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Iain Fraser
Kent Business School

Carly Stevens
The Open University

University of Kent

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Iain Fraser*
Kent Business School
University of Kent

and

Carly Stevens
Department of Biological Sciences
The Open University

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*** Address for Corresponding author:**
Applied Economics and Business Management
Kent Business School
University of Kent
Wye Campus
Wye
Ashford
Kent, TN25 5AH
UK

Tel: +44 (0)207 59 42623
Fax: +44 (0)207 59 42823
email: **i.m.fraser@kent.ac.uk**

Nitrogen Deposition and Loss of Biological Diversity: Agricultural Land Retirement as a Policy Response

Abstract

Current levels of nitrogen deposition, especially ammonia, seriously impact ecosystems biological diversity. However, land use policy maintaining and enhancing key ecosystems in the UK does not explicitly take account of this pollution in terms of onsite management prescriptions. In this paper we examine the economic potential of agricultural land retirement to reduce localised nitrogen deposition. Employing a case study that combines nitrogen deposition modelling and agricultural land use change, we evaluate the reduction in nitrogen deposition necessary to reverse the loss of floral diversity. Our results indicate that agricultural land retirement is a potentially credible policy option that can complement existing policy measures.

Key Words: Nitrogen deposition, Biological Diversity, Agricultural Land Retirement.

1. Introduction

The earth's atmosphere is 80 percent nitrogen which in its reduced and oxidised forms is an essential nutrient for plants as well as a pollutant. The main nitrogenous air pollutants include nitrogen dioxide, nitric oxide and ammonia. The contribution of ammonia to total nitrogen deposition in the UK is very significant, with the majority originating from local sources like agriculture, especially livestock (Sutton et al., 1998 and Schou et al., 2006). Cattle make the largest contribution followed by sheep, poultry and pigs (DEFRA, 2004). The importance of nitrogen deposition is recognised in the UNECE Protocol to Abate Acidification, Eutrophication and Ground-Level Ozone (Gothenburg Protocol) and the National Emission Ceilings Directive (2001/91/EC). The UK has a legally binding target of 297 kilotonnes of ammonia per annum by 2010. In addition, the EU Integrated Pollution, Prevention and Control Directive (IPPC), provides a common framework for control of ammonia from sources such as intensive pig and poultry operations. The control of nitrogen and ammonia is also covered by the Common Agricultural Policy (CAP) via the Single Farm Payment (SFP) and Cross Compliance. To meet Cross Compliance requirements, farmers implement Good Agricultural and Environmental Conditions (GAEC) which provide advice on how to minimise emissions.

The use of pollution targets in the EU has lead policy efforts to focus on least cost outcomes, focussing on high source activities (e.g., intensive livestock production).

However, many fragile and valuable ecosystems are at danger from ammonia pollution in the UK (Woodin and Farmer, 1993). These sites experience relatively low levels of ammonia pollution from agricultural non-point low source activities and are not the subject of current policy efforts (e.g., UNECE, 1999, and Stevens et al. 2004). The extent of the air pollution threat to fragile rural areas, especially upland ecosystems has been brought into focus by the Department for Environment, Food and Rural Affairs (DEFRA) announced Public Service Agreements (PSAs). In the case of Sites of Special Scientific Interest (SSSIs) in England's at least 95 percent need to be in Favourable Condition or Unfavourable Recovering Condition by 2010. However, the impact of air pollution, particularly nitrogen deposition and ammonia, on SSSIs is high and the likelihood of the PSA being achieved is zero (CJC Consulting, 2004). Furthermore, Agri-Environmental Policy (AEP) such as Environmentally Sensitive Areas (ESAs) and Countryside Stewardship (CS)[1] is currently designed, implemented and evaluated with a lack of recognition of the impact of air pollution.

According to economic theory the optimal level of environmental pollution control occurs when the marginal cost of abatement (control) equals the marginal damage. In the case of air pollution emanating from agriculture and the acidification of sensitive environments, for this condition to be satisfied requires that the off-site marginal damage of the ammonia pollution be equated to marginal costs of abatement on the farm. Land use policy such as AEP could be redesigned in such a way that it simultaneously considers land use on the farm and the impacts on adjacent areas of high environmental value. That is, a reduction in emissions where difference between benefits and costs are maximised.

