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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**

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Abstract

Current levels of nitrogen deposition, especially ammonia, seriously impact upon ecosystems biological diversity. However, land use policy maintaining and enhancing key ecosystems in the UK in most cases does not explicitly take account of this pollution in terms of onsite management prescriptions. In this paper the economic potential of agricultural land retirement to reduce localised nitrogen deposition is examined. Employing a case study that combines nitrogen deposition modelling and agricultural land use change, reductions in nitrogen deposition necessary to reverse the loss of floral diversity are examined. The results indicate that agricultural land retirement is in principle a potentially useful policy instrument for dealing with nitrogen deposition from extensive livestock production.

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 significant, the majority of which originates 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 led policy efforts to focus on high source activities such as intensive livestock production. However, many fragile and valuable ecosystems are at danger from ammonia pollution (Woodin and Farmer, 1993, and Krupa, 2003). These sites experience relatively low levels of ammonia pollution from agricultural non-point source, such as extensive livestock activities, and they 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) who 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 private marginal cost of abatement (control) equals the marginal social cost of the 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 social costs 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 the difference between total benefits and costs are maximised.

In this paper the issue of land use and localised air pollution using a hypothetical case study of an extensive livestock activity in close spatial proximity to an upland acid grassland designated as a SSSI is examined. Although hypothetical, all data and model estimates are for real land use activities and practices for extensive livestock farming on Exmoor in South West England. The policy option considered is the required level of agricultural land retirement[2] of pasture based livestock activities necessary to reduce the localised air pollution by a specified amount. Agricultural

[1] All existing AEP is now collected together under the new Environmental Stewardship (ES) scheme.
[2] For a review of agricultural land retirement and policy slippage see Fraser and Waschik (2005).

land retirement is defined as land use that is no longer employed for income generation from agriculture. Thus, land retirement does not imply land abandonment. Indeed it is assumed that the retired land will be maintained in such a way so that problems such as the emergence and spread of weeds onto land still in production are avoided.

The level of land retirement estimated in the case study is that required to reduce nitrogen deposition at the SSSI necessary to increase the total number of flora by one species. The dose-response relationship in this context is given by Stevens et al. (2004), who empirically demonstrated a reduction of a species for every additional 2.5 kg of nitrogen per hectare per annum deposited. The dose-response relationship provides 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]

Overall, this paper makes a number of contributions to the literature. First, it attempts to translate high profile science (i.e., Stevens et al., 2004) into a meaningful policy design. Second, this study highlights difficulties economists face evaluating policy with a biological diversity objective. Research typically focuses on biodiversity 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. The 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. The case study adds to a small literature that has examined this problem at the farm scale (e.g., Angus et al., 2006).

[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.

The structure of this paper is as follows. In Section 2 a review of the antecedent economics literature that has examined ammonia deposition is presented. In Section 3 the hypothetical case study is described. The case study combines scientific and economic information allowing an examination of 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 the main results are presented. In addition, various extensions and limitations of the case study and what they imply for policy design as well as interdisciplinary research are considered. Finally, in Section 5 a summary the implications of the case study and the wider implications for rural land use policy makers are presented.

2. Economics of Nitrogen Deposition

2.1. Cost Effectiveness

The need to achieve emissions targets for ammonia within the EU has meant that policy efforts have been focused on high concentration emitters. 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., 2006, Webb et al., 2005 and Schou et al., 2006). Most research has considered 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. (2006) combined an ammonia deposition 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. considered alternative buffer zone policies in terms of cost effectiveness using farm level data and combined with a local-scale deposition model that was then scaled up to the national level. They found that increasing the necessary area of buffer zones significantly added to the cost of policy implementation and such 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. (2005) considered several policies simultaneously to deal with ammonia, nitrous oxide and methane emanating from agricultural activities. They showed 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 is an important 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) considered acidification of the Scottish Highlands and non-market values from reductions in acid damage. They estimated a total (average per household) WTP per annum for future abatement of acid rain at low damage levels of £484 million (£247) and for high damage levels of £688 million (£351) for the Scottish population. In the Netherlands Ruijgrok (2004) employed CV to examine the use and non-use benefits

[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.

of increased nature quality. The results indicated total annual benefits from non-use values to be €207 million (€30 per household).

