based modelling concepts and techniques are well suited to the investigation of food system vulnerability to global environmental change. The actors in a food system are represented by agents in a computer model—responding to the environment, managing resources and learning from their experiences and each other. Thus, the *particular* vulnerabilities of local communities can be related to the *general* drivers of the stresses and shocks in social, economic and environmental change.

Introduction

Vulnerability in the context of global environmental change (GEC) entails a general mode representing global processes and conditions of vulnerability and a particular mode representing instances of local vulnerabilities. An enduring feature of vulnerability is that it is dominated by multiple stresses such that a range of outcomes can be expected at a local scale within the context of global storylines.

Agent-based models (ABM) use a bottom-up approach whereby phenomena, such as new forms of vulnerability, evolve as a result of the local, micro-level interactions between agents. For example, decisions by local farmers to grow a particular crop are affected by global trade and exchange considerations. Where the global price of a commodity drops below a certain level it no longer becomes feasible to cultivate that crop at a local level. By distinguishing between agents with respect to behavioural characteristics and system-related attributes (e.g. wealth, land holding, family size, climate, economy etc.), ABM methods allow for the examination of particular forms of vulnerability – the ways in which certain individuals are more or less vulnerable to food systems risks and uncertainties than other individuals or organisations.

Stakeholder analysis can be undertaken through direct evaluation of simulation results and emergent vulnerabilities as a result of processes at varying spatial scales. As stakeholder are represented as agents in the programme, accounts of stakeholder successes and failures are readily available in programme outputs. For evaluation purposes, criteria for success and failure of agents within the simulation must be determined. Varying the parameter space in multiple simulation runs allows the characteristics that consistently make agents vulnerable to failure or adaptive for success to be identified.

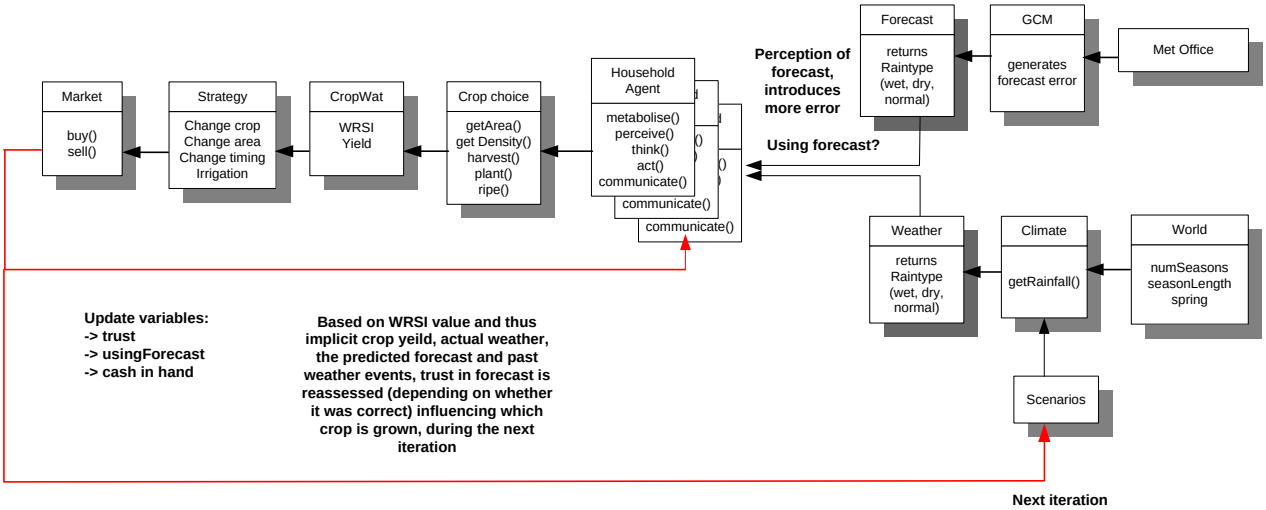
Disadvantages of a quantitative approach to vulnerability, such as not representing actor behaviour and the lack of a historical context, can largely be overcome using an ABM approach. The ability to experiment with the extent to which present climate coping strategies are able to withstand future threats is further justification for the relevance of ABM to vulnerability science.