In this paper we examine the issue of land use and localised air pollution using a hypothetical case study of livestock activity in close spatial proximity to an upland acid grassland designated as a SSSI. Although hypothetical, all data and model estimates are for real land use activities and practices for livestock farming on Exmoor in South West England. The policy option we consider is the required level

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[1] All existing AEP is now collected together under the new Environmental Stewardship (ES) scheme.

of agricultural land retirement[2] for pasture based livestock activities necessary to reduce the localised air pollution by a specified amount. By agricultural land retirement we mean that the land is no longer actively used for income generation from agriculture. The level of land retirement estimated in our case study is that required to reduce nitrogen deposition at the SSSI such that we observe an increase of one species. The dose-response relationship in context is given by Stevens et al. (2004), who empirically demonstrated a reduction of one species for every additional 2.5 kg of nitrogen per hectare per annum deposited. The dose-response relationship provides us with an explicit damage function that can be used to link land use and environmental damage. Importantly, there are indications that ecosystems can recover from short-term nitrogen additions both in terms of vegetation species composition and soil biogeochemistry. Indeed, Stevens et al., identified high species richness in areas of the UK where although deposition is currently low in comparison with the rest of the UK the cumulative deposition since 1950 is high (Fowler, 2004).[3]

The spatial link between land use at one site and the reduce nitrogen deposition at a SSSI is made using the SCAIL (Simple Calculation of Ammonia Impact Limits) model (Theobald and Sutton, 2002). The SCAIL model produces an estimate of ammonia deposition at a target site downwind of a source. To make this calculation the model requires information describing the agricultural activity at source, target site distance from source, wind speed and probability of wind direction. To date the SCAIL model has been used in a number of studies (e.g., Angus et al., 2005, and Wolseley et al., 2006) to examine various policy options designed to reduce ammonia air pollution.

Overall, this paper makes a number of contributions to the literature. First, we examine how to translate high profile science (i.e., Stevens et al., 2004) into a meaningful policy response. To do this requires not only a clear understanding of the science and the scientific method, but how this can be integrated with basic principles of policy design. Second, this study highlights difficulties economists face evaluating policy with a biological diversity objective. Research typically focuses on biodiversity

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[2] For a review of agricultural land retirement and policy slippage see Fraser and Waschik (2005).

[3] We assume that the biological response of reduced nitrogen deposition will be beneficial although specific ecosystem responses are uncertain. See Schlapfer et al. (2005) for a discussion.

in terms of individual species or habitats as opposed to diversity of species within an ecosystem when estimating Willingness-to-Pay (WTP) Third, agricultural land retirement and air pollutant buffer zones (e.g., Schou et al., 2006), are found to be closely related land management tools. Our analysis reveals the potential benefits of this type of policy mechanism as a means to deal with the effects of air pollution on sites of high conservation value, such as SSSIs. Fourth, the majority of research on nitrogen deposition has been conducted at a very aggregate scale. Our case study adds to a small literature that has examined this problem at the farm scale.

The structure of this paper is as follows. In Section 2 we briefly review the antecedent economics literature that has examined ammonia deposition. In Section 3 we present our hypothetical case study. The case study combines scientific and economic information allowing us to examine the benefit-cost implications of agricultural land retirement as a means to reverse biological diversity decline as a result of nitrogen deposition. In Section 4 we consider various extensions and limitations of the case study and what they imply for policy design as well as interdisciplinary research. In Section 5 we discuss the implications of our case study and the wider implications for rural land use policy makers.

2. Economics of Nitrogen Deposition

2.1. Cost Effectiveness

Policy has been concerned with achieving targets at least cost and not necessarily maximising net benefits. The emphasis in policy design is reflected in the economics literature to date (e.g., Klaassen, 1994, Cowell and ApSimon, 1998, Brink et al., 2004, Theobald., et al, 2004, Angus et al., 2005, Webb et al., 2005 and Schou et al., 2006). Most research considers how alternative strategies to reduce sources of nitrogen and/or ammonia impact on the costs of economic activity. For example, Webb et al., using a mass-flow model, estimated the relative cost effectiveness of 34 measures of agricultural waste management options to reduce ammonia. Other studies have taken a microeconomic approach to policy analysis. Angus et al. (2005) combined the SCAIL model with a linear programming model to examine how various abatement technologies can be employed on an intensive poultry farm to reduce the impact of ammonia on a nearby SSSI. They found that the necessary reduction in nitrogen deposition at the SSSI to ensure the desired environmental condition will not be achieved by existing legislation. Angus et al. concluded that the livestock activity will either need to be reduced below its current level of intensity of activity or be sited further away from the nature reserve.[4] This is equivalent to introducing buffer zones which have been examined in detail by Schou et al. (2006). Schou et al. consider alternative buffer zone policies in terms of cost effectiveness using farm level data and combined with a local-scale deposition model that is then scaled up to the national level. They found that increasing the necessary area of buffer zones significantly adds to the cost of policy implementation and that livestock activities may relocate to other areas reducing the overall benefits in air pollution.

