UK Data Archive

Study Number 6363

Sustainability of Hill Farming, 2007-2008

USER GUIDE

This is a sample choice card in the choice experiment.

	A	B	Do Nothing
Moorland – intensity of management	Less Intensive – less sheep and burning. More bird species	No Change in Intensity	More Intensive - more sheep and burning
Moorland Fringe – intensity of management	Less Intensive– less sheep and burning. More bird species	Less Intensive– less sheep and burning. More bird species	More Intensive – more sheep, fertiliser and drainage
Valley Bottom Farmland – intensity of management	No Change in Intensity	Less Intensive – less sheep and fertiliser. More bird species	More Intensive – more sheep and fertilizer.
Footpath Network	Improved	Degraded	Degraded
Tax Cost	£5	£55	£0
Please tick the option you prefer.	☐	☐	☐

This is the key for the choice experiment data.

K	Alternative specific constant	0,1
LOCAT		
CSET_no	Choice set number	1 to 16
EXP_no	Experiment number	1 to 6
WOR_no	Workshop number	1,2 (first or second workshop)
ID	Participant identifier	
ALTI	Alternative coding	0,1,2 (do nothing, A and B)
CHOICE	Choice made	1 for choice made
EXP1	Experiment 1 choices	Dummy variable 1=experiment 1
EXP2	Experiment 2 choices	Dummy variable 1=experiment 2
EXP3	Experiment 3 choices	Dummy variable 1=experiment 3
EXP4	Experiment 4 choices	Dummy variable 1=experiment 4
EXP5	Experiment 5 choices	Dummy variable 1=experiment 5
EXP6	Experiment 6 choices	Dummy variable 1=experiment 6
TiE	Number of questions answered in the experiment	
TiW	Number of questions answered in the workshop	
TiT	Number of questions answered in total	
MOOR	Moorland coding	
MOORLI	Moorland less intensive dummy coded	0,1
MOORMI	Moorland more intensive dummy coded	0,1
FRIN	Moorland fringe coding	
FRINLI	Fringe less intensive dummy coded	0,1
FRINMI	Fringe more intensive dummy coded	0,1
FARM	Valley bottom farmland coding	
FARMLI	Farmland less intensive dummy coded	0,1
FARMMI	Farmland more intensive dummy coded	0,1
PATH	Footpath coding	
PATHW	Worsened footpath network dummy coded	0,1
PATHB	Improved footpath network dummy coded	0,1
TAX	Tax cost attribute	5,11,18,26,33,55
TIME	Constant of 1	
ONSITE	Dummy for experiment 2	
POSTVIS	Dummy for experiment 3	
LOCAL	1 = considers themselves local	

Experiment 1 – choice experiment conducted prior to visit to the national park (measure of decision utility)
Experiment 2 – choice experiment conducted onsite in the national park (measure of experiential impact)
Experiment 3 – choice experiment conducted immediately after visit (measure of immediate impact of memory)
Experiment 4 – choice experiment conducted 4 months after visit (measure of long term impact of memory)
Experiment 5 – choice experiment conducted after expert witness testimony 1
Experiment 6 – choice experiment conducted after expert witness testimony 2

Socio-Economic Survey Questionnaire

Surveyor Initials:……………… Date of Survey:………………….

Sheffield RELU Farm Number:…………………

FBS code number: ……………
FCE Number ………………….

(Please estimate the farmer’s age: less than 30, 30-40, 40-50, 50-60, 60+)

Farm code number: …………….

Questionnaire 2006

1. Land Area

Q1a. Are you owner or tenant of this farm? Owner Tenant

Q1b. What is the total farm area? ……………...ha

- **Own land** ……………...ha
  - moorland ……………...ha
  - inbye ……………...ha

- **Rented land** ……………...ha
  - moorland ………….£/ha or ………… £/ head of sheep or …………
  - in-bye ………….£/ha or ………… £/ head of sheep or …………

			% of total	Location
• **Upland area (main holding)**	………...ha	or	…...%	……………...
o DA	………...ha	or	…...%	……………...
o SDA moorland	………...ha	or	…...%	……………...
o SDA non-moorland	………...ha	or	…...%	……………...
o Land outside of LFA	………...ha	or	…...%	……………...

- **Other land away from main holding** ………...ha or…...%…………...