In summary, the magnitude of the non-market benefit estimates is relatively large and they appear to be more than comparable to the costs estimates for control of ammonia. For example, Webb et al. (2005) estimated 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

The case study considers extensive agriculture on Exmoor National Park in south west England. Agriculture in this area is dominated by pasture based livestock activities. The impact of air pollution in this area is explicitly acknowledged in the 2001 Exmoor Biodiversity Action Plan (Exmoor National Park Authority, 2001). The case study considers an SSSI within Exmoor National Park for which detailed environmental data is available (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 heathland SSSI is currently in unfavourable recovering condition. 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 the SSSI several data sources are employed. 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, the analysis examines how a 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. Land Use-Deposition Relationship

To assess how much agricultural land retirement is required to yield the necessary reduction in air pollution from localised sources the SCAIL (Simple Calculation of Ammonia Impact Limits) model (Theobald and Sutton, 2002) is employed.[6] 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.[7]

In the analysis a level of nitrogen fertiliser application of 125 kg per hectare for all improved pasture is assumed. This is the maximum allowed under the ESA Tier 1 conditions in the case study area.[8] Based on known scientific data it was estimated 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) it was then estimated that the annual emission of ammonia per cow, assuming animals are kept in the field year round, is 6.17 kg.[9] Taking livestock activity and fertiliser together this gives a total emissions' source strength of 17.42 kg of nitrogen per hectare per annum.

[5]Full details of the current and previous Farm Business Surveys 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] The SCAIL model has been used in a number of studies (e.g., Angus et al., 2006, and Wolseley et al., 2006) to examine policy options designed to reduce ammonia air pollution.
[7] Although the sink in the SCAIL model is a single hectare there are additional benefits from nitrogen reduction on adjacent parcels of land.
[8] For more details see; http://www.defra.gov.uk/erdp/schemes/esas/stage3/exmoor.htm
[9] As no livestock shedding activity is assumed it means that no livestock waste management is required.

Employing the SCAIL model and with the beef enterprise down wind, for 100m intervals, ranging from 100m up to a maximum of 1 km the resulting level of nitrogen deposition at the sink (the SSSI) was estimated. 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 the number of hectares of agricultural land to be taken out of production to achieve the required reduction in nitrogen deposition at the SSSI could be calculated. It was also necessary to make various assumptions with the respect to the arrangement of source fields and the prevailing direction of the wind. A triangular land use arrangement with fewer fields' close to the SSSI, and more further away, as shown in Figure 1 was employed.

{Approximate Position of Figure 1}

A field pattern with a greater number of source hectares close to the SSSI, which was considered, resulted in fewer hectares of agricultural land needing to be retired from agricultural production conditional on the probability of the prevailing wind. However, the field pattern shown in Figure 1 used was selected because it yields a conservative, upper bound, on the necessary area of land to be retired from production to achieve the desired reduction in nitrogen deposition. The triangular field pattern is different to the type of buffer zone typically examined in the literature (e.g., Schou et al., 2006).

An overall summary of the 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 the given arrangement of source sites it is 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 the given pattern of land retirement only retire 100 hectares is necessary, whereas for the higher estimate more than 300 hectares is required. The difference in the required level of land retirement will clearly have major implications if attempting to scale up this analysis to the regional or national level.

3.3. Farm Income Loss

To assess the impact on farm incomes of this level of land retirement data from the south west Farm Business Survey for 2002/03 can be used. The survey splits its results into various farm types. Given the location of the SSSI it is assumed 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 not using gross margins but instead a measure of farm income that takes account of various fixed costs and payments for own farm labour very different estimates are derived. 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.

3.4. 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 its public good attributes, which results in a negative externality. To assess if agricultural land retirement is a credible policy option to resolve this problem it is necessary to examine if the non-market benefits of increased biological diversity are greater than the costs incurred. To do this benefit transfer methods (Navrud and Pruckner, 1997 and van Bueren and Bennett, 2004) are employed where monetary values estimated for one study are applied to another. Although popular, benefit transfer is subject to many limitations and the use in this case study can be considered to be at the lower end in terms of accuracy, as defined by Navrud and Pruckner. The main objective of the benefit transfer is to establish the likely magnitude (i.e., pence, pounds, hundreds of pounds) that the general public might be WTP for existence value for biodiversity at the SSSI.