Finally, the issue of pollution control has also considered the interdependence that exists in agricultural production between various pollutants. For example, Brink et al. (2004) consider several policies simultaneously to deal with ammonia, nitrous oxide and methane emanating from agricultural activities. They show that certain policy options to deal with ammonia can give rise to an increase in nitrous oxide emissions. Theobald et al. (2004) considered ammonia, nitrate leaching and nitrous oxide trade-offs for restrictions on pasture grazing. They found that reductions in pasture grazing by increased animal housing lead to reduced nitrous oxide emissions, but increased quantities of manure which an importance source of ammonia and methane emissions. Acknowledging these interdependencies may alter the potential benefits associated with any one policy.

2.2. Benefit Estimation

The non-market benefits from reduced air pollution have been examined and estimated using stated preference techniques such as Contingent Valuation (CV). Although ammonia has been covered in this research the broader research context has been to do with reductions in acid rain. For example, Macmillan et al. (1996) consider acidification of the Scottish Highlands and non-market values from reductions in acid damage. They estimated a total (average per household) annual WTP per annum for

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[4] The position of intensive livestock activities at greater distance from important conservation sites does not reduce the quantum of pollution entering the atmosphere, the current focus of policy efforts.

low damage of £484 million (£247) and for high damage £688 million (£351) for the Scottish population. In Holland Ruijgrok (2004) employed CV to examine the use and non-use benefits of increased nature quality. The results indicated total annual benefits from non-use values to be €207 million (€30 per household). The magnitude of the non-market benefit estimates is relatively large and more than comparable to the costs estimates for control of ammonia. Webb et al. (2005) estimates that for the UK to reduce ammonia emissions to achieve its Gothenburg Protocol targets it will cost £45 million per annum, a tenth of the Macmillan et al. estimates.

3. Case Study Data

3.1. Case Study Location

We focus on Exmoor National Park in south west England. Agriculture in this area is dominated by pasture based livestock activity. The impact of air pollution in this area is explicitly acknowledged in the 2001 Exmoor Biodiversity Action Plan (Exmoor National Park Authority, 2001). Our case study considers an SSSI within Exmoor National Park for which we have detailed environmental data (Stevens et al., 2004). This site is an area of acid grassland dominated by fine leaved grasses (e.g. *Festuca spp.*, *Agrostis capillaris*), low growing shrubs (heather and bilberry), mosses and several other species typical of upland acid grasslands. The SSSI is currently in unfavourable recovering condition due to the condition of the heathland. Designated as a Special Area of Conservation (SCA) under the EC Habitat Directive there is a legal obligation to maintain or restore the site to favourable condition. The site is at 350m altitude and is mainly grazed by deer at a low intensity. It has an average species richness of 11.4 species per 2x2m quadrat (Stevens et al., 2004).

To characterise farming activity immediately adjacent to our SSSI we employ several data sources. Lobley et al. (2004) provide a detailed analysis of the current state of farming in the region and current trends in land use activity. Drawing on this report and the annual Farm Business Survey for south west England and Exmoor in particular, we can examine how representative livestock farming activity in this region would be affected by the necessary changes in land use to bring about the recovery of one species as a result of reduce localised nitrogen deposition.[5]

3.2. Dose-Response Relationship

Our dose-response relationship is taken from Stevens et al. (2004). To use this relationship in our research we need to understand their data collection method. Sixty eight one hectare grasslands sites belonging to the same vegetation community (upland acid grassland) were randomly selected throughout the UK. Atmospheric nitrogen deposition ranged from 6 to 36 kgs of nitrogen per hectare per year. For each site five randomly placed 2x2 metre quadrants yielded measures of species richness. Based on these measures a negative linear relationship between species richness and nitrogen was derived showing that for every 2.5 kgs of nitrogen deposited per hectare a reduction in one species. Importantly the sampling design defines what is meant by species loss/recovery. Specifically, the recovery of a particular species at a given site in one of the five randomly placed quadrants requires that species to have been absent from the quadrats previously.