- **Nitrate Vulnerable Zone** ………...ha or ..…....%
- **Moorland Protected Area** (SSSI, SPA,SAC) ....ha or ....%
- **In-bye Protected Area** (SSSI, SPA, SAC) ....ha or ....%

Q1c. Do you rent out any land or grazing rights? Yes / No

Moorland ………ha ………….£/ha or ………… £/ head of sheep

In-bye ………….ha ………….£/ha or ………… £/ head of sheep

Q1d. What are the areas of the following land types? (Please indicate on the map where the different land types are.)

				% of total holding	Location
1.	Moorland	………...ha	or	…...%	……………...
2.	Rough grazing	………...ha	or	…...%	……………...
3.	Rush pastures	………...ha	or	…...%	……………...
4.	Permanent pasture	………...ha	or	…...%	……………...
5.	Temporary Grassland	………...ha	or	…...%	……………...
6.	Traditional hay meadow	………...ha	or	…...%	……………...

Q1e. How do you use the moorland?

- **Primarily managed for Grouse shooting** Yes/No ………….Ha
- **Stocking density** Yes / No ………LU/ha
- **OR Livestock numbers**…………………………

		Labour use (e.g. days per year)	Costs without labour (£/ha)
• Cutting	Yes / No	……………...	……………...
• Burning	Yes / No	……………...	……………...
• Other, …………..	Yes / No	……………...	……………...

(Other e.g. spraying, management for conservation, management imposed by landlord)

2. Crops

Q2a. Do you grow any cash crops?   Yes / No

Q2b. What types of crops did you grow last year (2006)?

Crop type	Area (ha)	Yield (t/ha)	Fertilizer use NPK (kg/ha)	Manure (t/ha)	Purpose
……………	………	..………	…………………	……….	on farm/ sale ……….£/t
……………	………	..………	…………………	……….	on farm/ sale ……….£/t
……………	………	..………	…………………	……….	on farm/ sale ……….£/t

Q2c. How much land do you have set-aside?   ……………ha

Q2d. What crop rotation do you use? Please, specify the sequence:

…………… …………… …………… ……………

3. Fodder

Q3a. Did you buy in any feed in the last 12 months Yes / No

If yes, please, specify what type of feed and (approx) how much:

Type of feed	**Amount (t)**	**Price (£/t)**
Concentrates		
Straights		
Hay		
Silage		
Straw (including for bedding)		

Q3b. Do you grow your own fodder? Yes / No.

Q3c. How much did you produce last year?

Type	**Area grown (Ha)**	**Weight Produced (tonnes)**	**No of Bales**	**Size of Bales**
Hay				
Silage				
Straw				
Rape/Kale				

4. Sheep

Q4a. Do you engage in sheep production? Yes / No.

Q4b. What types of sheep breeds do you use? (Percentages of total sheep numbers)

Hill breeds………………..% Mules & half breeds……………%

Pure lowland breeds………% Rare breeds……………………...%

(Surveyor – Fill in table below for total sheep holding but please ask if different average prices were achieved for different sheep breeds)

	Numbers	average price £/head	Numbers	average price £/head
Store lambs sold				
Fat lambs for sold				
Draft ewes for sale				
Live lambs born (nos.)				
Lambs still on farm (nos.)				
Breeding ewes put on the ram last autumn (nos.)				
Home bred replacement ewes (nos.)				

What percentage of your sales are (a) Direct Sales ………. (b) Auction house sales………?

Q4c. Do the sheep have year-round access to moorland? Yes / No

If not, when do they have access?

Spring (March, April, May) ……………...months

Summer(June, July, August) ……………...months

Autumn (September, October, November) ……………...months

Winter (December, January, February) ……………...months

5. Beef production

Q5a. Do you engage in beef production? Yes / No.

Q5b. What system of beef production do you use? Could you indicate the approximate numbers in each category?

	Numbers	**Breed**
Suckler cows		
Calves sold on as store cattle		
Calves finished on the farm		
Store cattle to be finished over winter		
Store cattle to be finished over summer		

Q5c. Could you indicate the number and price of cows/calves sold at market at the following ages over the last 12 months?

	Number	**Price (£/head)**	**Direct sale (%)**	**Auction sale (%)**
< 3 month				
4-11 month				
12-18 month				
19 months - 2 years				
> 2 years				

Q5d. Are there any in-winter facilities for cattle? Yes / No

If yes, how many cattle can be housed? …………..nos.

