



Biodiversity and Farming

A summary of research outputs from the Scottish Government's
"Environment – Land Use and Rural Stewardship" research programme



Introduction

The articles in this booklet are short summaries of a small part of the research undertaken by Scotland's Main Research Providers as part of the Environment – Land Use and Rural Stewardship research programme. It was funded by the Scottish Government's Rural and Environment Research and Analysis Directorate from 2006 to 2011.

The articles focus on the relationship between farming and biodiversity: what has happened to biodiversity in farming landscapes, how current policy might affect it and can we improve the way land is managed for biodiversity and other benefits.

The first article, *Modelling biodiversity in agricultural landscapes*, deals with the difficulty in developing agri-environment schemes and how an understanding of farmer behaviour is crucial in devising new ones. Recognising where farming practices have created areas of high biodiversity is important and the article on *Identifying and supporting High Nature Value farming systems* talks through the issues and the needs to focus support on these to prevent these systems and their associated biodiversity being lost. Such a HNV farming system is the focus of the third article, *Crofting and biodiversity on the Machair*, where long-term changes in this Priority Habitat are analysed.

The next article deals with a potential issue where managing for animal and human welfare may have detrimental impacts on biodiversity. *Farming sheep for tick control* shows that the use of sheep as 'tick mops' may work in certain circumstances, but in others the high sheep densities may lead to heather damage and eventual loss. Perhaps the terrestrial system we know least about is the soil, but the article on *Biodiversity in arable soil* shows how important this knowledge is and how our research is supporting the Scottish Soil Framework.

The final three articles deal with managing for multiple objectives. Such objectives include efficient farming to ensure food security and addressing the aims of the Scottish Biodiversity Strategy, but increasingly, other objectives are coming to the fore. Agricultural management can contribute to the aims of the Water Framework Directive and the article on *Managing riparian areas for multiple benefits* addresses how management can contribute to improving the ecological status of waters. As the draft Land Use Strategy identifies, management for soil carbon will be increasingly important and *Grassland extensification and biodiversity* and *Farmland management for multiple goals* both deal with the consequences of farming decisions on this ecosystem service.

I hope you will enjoy reading these articles and please get in touch with the authors if you would like more information or wish to discuss their research.

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Contents

Introduction	2
Modelling biodiversity in agricultural landscapes	4
Identifying and supporting High Nature Value farming systems	6
Crofting and biodiversity on the Machair	8
Farming sheep for tick control – implications for biodiversity	10
Biodiversity in arable soil	12
Grassland extensification and biodiversity	14
Managing riparian areas for multiple benefits	16
Farmland management for multiple goals: can we reach them all?	18

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Modelling biodiversity in agricultural landscapes

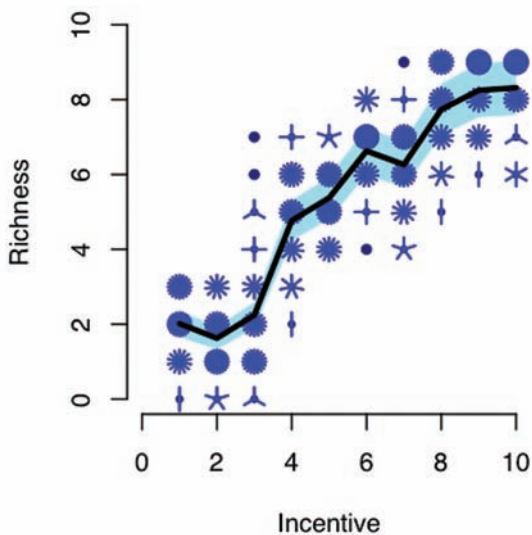


Background

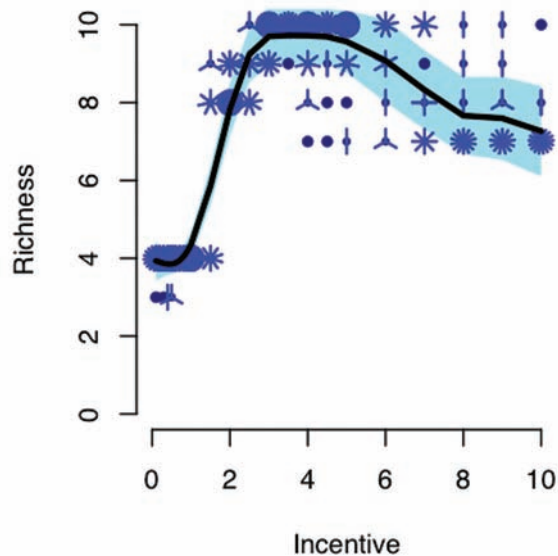
Some, particularly intensive, farming activities can prejudice biodiversity, but farming can also create new habitats for species. For example, spring-sown cereals provide both nesting grounds and winter food for species such as Reed Bunting, Corn Bunting, Linnet and Tree Sparrow. Farmers have a critical role to play in enhancing and maintaining Scotland's biodiversity as well as supplying the food we eat.

