

The evolution of agricultural intensification and environmental degradation in the UK: a data-driven systems dynamics approach

David I. Armstrong McKay (1), John A. Dearing (1), James G. Dyke (1), Guy Poppy (2), and Les Firbank (3)

(1) Geography and Environment, University of Southampton, Southampton, UK (d.armstrong-mckay@soton.ac.uk), (2) Centre for Biological Sciences, University of Southampton, Southampton, UK, (3) School of Biology, University of Leeds, Leeds, UK

The world's population continues to grow rapidly, yet the current demand for food is already resulting in environmental degradation in many regions. As a result, an emerging challenge of the 21st century is how agriculture can simultaneously undergo sustainable intensification and be made more resilient to accelerating climate change. Key to this challenge is: a) finding the "safe and just operating space" for the global agri-environment system that both provides sufficient food for humanity and avoids crossing dangerous planetary boundaries, and b) downscaling this framework from a planetary to a regional scale in order to better inform decision making and incorporate regional dynamics within the planetary boundaries framework. Regional safe operating spaces can be defined and explored using a combination of metrics that indicate the changing status of ecosystem services (both provisioning and regulating), statistical techniques that reveal early warning signals and breakpoints, and dynamical system models of the regional agri-environment system. Initial attempts to apply this methodology have been made in developing countries (e.g. China [Dearing et al., 2012, 2014; Zhang et al., 2015]), but have not yet been attempted in more developed countries, for example the UK.

In this study we assess the changes in ecosystem services in two contrasting agricultural regions in the UK, arable-dominated East England and pastoral-dominated South-West England, since the middle of the 20th Century. We identify and establish proxies and indices of various provisioning and regulating services in these two regions and analyse how these have changed over this time. We find that significant degradation of regulating services occurred in Eastern England in the early 1980s, reflecting a period of rapid intensification and escalating fertiliser usage, but that regulating services have begun to recover since 2000 mainly as a result of fertiliser usage decoupling from increasing wheat yield. Soil erosion / suspended sediment transport and atmospheric pollution have also declined, but some biodiversity degradation metrics continue to rise. Environmental degradation resulting from agriculture in this region appears to have followed the trajectory of an Environmental Kuznets Curve, with recent years showing that regional GDP growth has begun to decouple from ecological deterioration. The history of South-West England is complicated by the significant drop in livestock density as a result of the 2001 foot-and-mouth disease outbreak and highly variable erosion data, but in general a similar pattern of increasing degradation in the 1980s and a gradual recovery since ~2000 is observed. Data with higher spatial and temporal resolution is required in order to further investigate the differing behaviour of the agri-environment system in each region. Based on this analysis, the preliminary results of a prototype dynamical systems model of regional agri-environment systems in the UK is also presented. Further development of this model will enhance our ability to identify regional social-ecological system boundaries and to detect the potential presence of tipping points within them.