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, the analysis is only 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 the focus of the analysis is not specifically 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 per household per annum over 5 years (p. 109). What is also relevant about this research for the analysis presented here 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 the focus on upland grassland biological diversity there is no specific concern with high profile, "charismatic species". Finally, the Christie et al. 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. This is not the case in the analysis in this paper and as such these estimates can only be used to help gauge magnitude.

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.[10]

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 use here. As a result the analysis presented is for a wide array of results that encompasses the range of WTP estimates reported in the literature i.e., 1 pence, 10 pence, 30 pence, £1 and £50. This allows identification of the magnitude that WTP estimates necessary to make agricultural land retirement economically meaningful.

4. Benefit-Cost Analysis

A benefit-cost analysis of costs of retiring the required number of hectares to the non-market benefits from biological diversity is now presented. To conduct the benefit-cost analysis a number of important assumptions have been made.

1. It is necessary to aggregate the individual WTP estimates ascertained from the literature. The choice of population to whom to attribute the benefits is not obvious. For example, the appropriate population might be the annual visitors

[10] The AEP non-market benefit literature could also be considered (e.g., Hanley et al., 1999). But, these estimates have been challenged (Hodge and McNally, 1998). Also questions have been raised about the ecological benefits of AEP (Kleijn and Sutherland, 2003).

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. An alternatively the appropriate number might be the actual population in the local region (e.g., ENP and surrounds) which is 250,000. As the case study is only illustrative the latter figure is used.[11]

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 over the time period over which increased biological diversity will be observed it is assumed that the changes occur after 10 and 25 years. As a result 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. A discounting rate and the number of years over which the benefit-cost analysis is to be conducted needs to be selected. We employ exponential discounting, assuming a 5 percent discount rate and the analysis assumes a 50 year period of evaluation.[12]
4. Several additional conservation benefits that would result from the policy have been ignored. First, there will be an increase in biological diversity over a larger scale than the one hectare considered in the case study. Land adjacent 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. This would in turn minimise the risks associated with the retired land becoming a host for weeds which could then spread onto adjacent agricultural land.

4.1. Results

The results of the benefit-cost analysis are presented in Table 2.

{Approximate Position of Table 2}

[11] Potentially the whole UK population is appropriate to employ because SSSIs are of national significance.

[12] In the analysis it is assumed that abatement technology for dealing with these emissions remains constant.

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 impact of various assumptions on the analysis several combinations of benefits to costs are presented. Any benefit-cost ratio with a value greater than one implies that benefits are greater than costs.

The most obvious result from Table 2 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. However, it is to be expected that WTP should be smaller as the changes being experienced are over a very small parcel of land.

It is also noted that if benefits are realised earlier, say after five years, then 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 efficient 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. There 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.

Finally, it is noted that the design of policy will not in practice be entirely determined by the relative magnitude of WTP within benefit-cost analysis. Indeed, many policies that are employed to conserve biodiversity are also designed and informed by cultural and ethical concerns.

4.2. Scaling Up

It is possible, albeit heroic, to make an assessment of costs and benefits for land retirement implemented at a national scale. According to the most recent statistics available from English Nature[13] 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 it is necessary to retire 200 hectares to protect each hectare this yields a total estimate of 400,000 hectares to be retired. There are some 5 million hectares of grassland production in England. So retiring 400,000 hectares equates to 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 it appears that agricultural land retirement is a policy option worthy of further investigation as a means to tackle the effects of ammonia deposition on biological diversity. However, given the hypothetical nature of the case study and the many assumptions being made,results should be interpreted with caution.

4.2.1. The Cost of Land Retirement

It has been 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 when scaling 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 the need to target land use that is the source of pollution and also take account of differences in production and cost structures. With 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

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

how much they would be willing to accept to retire land. This type of incentive 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 of biological diversity will diminish. However, the analysis is 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 enhanced 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 these are consider if the loss of cultural heritage values associated with existing agricultural activities outweigh the environmental improvements as valued by the public.[14] 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 (i.e., variances) because although there 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 we cannot be certain that the average reflects the true extent of biological diversity. This is important for economic valuation because we are no

[14] 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.