Agricultural incentive schemes continue to shift toward environmental actions and ecosystem

service provision. Even if food security concerns reverse this trend, incentive schemes still can be structured to encourage farmers to continue to care for species, habitats and landscapes. Experimenting with incentive schemes is costly, time-consuming and can cause confusion, whereas computer models allow the principles of an incentive scheme to be tested without interfering in the busy daily lives of farmers and administrators.



Scenario A



Scenario B

Approach

Traditional approaches to modelling human decision making have required modellers to make unrealistic assumptions about the ways people behave: they have access to all necessary information, they do so instantly, and they maximise profits. Farmers have a challenge in profit maximisation as commodity prices fluctuate over the growing season for the fuel, animal feed, fertilisers and pesticides they use, and for the goods they produce.

Recent advances in computing power mean it is feasible to avoid making such assumptions. We are using agent-based models to study the behaviour of systems involving many interacting farm businesses. They can adjust what they grow and how it is managed as prices, incentives and the climate change, allowing us to explore the effect a proposed incentive scheme has on their decisions in the context of other influences on their behaviour.

Biodiversity is represented by a series of local populations, more or less able to thrive in a land parcel according to its use, and connected by the ability of organisms to move from one land parcel to another in the landscape. Bringing spatially explicit biodiversity and agricultural decision making models together, we can explore the influence of incentive schemes on biodiversity.

Results

Using our high performance computing facility, we can conduct large numbers of simulations—more than 20,000—to explore scenarios of incentives, farm business characteristics and change in prices. Our results reveal the nonlinear relationship between increasing incentives and biodiversity return.

Increasing incentive does not consistently lead to an increase in biodiversity, and can even lead to biodiversity loss (Scenario B). This is because some farming activities are embedded within the ecosystem: if large incentives reduce these activities, biodiversity suffers, just as it does if incentives are too small and farmers must rely on fluctuating markets to generate all their income.

Our results also show the uncertainty inherent in these systems (e.g. the range of species richness outcomes for different runs of incentive 3 in Scenario A). In some cases, whether or not an incentive scheme successfully maintained biodiversity depended on the details of how the farmers responded.

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Identifying and supporting High Nature Value farming systems



Background

The High Nature Value (HNV) farming concept recognises that many European habitats and landscapes of high nature conservation value are intimately associated with certain low-intensity farming systems. The principles of the HNV concept are that:

- Market, agricultural policy and social pressures are increasingly making HNV farming systems economically unviable.
- Any resulting intensification or abandonment of such farming systems would adversely impact on the associated HNV.
- There is therefore a justifiable case to be made for directing additional financial support to these farming systems to help maintain the HNV.
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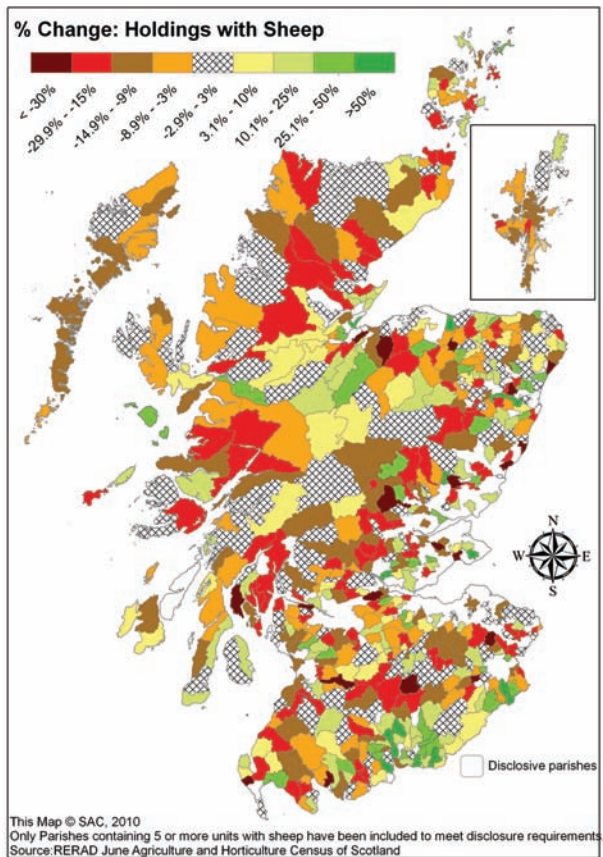
A large proportion of Scotland's farming systems, especially those on the islands and in the hills and uplands, are potentially of High Nature Value. We have been working with many partners to inform policy makers about the biodiversity importance of HNV farming systems and the issues facing them here in Scotland.

Approach

In 2009 we produced a report, *Farming's Retreat from the Hills*, which examined the changes in livestock numbers which have occurred since changes were made to the Common Agricultural Policy support payments in 2005. Additional research for Scottish Natural Heritage in 2010 investigated the likely impact on Scotland's biodiversity.