3.3. Land Use-Deposition Relationship

To assess how much agricultural land retirement is necessary to yield the necessary reduction in air pollution from localised sources we employ the SCAIL model (Theobald and Sutton, 2002). The model estimates source strengths by employing an inversion of Gaussian plume equations based on measured concentrations. SCAIL considers the source strength in terms of existing land use, distance from the source and wind speed and direction probabilities in calculating a broad indication of the amount of ammonia deposition from a given source on a specific sink area. In this case study agricultural pasture based grazing was taken as the source and the SSSI the sink.[6]

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[5] Full details of the current and previous Farm Business Survey for the south west of England can be obtained at the following web site; http://www.ex.ac.uk/crr/defra/fbs/fbs.htm.

[6] Although the sink in the SCAIL model is a single hectare there are additional benefits from nitrogen reduction on adjacent parcels of land.

In our analysis we assume a level of nitrogen fertiliser application of 125 kg per hectare for all pasture. This is the maximum allowed under the ESA Tier 1 conditions in the case study area.[7] Based on known scientific data we can estimate that fertiliser activity yields 1.6 percent of ammonia spread as inorganic fertiliser to grassland is emitted to the atmosphere giving 2 kg nitrogen per hectare per annum. Grazing intensity for a representative beef livestock enterprise was estimated at 2.5 cows per hectare (FBS various) on intensively grazed permanent pasture. Following Misselbrook et al. (2000) we estimate an annual emission of ammonia per cow, assuming animals are kept in the field year round, as 6.17 kg.[8] Taking livestock activity and fertiliser together this gives a total emissions' source strength of 17.42 kg of nitrogen per hectare per annum.

Employing the SCAIL model and assuming that the beef enterprise is down wind, we estimated at 100m intervals, from 100m up to a maximum of 1 km the resulting level of nitrogen deposition at the sink (the SSSI). This range of distance from source is supported by a growing body of scientific evidence in the literature (Schou et al., 2006). Using these estimates we calculated the number of hectares of agricultural land to be taken out of production to achieve the required reduction in nitrogen deposition at the SSSI. To do this we made various working assumptions including the arrangement of source fields and the prevailing direction of the wind. We have assumed a triangular arrangement with a few fields close to the SSSI and more further away, as shown in Figure 1.

{Approximate Position of Figure 1}

This field pattern is conservative because we have only removed land from production in the direction of the prevailing wind. Clearly, the greater the number of source hectares close to the SSSI the fewer the number of hectares of agricultural land that will need to be retired conditional on the probability of the prevailing wind. We also note that the triangular arrangement we considered here is different to the type of buffer zone typically examined in the literature (e.g., Schou et al., 2006). However, given that we are concerned with reducing deposition by a given amount we would argue that retiring land in a pattern that takes account of the probability of the prevailing wind direction is a reasonable assumption. An overall summary of the

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[7] For more details see; http://www.defra.gov.uk/erdp/schemes/esas/stage3/exmoor.htm

[8] We assume no livestock shedding activity, so no livestock waste management is required.

results of the SCAIL model conditional on the field configuration yielding the required number of hectares to be retired are reported in Table 1.

{Approximate Position of Table 1}

For our given arrangement of source sites we have estimated that it will require approximately 200 hectares of agricultural land to be retired for the given deposition level of nitrogen to be reduced by 2.5 kg per hectare per annum. Sensitivity analysis around the necessary reduction in nitrogen and the resulting level of land retirement is revealing. From Stevens et al. (2004) the 95 percent confidence interval for the reduction in nitrogen ranges from 2 to 3.1 kg per hectare per annum. These estimates yield significantly different quantities of land to be retired. For the lower bound estimate and our given pattern of land retirement we need only retire 100 hectares, whereas for the upper bound estimate we require in excess of 300 hectares. The difference in the required level of land retirement will clearly have major implications if we scale up our analysis to the regional or national level.

3.4. Farm Income Loss

To assess the impact on farm incomes we consider data from the south west Farm Business Survey for 2002/03. The survey splits its results into various farm types. Given the location of our SSSI we assume that the category, Hill Farms that run cattle and sheep that are over 120 hectares in size, best represent farming activity as considered in the case study. For this type of farm the reported gross margins are on average £300 per hectare. Of this approximately £100 is for AEP activities (e.g., ESAs). Alternatively if we do not use gross margins but instead a measure of farm income that takes account of various fixed costs and payments for own farm labour we arrive at very different figure. For the average farm Management and Investment Income (excluding breeding livestock appreciation) the survey reports £31 per hectare per annum. Based on these figures the loss of profits will be simply 200 hectares times £31 which is approximately £6,000.

