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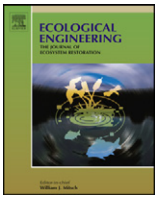

Evaluation of wildlife management through organic farming

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ABSTRACT

Organic farming has often been suggested as a way of increasing biodiversity in agricultural landscapes, but literature reports a variable success. The drivers in play are multi-factorial and include the particular species groups under consideration, the precise form of organic management, the landscape structural and management context, the area and scale considered, and the historical context. Here ALMaSS, a comprehensive agent-based model simulation system, was used to produce an assessment of the impact of organic and conventional farm types, landscape structure, and management context for six common agricultural wildlife species. ALMaSS outputs can be expressed as a simple index of relative change in abundance and distribution, allowing easy comparison between scenarios. Results indicate that organic farming generally had a beneficial effect, but the degree was variable with all factors considered and there were strong interactions between factors. Targeted managements provided much greater impacts than changes in farm types. Predictions of biodiversity impacts depended on precise inputs, underlying both the view of this system as being complex, and the necessity for detailed knowledge. However, this combination of detailed modelling platform with a simple index of impact provides an easily interpreted method for objective evaluation of impacts of potential policy scenarios.

1. Introduction

It has been suggested that changes in agriculture could drive changes in biodiversity almost as large as are expected from climate change (Tilman et al., 2001). These changes can be expected as a result of a complex of changes in land-use and changes in land management, particularly intensification (e.g. Donald et al., 2006). In many areas organic farming has been promoted as a way of combating potential biodiversity losses, and in Denmark this has resulted in a major government initiative (Anon., 2010). In this case increasing the area under organic farming was suggested as a way to counter-act the expected loss of biodiversity associated with the abolishment of the EU set-aside schemes.

However, the ability of organic farming to reliably deliver these biodiversity improvements has been questioned (e.g. Bengtsson et al., 2005; Brittain et al., 2010). Hole et al. (2005) reviewed the literature on comparative organic and conventional studies and found a tendency for higher species diversity on organic farms. They note that there is insufficient evidence to support the idea that holistic organic farming is better than targeted conservation measures. One of the problems noted by Hole et al. (2005) is that these comparative studies often embody methodological problems that limit their ability to draw quantitative conclusions. There are a number of reasons why this is the case. The primary reason is that it is not possible to control all factors when comparing two farms or locations. Smith et al. (2010) found an interaction between landscape heterogeneity and the impact of organic farming on bird diversity, but was unable to identify conclusively the causal factors. The problem was that it was impossible to separate components of landscape complexity and organic farming. Traditional field experiments are also difficult since organic farming has a temporal component, and there is a scale issue. Gabriel et al. (2010) demonstrate that there is interaction between on farm practices and the responses of biodiversity at multiple spatial scales. Another important complicating factor is that organic farming is not a single entity. Administratively, it can not only vary between country and region, but also encompasses a wide variation of farm types from arable production to upland hill farms. Likewise within individual organic farm types there is great variability in practices. Some farmers follow traditional holistic and even biodynamic principles, whilst others operate on large scales with intensive organic production. On top of these factors we must also acknowledge that biodiversity is made up of disparate ecological groups of species each with their own specific requirements. Hence we cannot expect biodiversity to react to organic farming factors in a simple unidirectional manner.

From the above issues it is clear that the biodiversity/agronomic landscape system is functioning as a complex socio-ecological system with feedback possibilities at multiple spatial and temporal

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scales. The decisions of individual farmers will be determined by multiple factors operating at local and larger scales, and the impact of these decisions will also vary with landscape, farm type, and the section of biodiversity under question. Hence, one size does not fit all, and biodiversity management must be carefully targeted to obtain desired responses. This complex of ecological, administrative and human behavioral components severely hinders the identification of clear management targets or guidelines.

Many of the environmental questions we are facing today fall in the domain of post normal science (Funtowicz and Ravetz, 1992); where facts are uncertain, stakes are high, and decisions are urgent. It is not uncommon that predictions of impact require the consideration of multiple drivers (e.g. Franklin, 2010). If we add the complex dynamics of socio-ecological systems to this mix we are in need of tools not only able to generate robust predictions, but also of being able to reconcile potentially conflicting goals, and provide clear recommendations. The ability of individual- or agent-based models (ABMs) to cope with spatio-temporal complexity and non-equilibrium dynamics is well documented (Uchmanski and Grimm, 1996). This together with the increasing awareness of how the whole system produces unique and combined emergent effects that are codetermined by the context and interactions with its environment (Hartvigsen et al., 1998; Corning, 2002), makes ABMs strong candidate tools for management and experimentation with complex systems from economic systems (Farmer and Foley, 2009) to in vivo systems such as the immune-response system (Forrest and Beauchemin, 2007).