How many months are the cattle housed for? …………. months

6. Dairy

Q6a. Do you have any dairy production? Yes / No.

Q6b. What type of breed do you use?

	Milking cows on farm	Total dairy replacements on farm	Beef calves sold	
Friesian/Holstein	…………..nos.	……………nos.	…………..nos.	...…………£/head
Ayrshire	……………nos.	……………nos.	…………..nos.	...…………£/head
Jersey	……………nos.	……………nos.	…………..nos.	...…………£/head
Guernsey	……………nos.	……………nos.	…………..nos.	...…………£/head

Q6c. What is the average milk yield per cow? ……………litres/year

7. Other livestock

Q7a. Do you have any other livestock? Yes / No

If yes, what type and how many? ………………… ……………nos.

………………… ……………nos.

8. Farm planning

Q8a. In the next two years, are you planning to change any of the following?

Sheep	Increase	Decrease	Stay the same	NA
Beef Cattle	Increase	Decrease	Stay the same	NA
Dairy	Increase	Decrease	Stay the same	NA
Land Area	Increase	Decrease	Stay the same	

9. Cutting Dates, Application of Fertilizer and Manure

Q9a. Please specify the fertilizer and manure applications along with cutting dates (include all dates) on the following land types, if relevant.

Land types	Amount and application date				Cutting dates e.g. "second week in June"
	Fertilizer NPK		Manure		
	kg/ha	Dates	t/ha	Dates	
Rough grazing					
Rush pastures					
Permanent pasture					
Temporary Grassland					
Traditional hay meadow					

Q9b. What types of manure do you use?

Straw bedding manure
Dairy cattle slurry
Beef cattle slurry
Other

Q9c. Drainage and Boundary Maintenance

Please specify type of work on drainage and boundaries, together with costs and labour.

Land types	Drainage e.g maintenance, gully blocking		Boundary maintenance, e.g walls, fences, hedges	
	Labour use (day)	Total cost (£)	Labour use (day)	Total cost (£)
Moorland				
Non-moorland				

10. Labour

Q10a. How many people work on the farm?

	Full Time	Part Time	Hours/Year	Wage
Family Unpaid				
Family Paid				
Hired Labour				

Q10b. What activities do you contract in on your own farm?

A contractor is defined as someone who is hired in and brings their own machinery but includes walling contractors.

Any other labour input should be included in Q10a as part-time hired labour

Activities	Unit (i.e. days, m, h)	Costs (£/unit)
………………	……………	……………
………………	……………	……………
………………	……………	……………

11. Machinery

Q11a. Does the farm own or hire any machinery?

			Valuation (£)
• Tractor	Own / Hire	……………nos.	……………
• Combine harvester	Own / Hire	……………nos.	……………
• Other	Own / Hire	……………nos.	……………
	Own / Hire	……………nos.	……………
	Own / Hire	……………nos.	……………
	Own / Hire	……………nos.	……………
	Own / Hire	……………nos.	……………
	Own / Hire	……………nos.	……………

Other – Vehicles for farm use and implements (e.g. baler, wrapper, trailers etc)

12. Predator control and species

Q12a. Is there any predator (e.g. Foxes, crows etc) control on your land? Yes / No

By whom?	Days per year
You	……………...
Gamekeeper	……………...
Gamekeeper from neighbouring properties	……………...
Other	………………

Q12b. Could you indicate whether you have noticed any changes in the numbers of the following species on your farm in the last 5 years?

Curlew	Increase	Decrease	No change	NA
Lapwing	Increase	Decrease	No change	NA
Golden Plover	Increase	Decrease	No change	NA
Snipe	Increase	Decrease	No change	NA
Foxes	Increase	Decrease	No change	NA
Crows/Rooks/Jackdaws	Increase	Decrease	No change	NA
Badgers	Increase	Decrease	No change	NA

13. Other income sources

Q13a Do you have a pheasant shoot on your land? Yes/No

Do you receive income? ………………..£

Or Days of shooting?...............................days

Q13b. What activities do you perform to carry out the shoot?

Activities	Unit (i.e. days, m, h)	Costs (£/unit)
………………	……………	……………
………………	……………	……………
………………	……………	……………

Q13c. How much household income comes from the following sources?