3.5. Non-Market Benefits of Biological Diversity

The motivation for agricultural land retirement stems from a desire to prevent, and if possible to increase in biological diversity at a SSSI that has been subject to nitrogen deposition. This type of land use management has a clear public policy motivation. The current decline in biological diversity results from the public good nature of the problem that results in a negative externality. To assess if agricultural land retirement is a credible policy option to resolve this problem we need to examine if the non-market benefits of increased biological diversity are greater than the costs incurred. To do this we employ benefit transfer (Navrud and Pruckner, 1997 and van Bueren and Bennett, 2004) where monetary values estimated for one study are applied to another. Although benefit transfer is popular it is subject to many limitations our use of benefit transfer is at the lower end in terms of accuracy, as defined by Navrud and Pruckner, as we are concerned with raising awareness as to the policy option we are proposing. Thus, we wish to establish the likely magnitude (i.e., pence, pounds, hundreds of pounds) that the general public might be WTP to maintain and/or enhance biodiversity at the case study site simply for the knowledge and satisfaction that the biological diversity exists and will be available for future generations.

What makes this a complex problem is that the dose-response relationship relates nitrogen deposition to biological diversity at a particular site. But the loss of species at one site does not mean the loss at all sites. Therefore, we are specifically concerned with loss of diversity at a specific site which has implications for resilience. This is because there may well be an impact on stability and at some threshold a capacity for the ecosystem to function. Diversity provides stability and greater numbers yield ecological insurance. As a result we are not specifically concerned with valuing an individual species being lost, but rather with biological diversity as it relates to resilience and stability.

There are relatively few papers in the economics literature that have attempted to value diversity. The literature typically examines the existence of a particular species or biological resources as opposed to the value of diversity *per se* (Nunes and van den Bergh, 2001). The lack of economics research on biological diversity can be traced to the difficulties inherent in framing this type of problem. This particular issue has been examined in a non-market study of biodiversity in the UK by Christie et al. (2004). This study exerted a great deal of effort trying to resolve the problem of conveying biological diversity as opposed to simple species loss. To overcome some of the complexities inherent in the valuation exercise Christie et al. found it necessary to employ simple concepts of biological diversity as opposed to much more complex ecological concepts. In two case studies employing Contingent Valuation and Choice Modelling they found that individuals are WTP significant amounts to implement AEP that yield enhanced biological diversity. They report several WTP estimates which are typically in the region of £50 (p. 109). What is also relevant about this research for our analysis is that Christie et al. argue that their results *"provide strong evidence that people are now appreciating the value of the 'non-charismatic species'."* (p. 110). Given we are concerned about upland grassland biological diversity we are not concerned with high profile, charismatic flora. However, these WTP estimates are for relatively large scale changes in land use (e.g., at the county level) and the anticipated changes in biodiversity are also relatively large.

Another study that yields potentially relevant WTP is Garrod and Willis (1997). They estimated WTP for non-use values associated with increases in biodiversity in remote upland coniferous forests in the UK. For small increases in biodiversity (1 percent) each household was WTP between £0.30 and £0.35 per annum and for a 30 percent increase this rose to £10-£11. There have also been a number of studies that examined WTP for the protection and improvement of SSSIs (e.g., Garrod and Willis, 1994 and Willis et al., 1996). For these studies the greatest part of the estimated WTP can be attributed to non-use values (which range from 50 pence to £1 per household per annum). However, these studies are not concerned with changes in the state of the SSSIs but simply the benefits that are currently provided. Furthermore, there are a number of methodological problems such as most survey respondents cannot separate biological diversity aspects of a SSSI from use values such as landscape consumption or recreational use.[9]

In summary, there are few estimates of WTP in the literature that consider biological diversity especially in terms of ecological change. These estimates are varied and as such provide minimal guidance for us to use here. As a result we present a wide array of result that encompasses the range of WTP estimates reported in the literature i.e., 1 pence, 10 pence, 30 pence, £1 and £50. This allows to us identify the magnitude that

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[9] We could also consider the AEP non-market benefit literature more generally (Hanley et al., 1999). But, the estimates have been questioned (Hodge and McNally, 1998) and questions have been raised about the ecological benefits of AEP (Kleijn and Sutherland, 2003).

WTP estimates need to be to make agricultural land retirement economically meaningful.

4. Benefit-Cost Analysis

We now compare the costs of retiring the required number of hectares to the non-market benefits from biological diversity. To conduct the benefit-cost analysis we have made a number of important assumptions.