Results

The Scottish sheep flock fell by 12.2% between 2004–2009. Map 1 shows this decline varies across Scotland, but many parishes showed a fall in the number of sheep farmers (24% for Torosay in the south of Mull). Overall there was a large reduction in holdings with sheep in a band across Scotland from the Western Isles (-12%), through Skye and Lochalsh (-12%), Lochaber (-11.5%) Perth and Kinross (-14%) and into Stirling (-11.5%).

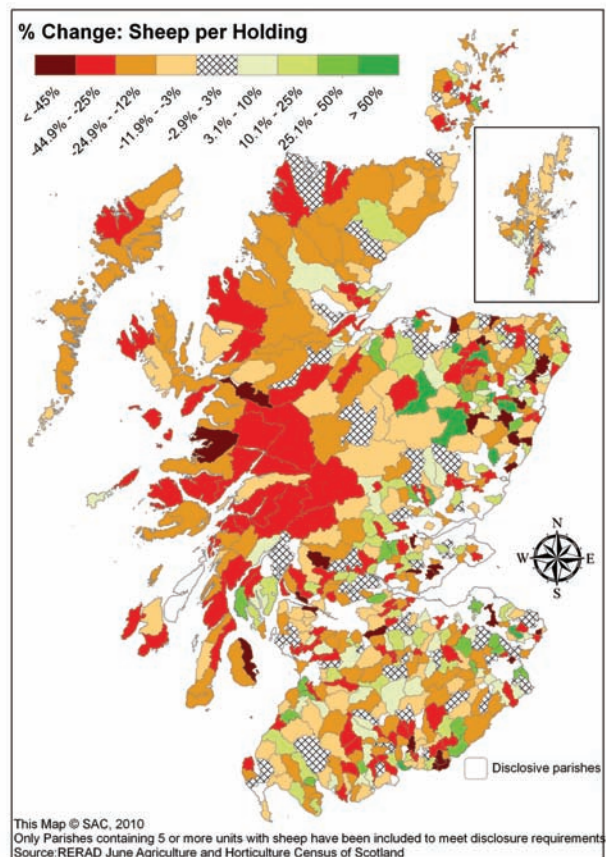


Map 1

Map 2 shows the percentage change in sheep numbers per holding at the parish level. It shows that sheep production appears to be extensifying, with many parishes seeing average flock sizes fall by over 25% since 2004 (all the red areas on the map). Hence, the overall decline has been driven by both farmers and crofters withdrawing from sheep production altogether and by others reducing the size of their flocks.

Conclusions

These marked changes in sheep numbers and grazing systems have led to fears that subsequent under-grazing might lead to changes in vegetation and the loss of particular habitats and thereby



Map 2

impact adversely on a large number of upland habitats and species of nature conservation concern.

Further debate is necessary to determine how best to manage and support Scotland's HNV farming systems for their biodiversity and social benefits. Research is ongoing for the Scottish Government, Scottish Natural Heritage and others to consider the extent of these systems, to identify different examples of HNV farming and evaluate the management regimes associated with them.

The outcomes from this research will help inform decisions on how best to use CAP funds in supporting Scottish HNV farming in the future.

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Crofting and biodiversity on the Machair



Background

Machair is a distinctive coastal grassland habitat. Only 25,000 ha exist world-wide, of which 70% is in Scotland.

Machair develops on calcareous sands deposited by onshore winds on exposed, western coasts, is comparatively plant species-rich and hosts a number of rare plant, invertebrate and bird species. These include the great yellow bumblebee, corncrakes, corn buntings, northern marsh orchid and frog orchid. It is a Priority Habitat within the UK Biodiversity Action Plan and included in Annex 1 of the EC Habitats Directive. The high nature value of Machair derives from its continued use for low-intensity agriculture and a land ownership structure which usually includes crofting tenants who often

manage the land communally within township units.

Approach

In 1976, as part of a Scotland-wide survey of sand dunes, much of the Machair was visited and the vegetation recorded. As this data had survived along with detailed maps of where vegetation sampling had been carried out (Fig. 1), we repeated the survey at five sites on South Uist, Benbecula and North Uist in 2009. In addition to assessing change in the vegetation we also interviewed crofters to assess how land use changes over the three decades between the surveys may have impacted vegetation change.

Results

Changes in crofting techniques

Interviews with the crofters revealed:

- A reduction in the number of people cultivating the Machair, though they often cultivate more individually than crofters would have done in the 1970s. This is backed up by a fall in survey points on arable land (Fig. 2).
- A general switch in livestock from cattle to sheep dominance.
- A general switch in fertilisers used from organic ones such as seaweed and manure to inorganic fertilisers, an increase in ploughing depth and in patches a replacement of hay and crops by silage cutting.