Income source	% of total farm income
On farm	
Diversification	
Off farm	

Q13d. Give details of off-farm and diversification activities, for example: Bed and Breakfast, farm shop, jobs off-farm, paid farm work off-farm etc:

………………

………………

………………

……………….

14. Subsidy payments

Q14. Do you take part in any of the following schemes? If not, please, go to question Q15.

If yes, how much payment did you get this year?

a)	Entry Level Stewardship	Yes / No	……………...£
b)	Higher Level Stewardship	Yes / No	……………...£
c)	Environmentally Sensitive Areas Scheme	Yes / No	……………...£
d)	Countryside Stewardship Scheme	Yes / No	……………...£
e)	Single Farm Payment	Yes / No	……………...£
f)	Hill Farm Allowance	Yes / No	……………...£
g)	PDNP Environmental Enhancement Scheme	Yes / No	……………...£
h)	Peak Bird Project's Scheme	Yes / No	……………...£
i)	Woodland Grant Scheme	Yes / No	……………...£
j)	Other …………………..	Yes / No	……………...£

If you are in ELS, HLS, ESA or CSS, please, give more details on subsequent pages.

14a) Entry Level Stewardship

Use the following list as a prompt for the main ELS Options that are available.

- **Options for the Uplands (LFA land)** (e.g. field corners, low input in-bye land, rush pastures, enclosed rough grazing, moorlands and rough grazing, mixed stocking)
- **Grassland outside LFA** (e.g. field corners, low input in-bye land, rush pastures, mixed stocking)
- **Boundary features** (e.g hedge, wall and ditch maintenance)
- **Trees and Woodland** (e.g. protection of in-field trees and maintenance of woodland edges)
- **Historic Landscape Features** (e.g. traditional buildings and archaeological features)
- **Buffer Strips and Field Margins**
- **Arable Land/Crop Types** (e.g. seed mixtures, beetle banks, skylark plots)
- **Soil Protection**

What activities do you do to comply with ELS options? List the top 5 most costly:

Activity	Labour required (hours/year)	If contractor Cost (£)
1 ……………	……………	……………
2 ……………	……………	……………
3 ……………	……………	……………
4 ……………	……………	……………
5 ……………	……………	……………

What was your target number of points? ……………

14b) Higher Level Stewardship

Use the following list as a prompt for the main HLS Options

- **Moorland and Upland Options** (e.g Moorland maintenance and restoration, upland heathland creation, maintenance and restoration of rough grazing for birds, seasonal livestock exclusion, shepherding, moorland re-wetting, managing heather etc by cutting or swiping)
- **Grassland** (e.g. species rich semi-natural grassland, wet grassland management for waders and waterfowl, management for semi-improved or rough grassland for target species)
- **Hedgerows**
- **Woodland Trees and Scrub** (e.g. ancient trees, woodlands, scrub)
- **Historic Features** (e.g. archaeology, traditional water bodies)
- **Arable and Arable options on set-aside** (e.g. margins, fallow plots, seed mix, low input cereals, fertiliser free areas)
- **Resource Protection** (e.g. run-off and erosion reduction)
- **Access Options** (e.g. permissive access, open access)
- **Lowland heathland/Wetland**
- **Supplements** (e.g. Braken control, cattle grazing, native breeds, small fields, difficult sties)

What activities do you do to comply with HLS options? List the top 5 most costly:

Activity	Labour required (hours/year)	If contractor Cost (£)
1 ……………	……………	……………
2 ……………	……………	……………
3 ……………	……………	……………
4 ……………	……………	……………
5 ……………	……………	……………

What was your target number of points? ……………

14c) Environmentally Sensitive Area Schemes

In which tier of ESA are you in and with how many hectares/meters?