Models and Methods

In agent based modelling, an agent is a self-contained programme that can control its own actions, based on its perceptions of its operating environment (Huhns and Singh 1998). The aim of agent design is to create programmes which interact intelligently with their environment and properties of agents can include: autonomy, social ability, reactivity and proactivity (Gilbert and Troitzsch 1999). The social aspect of agent behaviour means that agents do not succeed or fail based solely on their own characteristics but also on their social networks. The degree and quality of social networking and agent dependence upon it can be controlled by the programmer.

Agents also interact with their surroundings. Agent activities can take place against a backdrop of global environmental change. For instance, agents can act based on long-term or short-term climate predictions. Climate can also affect the success or failure of personal decisions or management regimes (e.g. climate will impact crop growth and therefore farm profits).

Agent based programming can be distinguished from procedural programming in its explicit representation of stakeholders, as agents, in the modelling code. This close correlation between the modelling agents and real actors provides an opportunity for the close involvement of stakeholders in model building and validation to ensure that agents appropriately represent their behaviours. The agent-based modelling process is used not just to produce a final model but as a forum for social learning for stakeholders and actors participating in the model building process. The process allows the sharing of viewpoints between stakeholders and the testing of system perceptions.



Example of an agent-based model, from the Cloud Project

Case Studies

The Cloud Project (funded by the School of Geography, Oxford, SEI and Tyndall Centre at UEA) focuses on the vulnerability of small-holder farmers in a communal irrigation scheme in Mangondi village, Limpopo Province, South Africa. An ABM is based on empirical fieldwork over three years. Farmers' use of various adaptation strategies is incorporated in the ABM to assess the effectiveness of various coping mechanisms under different scenarios. Seasonal forecasts, which some of the farmers are aware of and use, have been included as a source of information which enable further adaptation strategies to be adopted. The ABM enables experimentation with variations in the type of information that is disseminated and its impact on this community. Hypotheses regarding which strategies reduce and emphasise the vulnerability of individual farmers and the community as a whole can be rigorously tested. The results can then be subjected to further stakeholder analysis, serving to inform further fieldwork as well as output from the ABM. Practically, this can serve to improve way the information that is currently presented in the seasonal forecast so that it is understood and used correctly to increase the sustainability of the livelihoods of such small-scale farmers. (See: http://www.geog.ox.ac.uk/research/projects/cloud/)

The Virtual Food Court developed by McGeary and Decker (2001) shows the further potential of the ABM work currently being conducted at the SEI – placing individual agents within a market place with buyers and sellers. The Virtual Food Court (VFC) replicates a food market place with agents as consumers and providers of restaurant meals. In this model, an economic market place of rational agents is created where food vending and consuming agents attempt to maximise their own welfare using the behaviours and information they have available. The VFC furthers the modelling of market purchases and contracts and shows how a large number of interacting agents can be organised into workable units while still recognising their individual autonomy. The authors propose further work on how agents can work more freely in deciding what products to produce and what prices to charge.

References

Gilbert, N. and K. G. Troitzsch. 1999. Simulation for the Social Scientist. Open University Press, Buckingham.

Huhns, M. and M. P. Singh. 1998. Readings in Agents. Morgan Kaufmann, San Mateo, CA.

McGeary, F. and K. Decker. 2001. Making a Virtual Food Court Using DECAF. In S. Moss and P. Davidsson, editors. Multi-Agent-Based Simulation. Springer, Berlin, pp 68-82.

Other relevant briefing notes

- Vulnerability, global environmental change and food systems (overview of vulnerability concepts)
- Vulnerability assessment and mapping (use of indicators)
- Resilience: Contributions to vulnerability concepts and methods
- Political ecology: Contributions to vulnerability concepts and methods
- Vulnerability toolkit (overview of range of tools for vulnerability assessment)

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