Associated changes in plant biodiversity

Analysis of the survey data from 1976 and 2009 revealed:

- Species richness of vegetation had remained similar across time.
- Species diversity had declined – due to an increase in dominance of some species (Fig. 3).
- Species characteristic of disturbed sites – such as arable and early fallows – had declined, along with the amount of arable cultivation.
- In contrast, some species typical of less disturbed habitats increased, these included Frog orchid and Northern Marsh-orchid.
- Salt tolerant species had increased – possibly due to salt spray from storm events.

Conclusions

Although overall species diversity has declined, changes in crofting management have had some positive and some negative impacts on plant biodiversity dependent on the ecology and habitat requirements of the individual species. Further survey and analysis is ongoing to assess habitat specific changes in biodiversity, as well as changes specific to townships or different islands which have seen different changes in land use since the 1970s.

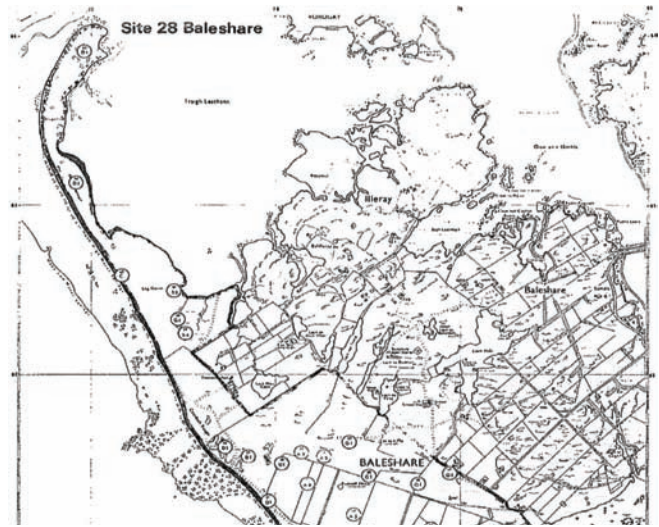


Fig. 1: Part of one of the original survey maps from the 1976 survey

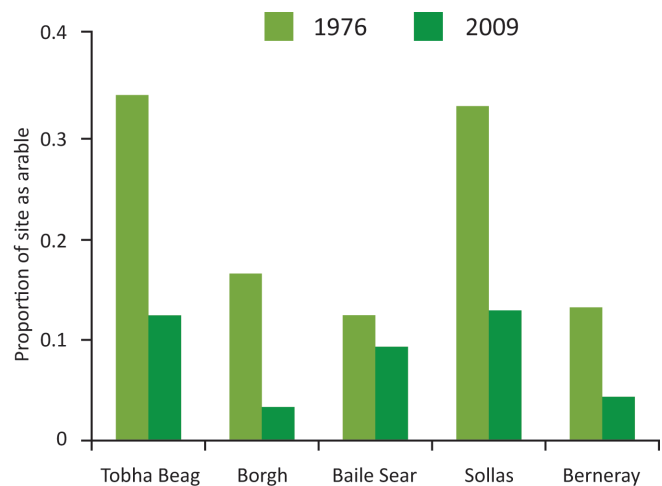


Fig. 2: A significant fall in the proportion of sampling sites under arable cultivation occurred between the two surveys

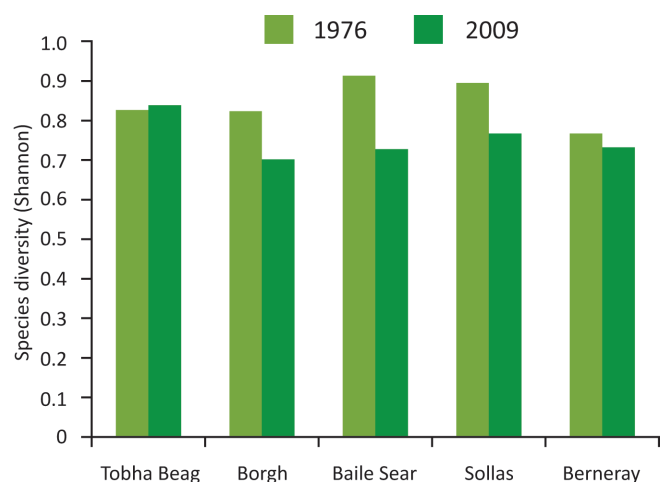


Fig. 3: A significant fall in diversity occurred at some of the five sites reflecting an increase in dominance by a few species

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Farming sheep for tick control – implications for biodiversity



Background

Ticks and tick-borne diseases, such as louping-ill and Lyme disease, are currently increasing in Scotland and have important implications for human and animal health and welfare. There are also clear biodiversity implications of these diseases, not only because ticks and tick-borne pathogens directly affect certain species (e.g. louping-ill virus can kill red grouse and ptarmigan), but also, and perhaps primarily, as a result of human attempts to control ticks (e.g. by culling keystone species such as mountain hares and deer).

In an attempt to control ticks and tick-borne diseases, land managers in some areas are now adding sheep flocks and treating them frequently

(up to every six weeks) with anti-parasite dips or pour-ons. The aim is to kill any ticks trying to attach to the treated sheep, thereby eventually reducing the tick population in the environment.