1. We need to aggregate the individual WTP estimates we employ in the case study. The choice of population to whom we attribute the benefits is not obvious. We might, for example, use annual visitor data to Exmoor National Park (ENP). For 1998 it has been estimated that the ENP Visitor Centre (Lynmouth) had 163,784 visitors. This estimate it is claimed is on the low side and that compared to other National Parks the number of children visiting is low. Alternatively we might take the actual population in the local region (e.g.,ENP and surrounds) in which case we assume a population of 250,000. As the case study is only illustrative we employ the latter figure.[10]
2. It is highly likely that it will take a number of years for the adjustment in land use to yield the desired biological diversity benefits. To take account of the uncertainty time period over which we will observe increased biological diversity we assume that the changes occur after 10 and 25 years. As a result we are assuming that there will be a stream of costs incurred every year in adjusting land use and that the benefits will only start to appear after the increase in biological diversity has occurred.
3. We need to select a discounting rate and select the number of years over which the benefit-cost analysis is to be conducted. We employ exponential discounting, assuming a 5 percent discount rate and the analysis assumes a 50 year period of evaluation.
4. We have ignored several additional conservation benefits that would results from the policy. First, there will be an increase in biological diversity over a larger scale than the one hectare considered in the case study. Land adjacent

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[10] Potentially the whole UK population is appropriate to employ because SSSIs are of national significance and because we consider non-use values.

to the target site will benefit from reduced deposition and experience some increase in biological diversity. Second, the land retired from agricultural production could be actively managed to further enhance biological diversity.

4.1. Results

Given the various assumptions made and the various cost and benefit estimates already presented we now present our benefit-cost analysis in Table 2.

{Approximate Position of Table 2}

The results in Table 2 are derived by multiplying the WTP estimates by 250,000 and converting all benefit and cost data into Present Value terms by discounting. To show the relative size of benefits to costs we also present benefit cost ratios for all combinations. Any benefit-cost ratio with a value greater than one implies that benefits are greater than costs.

The most obvious result from Table 2 and as we would expect, is that the further into the future the benefits occur (i.e. the longer it takes for there to be an improvement in biological diversity) the higher WTP needs to be for benefits to be greater than costs. This is simply because the opportunity cost of foregone profits increases. It is also clear from Table 2 that WTP estimates do not need to be very high for this level of land retirement to be economically justified. Even when the benefits do not occur until year 25 a WTP of 10 pence yields a benefit cost ratio of one. This is significantly less than the WTP estimates reported by Garrod and Willis (1997) for a 1 percent increase in biological diversity.

We can also infer what happens if we assume that the benefits are realised earlier, say after five years. The quicker the improvement in biological diversity is realised the smaller the WTP estimates need to be for the benefits to be greater than costs. This is an important observation for policy makers to be aware of when analysing the economic rationale for policy to enhance biological diversity. Indeed, it raises the issue if whether active land management to bring about the desired improvement in biological diversity more quickly is an economically sensible use of public money. The ability of ecosystems to regenerate in a timely manner, but more importantly in the way desired by policy makers is, as already noted in this paper, far from certain.

They are likely to be economic benefits from ensuring that the desired improvements in biological diversity are achieved and that they are achieved in a timely manner.

4.2. Scaling Up

We can make an assessment of costs and benefits if we implement land retirement at a national scale. According to the most recent statistics available from English Nature[11] in 2005 there were some 157 SSSIs, covering approximately 20,000 hectares that are subject to air pollution in England. Of this total land area only seven percent is significantly affected which is approximately 2,000 hectares. Assuming we need to retire 200 hectares to protect each hectare yields a total estimate of 400,000 hectares to be retired. There are some 5 million hectares of grassland production in England, so we are retiring only one percent of the total area. Assuming that each hectare retired yielded farm income of £50 per annum then the total cost would be £20 million per annum. To ensure that benefits are at least as great as costs would require a WTP of less than 50 pence per person in the England.

In light of these results we feel able to argue that agricultural land retirement is a feasible policy option to tackle the effects of ammonia deposition on biological diversity. However, we realise that the hypothetical nature of our case study is restrictive and that the scaling up of an agricultural land retirement policy is not without complication.