<u>Tiers for Dark Peak ESA</u>

Tier 1 A - All Land (Arable and Ley Grassland)	……………ha
Tier 1B - Unimproved grassland and enclosed rough grazing	……………ha
Tier 1B (i) Semi-improved permanent grassland	……………ha
Tier 1B (ii) Unimproved permanent grassland	……………ha
Tier 1B (iii) Enclosed rough grazing	……………ha
Hay meadow supplement	……………ha
Wet area supplement	……………ha
Tier 1 C – Moorland	……………ha
Tier 2 A - Moorland enhancement extensification	……………ha
Tier 2 B- Moorland exclosure	……………ha
Woodland	……………ha
Public Access Tier	……………ha
Restoration supplements	……………ha
Walls	……………metre
Hedges	……………metre

What activities do you do to comply with the ESA Tiers? List the top 5 most costly:

Activity	Labour required (hours/year)	If contractor Cost (£)
1 ……………	……………	……………
2 ……………	……………	……………
3 ……………	……………	……………
4 ……………	……………	……………
5 ……………	……………	……………

When does your ESA agreement end? ……………

<u>Tiers for South West Peak ESA</u>

Tier 1 (Part 1) - All land	……………ha
Tier 1 (Part 2) - Enclosed permanent grassland	……………ha
Tier 1 (Part 3 - Enclosed permanent rough grazing)	……………ha
Tier 1 (Part 4) - Moorland	……………ha
Tier 2 (Option 1) - Pastures and meadows	……………ha
Tier 2 (Option 1) Rm - Regeneration to extensive meadow	……………ha
Tier 2 (Option 1) Rp - Regeneration to extensive pastures	……………ha
Wet area supplement	……………ha
Tier 2 (Option 2) - Moorland	……………ha
Moorland regeneration supplement	……………ha
Small woodland management and regeneration tier	……………ha

What activities do you do to comply with the ESA Tiers? List the top 5 most costly:

Activity	Labour required (hours/year)	If contractor Cost (£)
1 ……………	……………	……………
2 ……………	……………	……………
3 ……………	……………	……………
4 ……………	……………	……………
5 ……………	……………	……………

When does your ESA agreement end? ……………

14d) Countryside Stewardship Scheme

What activities do you do to comply with CSS options? List the top 5 most costly activities:

Activity	Labour required (hours/year)	If contractor Cost (£)
1 ……………	……………	……………
2 ……………	……………	……………
3 ……………	……………	……………
4 ……………	……………	……………
5 ……………	……………	……………

When does your CSS end? ……………

Q15. Are you planning to go into one of these schemes in the future?

a) Entry Level Stewardship Yes / No

b) Higher Level Stewardship Yes / No

Linear Programming model

The general structure of the mathematical models has the form of the standard linear programming model (Hazell and Norton, 1986): Maximise {Z= *c'x*}, Subject to Ax = b and x = 0 where Z is the gross margin at farm level; x the vector of activities; c the vector of gross margins or costs per unit of activity; A the matrix of technical coefficients; b is the vector of resource endowments and technical constraints. The 14 columns of the matrix indicate typical upland farming activities/ practices: moorland, inbye land, fodder production for own use, sheep production, beef production, dairy production, seasonal labour, purchase of fertilizer, purchase of feed, animal production for sale, headage payment, single farm payment, hill farm allowance, and agri-environment payments. The 13 rows of the matrix indicate the type and form of the constraints included: land requirements, land types for fodder production, animal production for sale, labour requirements, housing requirements, feeding requirements, fertilizing requirements, nitrate vulnerable zone, headage payment, single farm payment, hill farm allowance, agri-environment schemes, livestock constraints for HFA and AES. Some activities also occur as constraints, since by choosing these activities (i.e. entering a particular agri-environment scheme and receiving payments), a farmer needs to fulfil the requirements connected with this scheme, which are then shown as constraints (for example, in terms of maximum livestock density per hectare). The objective function of the LP model is to maximise the gross margin, i.e. total returns from animal production and subsidy payments minus variable costs, including variable operations, fertilizer and seasonal labour. The output of the model includes the corresponding production plan with optimal land use, labour use and fertilizer application. To obtain the optimal solution for the LP models, the CONOPT solver was used in GAMS (General Algebraic Modelling System). Model is based on the results of the socio-economic survey carried out as part of this same grant.