Approach

We used mathematical models to (i) *test the effectiveness of using treated sheep for tick control* and (ii) *predict the effect of these management methods on biodiversity*, by examining scenarios of different sheep flock sizes and densities of wild hosts. Models were parameterised using field data, such as tick counts on sheep and deer.

Results

- The models predicted that treating 50 sheep km^{-2} with acaricide that kills 100% of the ticks (i.e. 100% efficacy) could be effective at reducing ticks in the environment only when deer densities are very low (e.g. less than 7 km^{-2}) (Fig. 1).
- This implies that, if sheep are to be managed in a way that successfully controls ticks, deer densities should be kept at very low levels, because deer are important tick hosts.
- However, reducing densities of keystone species such as large herbivores can have important impacts (either positive or negative, depending on grazing levels) on wider biodiversity, such as ground vegetation composition, invertebrates, birds and small mammal populations.
- The models also predicted that treating sheep will control tick populations in the environment only at high densities of treated sheep (Fig. 2). Again, there are well-studied biodiversity implications of livestock grazing, such as heather being replaced with grass when more than 30% of each year's heather growth is browsed.
- The models also predicted, unsurprisingly, that treating sheep would be effective at controlling ticks only with very high efficacy of the dip/pour-on, which would require frequent applications and high doses to achieve.
- The implications of such frequent application of dips and pour-ons (which are toxic to a range of invertebrates) to biodiversity, to sheep welfare and to human health are not known and would be a useful area for future research.

Conclusions

Our models predicted that frequent treatment of sheep could effectively reduce ticks in the environment when there are (i) very few wild tick hosts such as deer, (ii) high densities of treated sheep added, (iii) high efficacy levels of dips and pour-ons. Importantly, a systems approach is now needed to assess the overall costs of treatment against the benefits of controlling ticks. Further

work is also needed to determine how the exact values of deer, sheep and ticks predicted by the model will vary according to local situation such as habitat and climate.

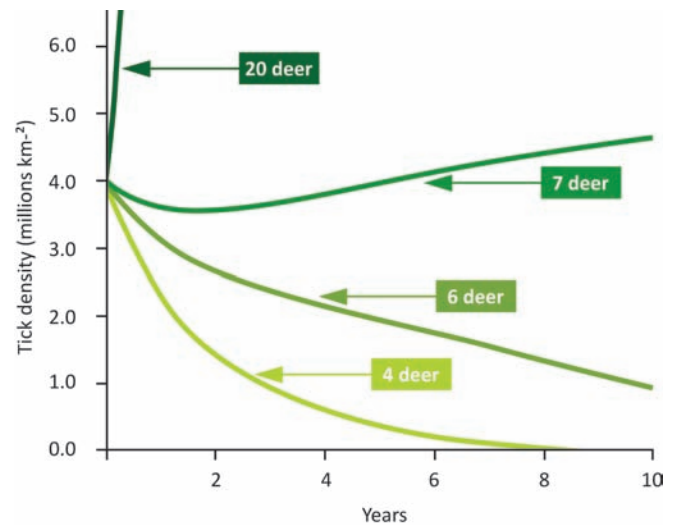


Fig. 1: The effect of different deer densities (km^{-2}) on the effectiveness of treating 50 sheep km^{-2} with 100% efficacious acaricide

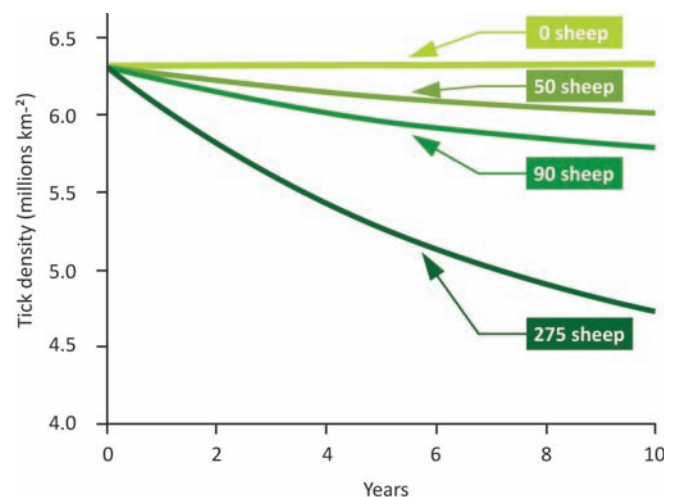


Fig. 2: The effectiveness of treating different sheep densities (km^{-2}) with 100% efficacious acaricide in the presence of 6 deer km^{-2}

Further reading:

This work was carried out in collaboration with the University of Stirling and was part funded by Natural Environmental Research Council. Porter, R., Gilbert, L., & Norman, R. (2010) Controlling tick borne diseases through domestic animal management: a theoretical approach. *Theoretical Ecology* (published online 20 May 2010, DOI: 10.1007/s12080-010-0080-2).