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

This paper has 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 it has been shown that agricultural land retirement on a small scale is potentially economically feasible even for very small non-market WTP values of biological diversity that do not occur immediately. This finding suggests that there is a need for further investigation into the use of land retirement as a policy instrument to protect areas of high conservation value from air pollution.

The main reason why this type of research is feasible is because of the very detailed dose-response relationship derived by Stevens et al. (2004). The dose-response relationship has allowed both the costs and benefits of a policy to be examined, as well as identifying limitations in the economics literature relating to understanding and evaluation of the benefits of biological diversity.

In the case study it was assumed that a reduction in the level of deposition will result in an increase in biological diversity. This is not a trivial assumption. The analysis has considered 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 shown, 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 such land use management decisions are to be part of a policy package it is essential that there is an improved understanding of the way in which ecosystems respond.

More generally these 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 is speculation as to the likely course of action that many farmers will follow, but agricultural land retirement is a feasible option. 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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References

Angus, A.J., Hodge, I.D. and Sutton, M.A. (2006). Ammonia Abatement Strategies in Livestock Production: A Case Study of a Poultry Installation, *Agricultural Systems*, **89(1)**: 204-222.

Brink, C., van Ierland, E., Hordijk, L. and Kroeze, C. (2005). Cost-Effective Emission Abatement in Agriculture in the Presence of Interrelations: Cases for the Netherlands and Europe, *Ecological Economics*, **53(1):** 59-74.

CJC Consulting (2004) Cost Effectiveness Study of Approaches for Delivery of PSA Target Relating to SSSIs, Final Report for Department for Environment, Food and Rural Affairs, London (http://statistics.defra.gov.uk/esg/reports/???.pdf)

Christie, M., J. Warren, N. Hanley, K. Murphy, R. Wright, T. Hyde and N. Lyons (2004). Developing Measures for Valuing Changes in Biodiversity: Final Report, Report to DEFRA, London (http://statistics.defra.gov.uk/esg/reports/biovalue/mainrep.pdf)

Cowell, D.A. and Apsimon, H.M. (1998). Cost-Effective Strategies for the Abatement of Ammonia Emissions from European Agriculture, *Atmospheric Environment*, **32** (3): 573-580.

DEFRA (2004). Ammonia in the UK – Key Points, DEFRA, London.

Exmoor National Park Authority (2001). Exmoor Biodiversity Action Plan, Exmoor National Park and English Nature.

Fowler, D., O'Donoghue, M., Muller, J.B.A., Smith, R.I., Dragosits, U., Skiba, U., Sutton, M.A. and Brimblecombe, P. (2004). A Chronology of Nitrogen Deposition in the UK Between 1900 and 2000, *Water, Air, and Soil Pollution: Focus*, **4**: 9-23.

Fraser, I.M. and Chisholm, A.C. (2000). Conservation or Cultural Heritage? Cattle Grazing in the Victorian Alpine National Park, *Ecological Economics*, **33**: 63-75.

Fraser, I.M. and Waschik, R. (2005). Agricultural Land Retirement and Slippage: Lessons from an Australian Case Study, *Land Economics*, **81** (2): 206-227.

Garrod, G.D. and Willis, K.G. (1994). Valuing Biodiversity and Nature Conservation at a Local Level, *Biodiversity and Conservation*, **3**: 555-565.

Garrod, G.D. and Willis, K.G. (1997). The Non-Use Benefits of Enhancing Forest Biodiversity: A Contingent Ranking Study, *Ecological Economics*, **21**: 45-61.

Hanley, N., Whitby, M. and Simpson, I. (1999). Assessing the Success of Agri-Environmental Policy in the UK, *Land Use Policy*, **16**: 67-80.

Hodge, I. and McNally, S. (1998) Evaluating Environmentally Sensitive Areas: The Value of Rural Environments and Policy Relevance, *Journal of Rural Studies*, **14**: 357-367.

Klaassen, G. (1994). Options and Costs of Controlling Ammonia Emissions in Europe, *European Review of Agricultural Economics*, **21**: 219-240.