Farm model structure

The general structure of the upland farm models is shown in Table 1 and has the form of the standard linear programming model (Hazell and Norton, 1986):

Maximise$\{Z = c^{T}x\}$

Subject to $Ax \leq b$

and $x \geq 0$

where:

Z - gross margin at farm level

x - vector of activities

c - vector of gross margins or costs per unit of activity;

A - matrix of technical coefficients

Table 1. General structure of the linear protramming models

Activities	Moorland	Inbye land	Fodder production for own use	Sheep production	Beef production	Dairy production	Seasonal labour	Purchase of fertilizer	Purchase of feed	Animal production for sale	Headage payment	Single Farm Payment	Hill Farm Allowance	Agri-Environment Payments	Resource endowments and technical constraints
Constraints															
Land requirements	1	1													≤ available hectares
Land types for fodder production	-1	-1	1												≤ 0
Animal production for sale				-aij	-aij	-aij				+aij					
Labour requirements			+aij	+aij	+aij	+aij	-1								≤ available fixed labour in hours
Housing requirements				+aij	+aij	+aij									≤ avaible cattle places
Feeding requirements			-aij	+aij	+aij	+aij			-aij						≤ 0
Fertilizing requirements			+aij		-aij	-aij		-aij							≤ 0
Nitrate Vulnerable Zone		+aij		-aij	-aij	-aij									≤ maximum manure application
Headage Payment				+aij	+aij	+aij					-aij				≤ 0
Single Farm Payment	+aij	+aij										-aij			≤ 0
Hill Farm Allowance	+aij	+aij											-aij		≤ 0
Agri-Environment Schemes	+aij	+aij												-aij	≤ 0
Livestock constraints for HFA and AES				+aij	+aij	+aij									≤ maximum and ≥ minimum livestock unit
Objective function	Costs (£/ha)	Costs (£/ha)	Costs (£/ha)	Gross margin (£/head)	Gross margin (£/head)	Gross margin (£/head)	Costs (£/hour)	Costs (£/kg)	Costs (£/unit)	Revenue (£/head)	Revenue (£/head)	Revenue (£/ha)	Revenue (£/ha)	Revenue (£/ha)	

UNIVERSITY OF STIRLING

DEPARTMENT OF ECONOMICS

The effect of decoupling on marginal agricultural systems: implications for farm incomes, land use and upland ecology

Szvetlana Acs

Nick Hanley

Martin Dallimer

Kevin J. Gaston

Philip Robertson

Paul Wilson

Paul R. Armsworth

Stirling Economics Discussion Paper 2008-18

September 2008

Online at http://www.economics.stir.ac.uk

The effect of decoupling on marginal agricultural systems:

implications for farm incomes, land use and upland ecology

S. Acs, N. Hanley, M. Dallimer, K. J. Gaston
P. Robertson, P. Wilson, and P. R. Armsworth

Abstract

In many parts of Europe, decades of production subsidies led to the steady intensification of agriculture in marginal areas, but the recent decoupling of subsidies from production decisions means that the future of farming in these areas is uncertain. For example, in the uplands of the United Kingdom, an area important both for biodiversity conservation and ecosystem service provision, hill farmers steadily increased stocking densities in response to headage payments but must now reconfigure farm businesses to account for the shift to the Single Farm Payment scheme. We examined hill farming in the Peak District National Park as a case study into the future of marginal agriculture after decoupling. We surveyed 44 farm businesses and from this identified six representative farm types based on enterprise mix and land holdings. We developed linear programming models of production decisions for each farm type to examine the impacts of policy changes, comparing the effects of decoupling with and without agri-environment and hill farm support, and evaluating the effects of removal of the Single Farm Payment. The main effects of decoupling are to reduce stocking rates, and to change the mix of livestock activities. Agri-environmental schemes mediate the income losses from decoupling, and farmers are predicted to maximise take up of new Environmental Stewardship programmes, which have both positive and negative feedback effects on livestock numbers. Finally, removal of the Single Farm Payment would lead to negative net farm incomes, and some land abandonment. These changes have important implications for ongoing debates about how ecological service flows can be maintained from upland areas, and how marginal upland farming communities can be sustained.

KEYWORDS: CAP reform, de-coupling, ecological-economic modelling, upland farming.

JEL codes: Q12, Q57.

1. **Introduction**

In many parts of Europe, decades of production subsidies led to the steady intensification of agriculture in marginal areas. However, the recent decoupling of subsidies from production decisions means that the future of farming in these areas is uncertain. European uplands are nationally and internationally important for biodiversity as well as being of significant landscape, archaeological, recreational and heritage value (Hanley et al, 2007). The UK uplands play a key role in supporting habitats and species of conservation concern (Ratcliffe & Thompson, 1988; Rodwell, 1991). However, large areas of upland habitat deteriorated throughout the last century (Anderson & Yalden, 1981; NCC, 1987; Tudor & Mackey, 1995), due in part to the steady intensification of hill farming (Anderson & Yalden, 1981). English Nature recently found that two thirds of the most valuable moorland areas in England are now in an unfavourable condition with historical and current overgrazing by sheep presenting the most common threat (English Nature, 2005).