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Biodiversity in arable soil

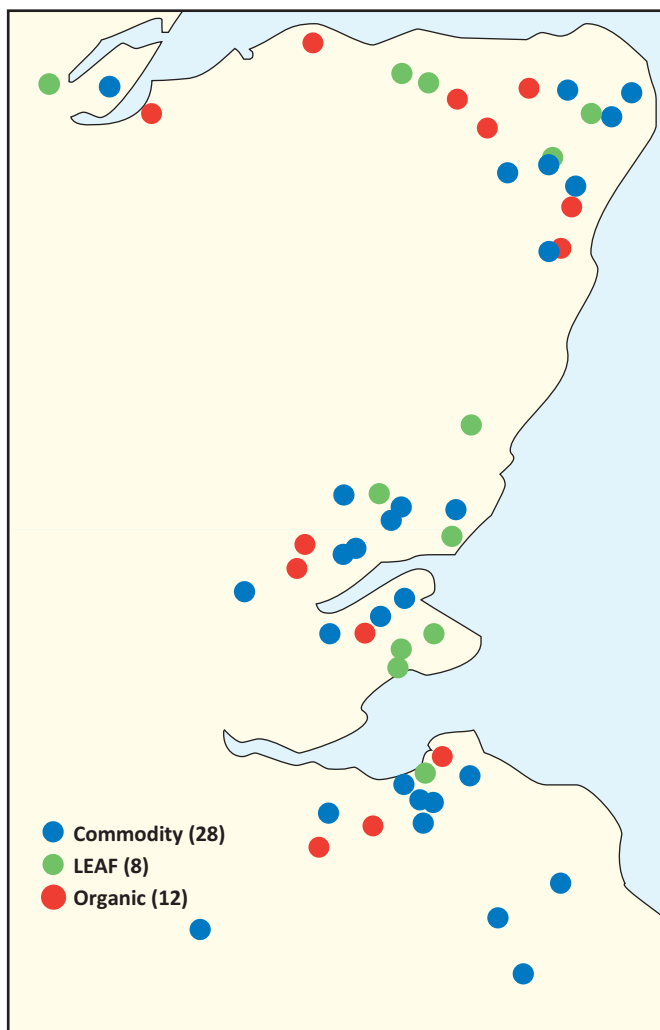
Background

Significant biodiversity exists in the soil underfoot - it is a product of a highly complex environment with many gradients and a convoluted structure of pores. This results in an extremely diverse soil biota, but it also makes it difficult to isolate organisms from their natural environment. This combination of circumstances has resulted in a relatively poor understanding of soil functionality, but it is essential to change this as we rely on the soil for many ecosystem processes such as nutrient cycling, erosion resistance and pollution attenuation as well as continued food production. Despite the high resilience of soil systems to the stresses imposed by arable farming, there are

many examples of agricultural collapse, with many ascribable to poor soil management. These events tend to occur when critical thresholds are exceeded resulting in loss of fertility or severe erosion. Recent research has been developing a wide range of techniques to further our understanding of soil function and ecology.

Scotland-wide patterns of arable soil biodiversity

An extensive farm survey of arable biodiversity was carried out across the major arable areas and farming approaches prevalent in Scotland. A wide variety of measures of above and below



ground diversity and function were taken to assess the current state of the Scottish arable system. Above-ground biodiversity (weeds and invertebrates) showed significant responses to farm type (organic, integrated and conventional) and, to a lesser extent, region (north-south). Patterns in measures of below-ground bacterial community structure and functional resilience showed that geographic region had a far greater

controlling effect than farming type, in contrast to the above-ground measures.

Soil amendments

One way of improving arable soil structure is with amendments of bulky organic fertilisers such as urban green waste compost and cattle slurry. This also helps with disposal of such materials and has the potential to lock up carbon in the soil. Experimental work has been investigating the resilience of the soil system to these applications. For instance, the activity and community structure of nitrogen cycling organisms is affected by high levels of amendment but that the perturbation is short lived with both microbial structure and function returning to control levels by the end of a crop cycle.

Developing functional indicators

To understand how management is impacting soil quality and function we need to develop appropriate indicators. A recent DEFRA funded study provided a ranking of a number of soil quality indicators. One given a high priority was nematode community analysis as this keystone group spans many trophic levels in the soil food web. However, it is a tool with a heavy reliance on time consuming morphological methods for identification. To address this we have developed a high throughput molecular methodology for nematode identification, enabling the rapid assessment of soil health.

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Grassland extensification and biodiversity



Background

In Scotland, improved grassland covers around 900,000 ha (11.2%) of the country. Past agricultural improvement to increase livestock production was associated with large reductions in biodiversity due to increased fertiliser use as well as higher stocking densities. Changing agricultural support mechanisms may offer the opportunity to redress these losses through the extensification of grassland management.