Kleijn, D. and Sutherland, W.J. (2003) How effective are European agri-environmental schemes in conserving and promoting biodiversity? *Journal of Applied Ecology*, **40**: 947-69.

Krupa, S.V. (2003). Effects of Atmospheric Ammonia (NH3) on Terrestrial Vegetation: A Review, *Environmental Pollution*, **124**: 179-221.

Lobley, M., Wakefield, D., Butler, A. and Turner, M. (2004). The State of farming on Exmoor 2004: A Report to Exmoor National Park Authority, Centre for Rural Research, University of Exeter, Exeter (Report downloaded from www.ex.ac.uk/crr/).

Macmillan, D., Hanley, N. and Buckland, S. (1996). A Contingent Valuation Study of Uncertain Environmental Gains, *Scottish Journal of Political Economy*, **43** (5): 519-533.

Misselbrook, T.H., van der Weerden, T.J., Pain, B.F., Jarvis, S.C., Chambers, B.J., Smith, K.A., Phillips, V.R., Demmers, T.G.M., 2000. Ammonia emission factors for UK agriculture. *Atmospheric Environment,* **34**: 871-880.

Navrud, S. and Pruckner, G.J. (1997). Environmental Valuation – To Use or Not to Use? *Environmental and Resource Economics*, **10**: 1-26

Nunes, P.A.L.D. and van den Bergh, J.C.J.M. (2001). Economic Valuation of Biodiversity: Sense or Nonsense? *Ecological Economics*, **39**: 203-222.

Policy Commission (2002) Farming and Food: A Sustainable Future, Report of the Policy Commission on the Future of Farming and Food, Cabinet Office, London, UK

Ruijgrok, E.C.M. (2004). Reducing Acidification: The Benefits of Increased Nature Quality. Investigating the Possibilities of the Contingent Valuation Method, Nota Di Lavoro 65.2004, The Fondazione Eni Enrico Mattei Note di Lavoro.

Schlapfer, F., Pfisterer, B. and Schmid, B. (2005) Non-Random Species Extinction and Plant Production: Implications for Ecosystem Function, *Journal of Applied Ecology*, **42**: 13-24.

Schou, J.S. and Birr-Pedersen, K. (2001). The Cost of Spatial Management, *European Environment*, **11**: 211-219

Schou, J.S., Tybirk, K., Lofstrom, P. and Hertel, O. (2006). Economic and Environmental Analysis of Buffer Zones as an Instrument to Reduce Ammonia Loads to Nature Areas, *Land Use Policy*, (forthcoming).

Sutton, M. A., Milford, C., Dragosits, U., Place, C. J., Singles, R. J., Smith, R. I., Pitcairn, C. E. R., Fowler, D., Hill, J., ApSimon, H. M., Ross, C., Hill, R., Jarvis, S. C., Pain, B. F., Phillips, R., Harrison, R., Moss, D., Webb, J., Espenhahn, S. E., Lee,

D. S., Hornung, M., Ullyett, J., Bull, K. R., Emmett, B. A., Lowe, J., and Wyers, G. P. (1998). Dispersion, deposition and impacts of atmospheric ammonia: Quantifying local budgets and spatial variability, *Environmental Pollution*, **102**: 349-361.

Stevens, C.J., Dise, N.B., Mountford, J.O. and Gowing, D.J. (2004) Impact of Nitrogen Deposition on the Species Richness of Grasslands, *Science*, **303**: 1876-1879.

Theobald, M.R. and Sutton, M.A. (2002) SCAIL v 1.1. (Simple Calculation of Ammonia Impact Limits) Computer model written in C++ as a screening tool for the impacts of large pig/poultry units on semi-natural habitats. CEH Edinburgh, for the Environment Agency.

Theobald, M.R., Dragosits, U., Place, C.J., Smith, J.U., Sozanska, M., Brown, L., Scholefield, D., Del Prado, A., Webb, J., Whitehead, P.G., Angus, A., Hodge, I.D., Fowler, D. and Sutton, M.A. (2004). Modelling Nitrogen Fluxes at the Landscape Scale, *Water, Air and Soil Pollution: Focus*, **4**: 135-142.

