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An agent-based model of a social-ecological system: A case study of disease management in potato cultivation

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The Netherlands is a large producer of seed, ware and starch potatoes (*Solanum tuberosum*) and therefore has a high density of potato. Damage due to pests and diseases has been identified as one of the main factors that is responsible for yield loss. One of the most important diseases in potato production is *Phytophthora infestans* (late blight). This pathogen has a short life cycle and because the spores disperse by wind, a late blight epidemic can spread over large regions. Climatic conditions in the Netherlands are favourable for late blight which can lead to large outbreaks. The application of fungicides is the most important control method, but the costs are enormous and the chemicals are very harmful to the environment (Haverkort et al., 2008).
Sustainable management of the disease includes the use of resistant varieties which are recently being developed by commercial breeding companies. However, when more farmers grow resistant cultivars there is an increased risk that new *Phytophthora* strains with compatible virulence genes emerge. As a result, resistance of several cultivars has been broken in the past. Resistance management practices are required to protect new and scarce resistant genes in varieties from breakdown in the future. Since the overall infection in a landscape depends on decisions of stakeholders as well as disease epidemiology, this is an example of a social-ecological system.
The system consists of several stakeholders such as farmers, breeding companies and governmental organisations, each with their own set of interests. Farmers aim to maximize their profits and can decide to take crop protection measures such as the application of fungicides, the removal of infection sources and the use of resistant cultivars. In adopting these strategies farmers are strongly influenced by other stakeholders. For example there is a Dutch governmental policy that states that potato fields have to be burned down when infection with *Phytophthora* reaches a certain level. Furthermore, for the availability of resistant cultivars farmers rely on breeding companies. Since breeding and propagation of new potato cultivars requires large investments and takes place in a highly competitive market, breeders generally aim to market new resistant cultivars as quickly and widely as possible. Spatial allocation of cultivars with different resistance genes could help to avoid loss of resistance, but this requires cooperation between farmers and breeding companies. Both farmers and breeders are hesitant to adopt spatial strategies since they are afraid for transaction costs and reduced autonomy in cultivar choice. Since in this system many different stakeholders and processes are involved it is necessary to use a complex adaptive system approach in order to analyse sustainable use of resistant cultivars in *Phytophthora* management strategies.
An agent-based model (ABM) was developed to understand how *Phytophthora* management strategies by farmers affect the spread of *Phytophthora* infections through a landscape and the durability of resistant cultivars. To collect input for model development, in-depth interviews with farmers, breeders and experts were carried out to identify current *Phytophthora* management strategies and the factors involved in decision making. The findings were compared to data in literature and social theories on farmers' decision making. The epidemiological model of *Phytophthora* was achieved by simplifying an existing model (Skelsey, 2008).
This resulted in a model with many different levels, interactions and feedback mechanisms. The model represents an agricultural landscape that consists of farms and fields in which farmers and breeding companies operate. A fraction of the fields is occupied by potato crops which can be infected by *Phytophthora* that disperses through the landscape. Important processes in the model are farmers' decision making, marketing strategies of breeding companies and biophysical processes such as potato growth and dispersal of *Phytophthora* within a certain landscape configuration.
Two different farmer types, conventional and organic farmers, are distinguished in the model since they considerably differ in their management practices. *Phytophthora* management strategies include the application of fungicides, the removal of infection sources in potato fields and the use of resistant cultivars. Farmers' decisions on *Phytophthora* management are based on yield optimisation, the farmers' network, personal characteristics and availability of cultivars by breeding companies. *Phytophthora* dispersal in the landscape is affected by weather conditions, potato variety and planting patterns. Potato growth is dependent on the specific cultivar and infection level of *Phytophthora*. The processes are updated at a daily time step and the model is run for several years to study long term effects of farmers' management strategies.

To analyse a specific case study a model is being developed that represents a 10km by 10km agricultural region in the Netherlands that includes the model components and processes previously described. At the moment the agent-based model is still under development and at the conference the first results of the simulation will be presented.

References

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