The main advantage of agent-based models is their ability to represent 'real' non-equilibrium dynamics. This is a function of their methods of construction, essentially by representing real world objects and describing their interactions. This property allows complex behavior to arise from simple behavioral rules (e.g. Conway's Game of Life) that describe not only what the model object is but also how it goes about being. Thus the inherent dynamics of ABMs provide a way of implicitly handling the non-linearities and positive and negative feedback loops that constitute structural-stability related, i.e. developmentally important, features of complex living systems. Another key ABM attribute is its explicit handling of agent heterogeneity and informational asymmetry, in contrast to the need for simplifying assumptions which is a basic feature of existing analytic tools. In real systems these features are clearly important. In the present context this allows the specification of particular farming types and their interactions with differing species and their local environment, rather than treating these as homogenous variables.

In this paper we apply ALMaSS, the Animal Landscape and Man Simulation System (Topping et al., 2003), a comprehensive landscape-level agent-based simulation system, to the question of whether organic farming can benefit a range of animal species in the Danish agricultural landscape, and by how much. The ALMaSS system combines human behavior in terms of farm management with the behavior and ecology of six widely differing animal species and is capable of evaluating the interactions between these in different physical environments. Although this system stops short of simulating the self-reflexive system that would ensure as a result of including policy makers in the assessment, it does provide a platform to address the impacts of potential policy changes. The very real restriction if using this type of approach is that it can only be employed where the ecology and behavior of species is well understood and where the environments that the species are placed can be modelled in sufficient detail. Hence the limited range of species currently available.

This ABM approach also implicitly avoids issues of collinearity, for instance in habitat area and fragmentation drivers identified by (Smith et al., 2009), since these drivers are integrated by the model. This provides another management option, only possible with *in silico* complex systems, and that is to experimentally manipulate the system isolating individual factors. This has been done with ALMaSS previously to isolate components of skylark population responses to changes in pesticide taxation (Topping, 2005), and in this study by using farm management as a independent variable. This approach was used in this study to evaluate the impact of extensive/intensive organic and conventional farming types on a limited range of faunal species, and to place this in context of targeted management options.

2. Methods

2.1. The model system

ALMaSS was designed as a tool to provide answers to policy-level questions related to changing land-use or management and the resultant impacts on animal wildlife. The ALMaSS project is an open source project hosted on CCPForge (http://ccpforge.cse.rl.ac.uk), where program code can be downloaded. The ALMaSS program itself is a large system comprised of many interacting models and hence a detailed description cannot be provided here. The reader is therefore directed to the online documentation found at www.almass.dk. This documentation follows ODdox format (Topping et al., 2010b), combining model description with doxygen (van Heesch, 1997) code documentation. The animal models comprising ALMaSS have been tested using a pattern oriented approach (Grimm et al., 2005; Topping et al., 2010b) to maximize confidence in their structure and function. The models are quite detailed in their behavior and hence run times for ALMaSS can be long, usually measured in hours or even days. This is particularly the case for invertebrate model simulations which have been recorded as having up to 27 million concurrent agents.

2.1.1. ALMaSS – short overview

ALMaSS is comprised of two main components, the environment and its associated classes and the animal representations (classes). The environment interface is provided by the 'Landscape' class. This class contains a map of the landscape to be simulated together with individual landscape elements such as fields, hedges, roads and woodlands. Fields are a special case. Fields are linked in groups to form farms. These groups are typically based on ownership or management information from municipal or EU-farming subsidy sources. Each farm is an instance of the Farm class which simulates the detailed management of its fields, dependent upon its farm type, the weather, soil type, and past history of management. There is a degree of stochasticity in farmer decisions, and hence the result is a dynamic pattern of farm management across the landscape, with farmers of the same farm type, growing the same crops making similar but not identical decisions.

All vegetated landscape elements (crops and non-crops) undergo type-specific daily vegetation development based on weather and fertilizer inputs as drivers. Farm management events (e.g. harvest or plowing) directly interact with vegetation height and biomass, providing a dynamic picture of changing landscape conditions as a result of both environmental and anthropogenic processes and factors.

The second main ALMaSS component is the simulation of animals, represented by specific species classes all derived from a common base class. All animals are agents and are affected by environmental variables, vegetation structure, and by direct interaction with other agents or farm management. Each animal represents an individual of a particular species, with its own behavioral rules and interactions with its environment. Animals