Approach

The impacts of changing the management of intensively managed pastures were examined

using two long-term (16 year) experiments at Hartwood in Lanarkshire and Sourhope in the Borders. They compared the impacts of continuing intensive pasture management for sheep with a range of three less intensive management options. Swards in the intensive treatment were kept at a height of 4cm by adjusting the number of sheep present. The other three had their fertiliser use stopped and had three different levels of grazing intensity: one kept at 4cm, one at 8cm and one left ungrazed. Animal productivity, plant species richness and composition, and soil characteristics were all monitored regularly.

Results

- Extensive grazing led to slow but continual changes in plant species composition, with some increase in diversity compared to intensive grazing (Fig. 1).

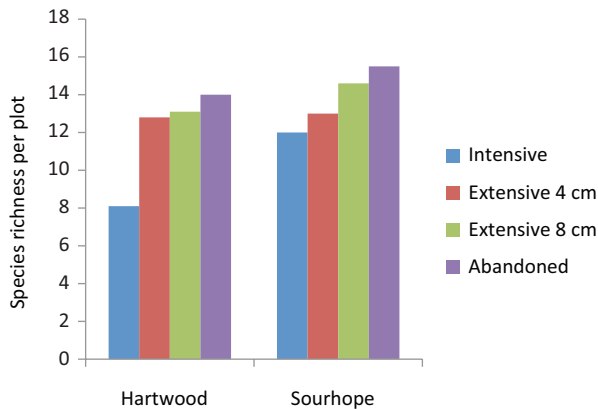


Fig. 1. Impacts of reducing grazing on species richness. Data are averaged across the last five years of the experiment.

- Abandonment led to rapid changes in composition followed by stabilisation, as there were no woody species nearby to invade and lead to further changes.
- Agricultural productivity did not decline significantly with time in any of the treatments. Also, the extensively managed treatments produced ewes in better condition and larger lambs. At the drier of the two sites (Sourhope, 18km SE of Kelso) extensive grazing was better than intensive grazing at buffering the impacts on productivity of year-to-year variations in the weather.
- The extensively managed treatments in these experiments did not show any substantial increase in undesirable weeds that could compromise sward productivity. However, the abandoned pastures did; so if management had to be reversed in the future then there could be a problem dealing with pasture weeds (Photo 1).
- Sites differed in how the soils responded to the change in management. At the drier site, the extensively grazed treatments showed increased soil carbon levels, whilst at the wetter site (Hartwood – 27km E of Glasgow) they did not. Removing grazing altogether did not increase soil carbon, as much of the plant material remained above ground as litter.

Conclusions

Biodiversity gains from extensification within productive landscapes may be a slow process.

This is partly a result of the inherent slow dynamics of grassland systems under grazing management and partly a result of the lack of suitable species in highly managed landscapes that could invade and spread. Substantial increases in biodiversity would require intensive restoration management.

At the two sites studied, extensive management appeared to be sustainable in the long-term. Where a farmer has a choice between reducing management across a number of fields or maintaining intensive management on some and abandoning others, the results of this study clearly show the benefits of the former strategy. This results in some biodiversity gains, improved individual animal performance and few weed problems. However, the picture becomes more complicated if managing for soil carbon becomes a major objective.

Further reading:

Marriott, C.A. et al. (2009) Long-term impacts of extensive grazing and abandonment on the species composition, richness, diversity and productivity of agricultural grassland. *Agriculture Ecosystems and Environment*, 134, 190–200.

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Photo 1



Managing riparian areas for multiple benefits



Background

Riparian describes the land immediately adjacent to streams, rivers and lochs. Healthy riparian areas have the potential to provide a wide range of benefits to society and nature, increasingly being referred to as ecosystem services. These include increased habitats to aid in the conservation of biodiversity, nutrient/pollutant trapping, shading of waters to improve fish habitat, water and carbon storage, biomass production and cultural benefits. Pollution, loss of habitat and intensive agricultural activities have all acted to degrade riparian areas with a subsequent loss of their functions and benefits. Establishing vegetated buffer strips

along these riparian margins has been promoted as a principal means of improving water quality by controlling diffuse pollution. For instance, a 2 metre buffer strip between watercourses and cultivated land has become among the statutory requirements in Scottish diffuse pollution regulation. However, the degree to which these are successful for pollution control remains uncertain. We have investigated whether buffer strips, after several years placement, have been effective in providing multiple benefits for diffuse pollution control and habitat improvement and restoration.

Approach

We have been carrying out work in the River Dee and Ugie catchments (Aberdeenshire) and Lunan (Angus) to determine the effectiveness of buffer strips as part of wider agricultural best management practices. We have specific programmes assessing cycling of the key nutrient phosphorus, and ground beetles (Carabids) and plants as ecological indicators.



Results

Buffer development increased the rates of phosphorus cycling and soil phosphorus solubility leading to enhanced leaching of this nutrient to watercourses. In some circumstances, buffer strips were found to be effective at trapping sediment particles. However, this function diminished at high flows. These results suggest that in the longer term, vegetation management, such as cutting or grazing, may be required so that the buffers can continue to provide nutrient and sediment storage.

