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TOWARDS AN AGENT-BASED MODEL FOR SUSTAINABLE AGRICULTRUAL PRACTICES ON SCOTTISH FARMS

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ABSTRACT

Recent years have seen increasing awareness of the impact of conventional agricultural practices on our planet. High input farming systems have been successful in dramatically increasing food production for an exponentially growing global population, but they are also leading contributors to GHG emissions and biodiversity loss. There is therefore much interest in alternative, more sustainable, farming practices. We propose the development of an agent-based model, in close collaboration with Scottish farmers, to explore land-use decision-making. It is envisaged that this study will give insight into the uptake of more sustainable farming practices in Scotland, while also enhancing understanding of the utility of agent-based modelling for agroecological systems.

1 INTRODUCTION

The environmental impact of high input agricultural systems is now well understood, with food production responsible for up to a third of GHG emissions globally and a leading cause of biodiversity loss. Moreover, conventional agriculture, embodied by monoculture and intensive livestock production, is linked to the increasing prevalence of non-communicable diseases, such as cardiovascular disease and diabetes (Willett et al. 2019). In Scotland, agriculture is a leading contributor to GHG emissions and conventional practices are depleting farmers' most important asset – their soils (Montgomery 2007). With growing concern over the long-term sustainability of these systems some individuals are turning to alternative practices, based on agroecological principles, and aimed at improving soil health and farm productivity without a heavy dependence on synthetic chemicals. These practices include no till drilling, cover cropping, crop rotation, agroforestry and livestock integration, and are incorporated as part of a systems view of farm management. The impacts of such changes in land-use decision-making, however, are currently not well understood.

2 CHALLENGES

Agricultural systems are coupled human and nature systems (An 2012), whose modelling requires consideration of agricultural science, socioeconomic factors, decision-makers, and the interactions between them (Huber 2018). As such, understanding the impacts of land-use decision-making requires modelling of not only farmer-environment interactions, but also farmer-farmer interactions. Specific challenges for agricultural systems models are to capture farmer learning and effectively model social interaction (Huber et al. 2018). One promising approach is agent-based modelling (ABM), which has been widely applied to land-use modelling, and specifically to explore decision-making in Scottish agriculture (Brown et al. 2017).

Further challenges of data availability and communication of output have been reported in agricultural systems modelling (Jones et al. 2017). Additionally, an understanding of relationships between key input and output parameters is critical to acceptance within the farming community, however, farmers frequently do not have a strong technical background, complicating the interpretation and communication of results (An 2012). Various metamodelling techniques have been utilised in a range of simulation studies to elicit and make explicit relationships between input and output parameters of interest (Barton 2015). Finally, validation is also noted as a key challenge for the practical application of ABMs. Access to both empirical data and expert judgment is typically required to support this process.

3 PROPOSED METHODOLOGY

We propose an exploration of land-use decision-making, with respect to the uptake of sustainable practices, through the development of an agent-based model. The diversity of management can be handled using an established framework to define typologies for farm classification (Valbuena et al. 2008). Validation can be achieved by constructing the model in accordance with economic and agroecological theory, by comparing model output with observed land-use (Schreinemachers and Berger 2011), and by facilitating participatory group exercises for farmers. Engaging farmers will facilitate access to data, as well as an enhanced understanding between decision-maker and modeller. Furthermore, collaboration with SAOS, a Scottish agricultural organisation who work closely with farming co-operatives, is expected to be especially beneficial for modelling social interactions between farmers, as they have a comprehensive understanding of collaboration and farm-farm interaction within the Scottish farming sector.

Participatory modelling with farmers could result in mutually beneficial outcomes: enhanced understanding of land-use decision-making and access to empirical data through discussions and available datasets for modellers; and greater knowledge and appreciation of the potential benefits of agricultural systems modelling for farmers, translating into enhanced decision-making and improved farm performance. Collaboration with the farming community could also help shape future data collection strategies.

REFERENCES

An, L. 2012. “Modeling Human Decisions in Coupled Human and Natural Systems: Review of Agent-Based Models”. *Ecological Modelling* 229:25-36.

Barton, R. R. 2015. “Tutorial: Simulation Metamodeling”. In *Proceedings of the 2015 Winter Simulation Conference*, edited by L. Yilmaz, W. K. V. Chan, I. Moon, T. M. K. Roeder, C. Macal, and M. D. Rossetti, 1765-1779. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc. .

Brown, C., I. Bakam, P. Smith, and R. Matthews. 2016. “An Agent-Based Modelling Approach to Evaluate Factors Influencing Bioenergy Crop Adoption in North-East Scotland”. *Gcb Bioenergy* 8(1):226-244.

Huber, R., M. Bakker, A. Balmann, T. Berger, M. Bithell, C. Brown, A. Grêt-Regamey, H. Xiong, Q. B. Le, G. Mack, P. Meyfroidt, J. Millington, B. Müller, J. G. Polhill, Z. Sun, R. Seidl, C. Troost, and R. Finger. 2018. “Representation of Decision-Making in European Agricultural Agent-Based Models”. *Agricultural Systems* 167:143-160.

Jones, J. W., J. M. Antle, B. Basso, K. J. Boote, R. T. Conant, I. Foster, H. C. J. Godfray, M. Herrero, R. E. Howitt, S. Janssen, B. A. Keating, R Munoz-Carpena, C. Porter, C. Rosenzweig, and T. Wheeler. 2017. “Toward a New Generation of Agricultural System Data, Models, and Knowledge Products: State of Agricultural Systems Science”. *Agricultural Systems* 155:269-288.

Montgomery, D. R. 2007. “Soil Erosion and Agricultural Sustainability”. *Proceedings of the National Academy of Sciences* 104(33):13268-13272.

Schreinemachers, P., and T. Berger, 2011. “An Agent-Based Simulation Model of Human–Environment Interactions in Agricultural Systems”. *Environmental Modelling & Software* 26(7):845-859.

Valbuena, D., P. H. Verburg, and A. K. Bregt, 2008. “A Method to Define a Typology for Agent-Based Analysis in Regional Land-Use Research”. *Agriculture, Ecosystems & Environment* 128(1-2):27-36.

Willett, W., J. Rockström, B. Loken, M. Springmann, T. Lang, S. Vermeulen, T. Garnett, D. Tilman, F. DeClerck, A. Wood, M. Jonell, M. Clark, L. J. Gordon, J. Fanzo, C. Hawkes, R. Zurayk, J. A. Rivera, W. De Vries, L. M. Sibanda, A. Afshin, A. Chaudhary, M. Herrero, R. Agustina, F. Branca, A. Lartey, S. Fan, B. Crona, E. Fox, V. Bignet, M. Troell, T. Lindahl, S. Singh, S. E. Cornell, K. S. Reddy, S. Narain, S. Nishtar, and C. J. L. Murray. 2019. “Food in the Anthropocene: the EAT–Lancet Commission on Healthy Diets from Sustainable Food Systems”. *The Lancet* 393(10170):447-492.