4.2.1. The Cost of Land Retirement

We have assumed that land can be retired at a constant cost per hectare which is reasonable when dealing with a single farm, or even a group of farms in the same area practicing the same form of agricultural production. But if we are to scale up the analysis there is a great deal of heterogeneity which will obviously be manifest in costs of production (e.g., Schou and Birr-Pedersen, 2001). The key issue that arises as a result of this is that we not only have to target land use that is the source of pollution but also take account of differences in production and cost structures. With

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[11] For details see http://www.english-nature.org.uk/special/sssi/reportIndex.cfm

limited funds to implement a policy there are a number of policy mechanisms that might be employed to deal with this issue. For example, farmers could be asked to submit bids indicating how much they would be willing to accept to retire land. This type of auction mechanism has been used in the England with the CSS.

4.2.2. The Benefits of Land Retirement

Potentially, by scaling up land retirement it is likely that the associated marginal benefits will diminish. However, we are considering agricultural land retirement as a policy to protect areas of high conservation value (e.g., SSSIs) so it is possible that the range and significance of the biological diversity we enhance will be such that marginal benefits do not rapidly approach zero. It also needs to be borne in mind that there are significant cultural heritage benefits associated with current land use practices in the UK (e.g., Hanley et al., 1999, and Policy Commission, 2002). It is, therefore, essential that we consider if the loss of cultural heritage values associated with existing agricultural activities outweigh the environmental improvements as valued by the public.[12] Until we are clear about the relationship between the area farmed in a given region and the associated cultural and heritage values, the optimal land use solution will remain uncertain. This question raises another issue with the case study in that the WTP benefits associated with biological diversity are off-site whereas the cultural heritage WTP benefits are on-site. This means we are not necessarily looking at a policy that provides a win-win outcome. This is in contrast to existing AEP which is perceived to yield multiple benefits as a result of multi-functionality.

4.2.3. Small Science and Large Policy

Stevens et al. (2004) is a small-scale observational study and as such the average quantity of biological diversity in a given region is only that, an average. We need to take account of higher order moments because although they may be a reduction on average within a given area there may be no actual species loss, just a reduction in density. This reduction on average may indicate that certain species are threatened but

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[12] Fraser and Chisholm (2000) examine the trade-off in cultural heritage and environmental conservation in terms of rural land use for cattle grazing in the Australian Alpine National Park.

we cannot be certain that the average reflects the true extent of biological diversity. This is important for economic valuation because we are no longer concerned with loss, or even threatened loss, but simply a reduction in abundance. Policy that aims to increase the average number of species may in fact only be increasing the abundance of species already present and it is unclear if society places a high non-market value on this aspect of biological diversity. From a non-market valuation perspective what is being considered is ecosystem stability and abundance as a form of ecosystem insurance and this is an area that warrants further research.

5. Summary and Conclusions

In this paper we have proposed and examined the economic case for employing agricultural land retirement as a policy response to reverse the loss of biological diversity at sites of high conservation value as a result of nitrogen deposition. Employing a hypothetical case study that combines scientific modelling of nitrogen deposition with economic analysis we have shown that agricultural land retirement on a small scale is economically feasible even for very small non-market WTP values of biological diversity that do not occur immediately.

We have been able to conduct this research because of the very detailed dose-response relationship derived by Stevens et al. (2004). The dose-response relationship has allowed us to consider both the costs and benefits of a policy, as well as identifying limitations in the economics literature relating to understanding and evaluation of the benefits of biological diversity.

In the case study we assume that a reduction in the level of deposition will result in a reversal of biological diversity. This is not a trivial assumption. Our analysis does consider variation in the time period over which the benefits occur and the impact this can have on the economic feasibility of a policy proposal. As we indicate, if a reversal in biological diversity can be brought forward there may well be a case for incurring the costs of active land management on the conservation site. However, if we are to make such land use management decisions as part of a policy package it is essential that we have an improved understanding of the way in which ecosystems respond.

More generally our findings raise questions about the future design of AEP at the landscape level and the potential benefits from reducing localised air pollution. Currently the SFP gives farmers the option to manage their land according to GAEC but without any requirement that there be any form of agricultural output. There speculation as to the likely course action that many farmers will follow, but agricultural land retirement is a feasible. Thus, although the agricultural land retirement option considered in this paper might appear radical it is the case that current rural land use policy changes explicitly support the retirement of marginal land from agricultural production. It will, therefore, be interesting to see if the SFP becomes the policy change necessary to bring about the land use change examined in this paper.