UNECE (United Nations Economic Commission for Europe) (1999). Protocol to the 1979 CLRTAP to Abate Acidification, Eutrophication and Ground-Level Ozone, UNECE.

Van Bueren, M. and Bennett, J. (2004). Towards the Development of a Transferable Set of Value Estimates for Environmental Attributes, *Australian Journal of Agricultural and Resource Economics*, **48**(1): 1-32.

Webb, J., Menzi, H., Pain, B.F., Misselbrook, T.H., Dammgen, U., Hendriks, H. and Dohler, H. (2005). Managing Ammonia Emissions from Livestock Production in Europe, *Environmental Pollution*, **135**: 399-406.

Willis, K.G., Garrod, G.D., Benson, J.F. and Carter, M. (1996). Benefits and Costs of the Wildlife Enhancement Scheme: A Case Study of the Pevensey Levels, *Journal of Environmental Planning and Management*, **39**: 387-401.

Woodin, S.J. and Farmer, A.M. (1993). Impacts of Sulphur and Nitrogen Deposition on Sites and Species of Nature Conservation Importance in Great Britain, *Biological Conservation*, **63**: 23-30.

Wolseley, P.A., James, P.W., Theobald, M.R. and Sutton, M.A. (2006). Detecting Changes in Epiphytic Lichen Communities at Sites Affected by Atmospheric Ammonia from Agricultural Sources, *The Lichenologist*, **38**(2): 161-176.

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 (Theobald and Sutton, 2002)**

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 1 pence	27,870	11,143
If WTP of 10 pence	278,702	111,432
If WTP of 30 pence	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 1 pence	0.2	0.1
If WTP of 10 pence	2.4	1
If WTP of 30 pence	7.2	2.9
If WTP of £1	24.1	9.6
If WTP of £50	1206.1	482.2

Assumptions:

1. Assuming 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

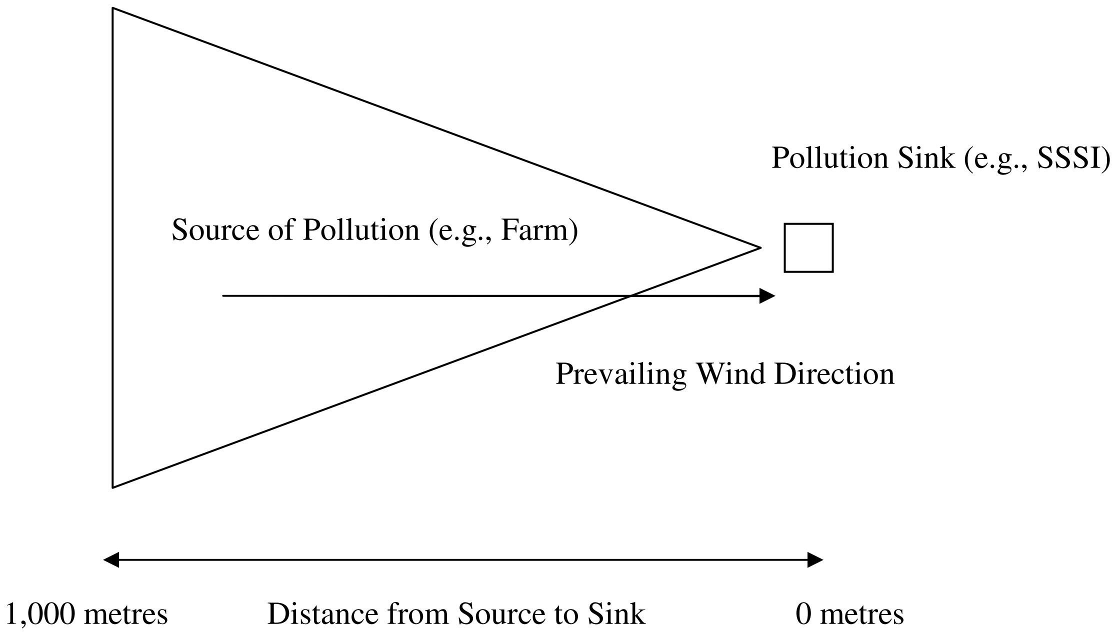

Figure 1: Hypothetical Triangular Land Use Configuration