Establishing buffer strips resulted in significant changes in terms of soil and vegetation characteristics, and carabid assemblages. Changes were more apparent, and possibly driven by, an increasing tree canopy layer. Carabids were more responsive than plants to changes in riparian conditions. Buffers failed to attract the species more typical of reference conditions and associated with stable, undisturbed, ungrazed and/or wooded sites. In the absence of any

intervention, these buffers became increasingly homogenous over time with a decline in species richness.

Conclusion

Our results show that narrow, unmanaged buffer strips do not maximise multiple benefits. Ongoing interdisciplinary research in the catchment of Rescobie Loch in eastern Scotland is investigating how riparian buffers can be better designed and managed to provide a wider range of environmental benefits. This includes integrating biophysical estimates of phosphorus losses from land, the abatement of this loss by the riparian buffer strips, and the potential biodiversity benefits of riparian management with the economic implications of buffer strip placement.

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Farmland management for multiple goals: can we reach them all?



Background

The impacts of agricultural improvement have been seen as a trade-off between production and biodiversity. However, land has to provide many other 'services' for humankind: services are the benefits that people and society gain from an ecosystem and can range from climate regulation to aesthetics. It has been a general assumption that preserving biodiversity maximises the other services delivered; however, there is no reason for this to hold all the time. It is clearly the case that intensive farming, where 'provisioning services' are maximised, is largely incompatible with biodiversity conservation. There may be similar choices to be made between biodiversity

and other ecosystem services, and hence the management of multi-functional landscapes becomes a matter of trade-offs and choices.

Approach

We studied the potential trade-offs between biodiversity and carbon sequestration using a traditional crofting area as an example system (many contrasting land uses were available in a small area). The study compared the possible consequences of abandoning traditional hay cropping and its replacement by silage making, winter grazing, conversion to pasture or the complete abandonment of management.

Biodiversity assessments of ground beetles (Carabidae), bees and vascular plants were made on these land use types during the summer of 2007 on the National Trust for Scotland’s Balmacara Estate using standard methods. Three indicators of carbon dynamics were assessed; above-ground net primary production, litter decomposition rate and litter quality.

Results

Changing from traditional hay cropping to any form of more intensive grazing or silage production resulted in a drop in biodiversity measured in terms of species richness of plants, beetles, and bees (Table 1). Only silage had a higher productivity than the meadows. There were no differences in the decomposition rate of standard litter between sites. Pasture and the abandoned sites had significantly poorer litter quality than the other land uses. This indicates that managing for soil carbon would identify silage, pasture or abandonment as suitable replacement management for hay cutting. However, this would be at the expense of species richness in all three surveyed groups for most of the transitions.

	Carbon				Diversity		
	Productivity	Litter quality	Litter decomposition	Overall soil carbon	Plants	Bees	Beetles
Silage	↑	=	=	↑	↓	↓	↑
Winter grazed	=	=	=	=	↓	=	=
Pasture	=	↓	=	↑	↓	↓↓	↓↓
Abandoned	=	↓	=	↑	↓↓	↓↓	↓

Table 1: A summary of changes in selected measures of carbon dynamics, overall prediction for carbon sequestration by soil and species richness on four alternative land uses relative to traditional hay meadows

Conclusions

In some situations, such as filling in grips (drainage ditches) on moorland, there are clear benefits to biodiversity and to ecosystem services – soil carbon should increase as the

moorland becomes wetter. In contrast, planting blanket bog with forestry will have negative effects on both biodiversity and soil carbon stocks. However, there are other scenarios, such as those tested here, where there appears to be no win-win situation that maximises a ‘key’ service and also maximises biodiversity.

Largely, analysing trade-offs has focussed on biodiversity and the production of food, fibre and wood. Recently, managing land to ensure the regulation of water quality has become more common and studies are ongoing on the impact on biodiversity. As more focus is put on managing for other ecosystem services, such as for soil carbon sequestration, then the analysis of these trade-offs becomes more complex. This is because multiple goals have to be taken into account, as have the wishes of multiple stakeholders. New methods need to be developed to analyse these trade-offs and to alter management to optimise these multiple goals.

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This booklet summarises some of the key findings concerning the relationship between farming and biodiversity that have arisen from the Scottish Government Rural and Environment Research and Analysis Directorate's funded research programme "Environment – Land Use and Rural Stewardship".

The research programme involved researchers from:

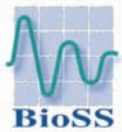
Biomathematics and Statistics Scotland

Macaulay Land Use Research Institute

Royal Botanic Garden Edinburgh

Scottish Agricultural College

Scottish Crop Research Institute



Royal
Botanic Garden
Edinburgh



Further information can be found at
<http://www.programme3.net/>

<http://www.knowledgescotland.org/>



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