Finally, the importance of AEP in terms of rural land use and the contractual provision of rural environmental quality brings' with it an increasing need to monitor the efforts and outcomes achieved by land managers. In the case of AEP it is highly likely that the inability to achieve desired outcomes may well be less a failure of rural land management, but rather policy design which is not cognisant of key exogenous influences such as air pollution. Indeed, the UK Joint nature Conservation Committee in its October 2005 Air Pollution Bulletin Number 3 recently stated that, *"There is a paucity of information on the impacts of air pollution on semi-natural habitats, particularly in relation to the UK's legislative and policy commitments for biodiversity."* (p. 4). This issue increases in importance as AEP monitoring and evaluation becomes more output based in focus and less input based. This potentially unsatisfactory outcome highlights a gap in policy design with respect to agricultural sources of nitrogen and ammonia, the resulting impact on semi-natural environments, and the design, implementation and evaluation of AEP.

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Table 1: Ammonia deposition at 100m intervals

Distance from source to sink (metres)	Deposition kg nitrogen per hectare per annum*	Number of source hectares	Cumulative Deposition kg nitrogen per annum*
200	0.062	11	0.677
300	0.029	15	1.117
400	0.017	20	1.554
500	0.012	24	1.831
600	0.008	28	2.062
700	0.006	32	2.261
800	0.005	36	2.436
900	0.004	40	2.593
1000	0.003	0	0
Total		206	2.593

***Source: SCAIL**

Table 2: Benefit-Cost Analysis in Present Value Terms of Retiring 200 Hectares of Agricultural Land to Reduce Nitrogen Deposition at a SSSI

	Number of Years Before Benefits to Occur	
	10 Years	**25 Years**
Benefits (£)		
If WTP of 1p	27,870	11,143
If WTP of 10p	278,702	111,432
If WTP of 30p	836,107	334,296
If WTP of £1	2,787,206	1,114,321
If WTP of £50	139,351,297	55,716,046
Costs (£)	115,536	115,536
	Benefit/Cost Ratios	
If WTP of 1p	0.2	0.1
If WTP of 10p	2.4	1
If WTP of 30p	7.2	2.9
If WTP of £1	24.1	9.6
If WTP of £50	1206.1	482.2

Assumptions:

1. Assumed a 5% discount rate
2. Costs and benefits are evaluated over 50 year time period
3. All WTP estimates have been multiplied by 250,000
4. Costs are incurred in all years assuming 200 hectares are retired from farming

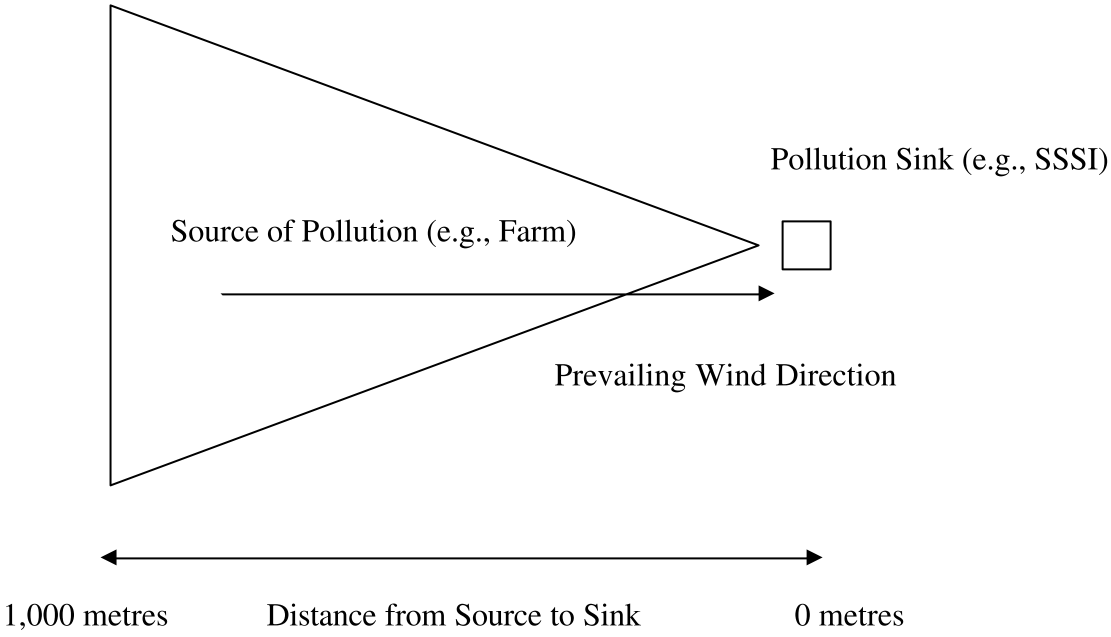

Figure 1: Hypothetical Triangular Land Use Configuration

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