Upland farming communities are also seen as being important to maintaining social capital, and for many years governments have offered additional supports to upland farmers in an attempt to sustain incomes, rural services and populations in these areas. The impacts of policy change on the uplands is thus of interest for both environmental and social reasons.

The Common Agricultural Policy (CAP) has been the most important land use policy within the EU. Production-based direct (headage) payments under the CAP provided an incentive for farmers to stock at high densities, which in some cases led to damage to natural and semi-natural vegetation through overgrazing. Problems of surplus accumulation and trade interventions were also important factors for reform of the CAP (HM Treasury & Defra, 2005). The CAP has since undergone a series of significant reforms, most recently those of Agenda 2000 (1999) and the Mid Term Review (June 2003 and April 2004). These reforms are phasing out production-linked support and protection ("de-couling"), and re-targeting support on environmental and rural development outcomes. In 2005, the Single Farm Payment scheme (SFP) was introduced, replacing most existing crop and livestock payments. The SFP is planned to be progressively reduced and phased out (HM Treasury & Defra, 2005), being currently only guaranteed until 2013.

Hill-farmers have come to depend on subsidy programmes additional to those received by farmers outside the uplands, such as the Hill Farm Allowance (HFA), and on payments from agri-enviroment schemes (AES). These programs are also in flux. The Environmentally Sensitive Areas (ESA) program and Countryside Stewardship Scheme (CSS) are in the process of being replaced with the Environmental Stewardship Entry Level (ELS) and Higher Level (HLS) schemes. The current version of the HFA program was due to end in 2007, although it has been extended to 2009. What form any new scheme will take is subject to an ongoing policy debate in the context of the new Rural Development Regulation which covers the period 2007-2013 (Defra, 2006). Reforms to the HFA will have to be in line with the current re-directing of CAP support away from production and towards Second and Third Pillar measures (Latacz-Lohman and Hodge, 2003); it thus seems likely that the HFA will become an agri-environmental scheme targeted at landscape and biodiversity concerns in upland areas.

Changes in core support to upland farmers through the SFP and the HFA, and in agri-environment provisions, could be expected to have significant impacts on how farms are managed, on hill-farm income, and on the ecological impacts of hill-farming (for example, through changes in stocking rates). This paper quantifies these policy reform effects for a range of farm types in the English uplands, for a range of policy scenarios. We use hill farms in the Peak District National Park (PDNP) as a case study. The challenges faced in what is Britain's oldest National Park epitomise those faced throughout the UK uplands. The area is rich in biodiversity, a major carbon store, and provides a major recreational resource for one-third of the UK population that lives within an hour's drive. However, local hill farmers constitute one of the most deprived farming communities in the UK (PDRDF, 2004), with contemporary data indicating that Less Favoured Area (LFA) farms make an average loss (Farm Business Income basis) of £16,000 per farm, from crop and livestock production, offset only by SFP, HFA, AES and diversification revenue to generate a headline Farm Business Income of £10,800; Net Farm Income averaged approximately £6000 per farm (Franks et al 2008). These data clearly demonstrate the link between support payments and farming activity in the uplands of the UK

Given the explicit link between agricultural and environmental activity in the uplands, the analysis of the link between public support and agricultural and environmental activity has received research attention. Several studies have analysed decoupling at the EU level using partial equilibrium models (e.g Witzke and Zintl, 2005; Banse *et al*., 2005; Binfield *et al*., 2005; Chantreuil *et al*., 2008; Britz, 2004) and general equilibrium models (Gohin, 2006; Hertel, 1997), as well as regional and sector models (Shrestha *et al*., 2007; Schmid and Sinabell, 2007) and agent based simulation models (Happe *et al*., 2005). Some studies have investigated the effects on farm outputs and incomes at the farm level (Matthews *et al*., 2006); others have utilised multi-period LP models (Breen *et al*., 2005) in their analysis. However, only Revell and Oglethorpe (2003) have analysed the effects of CAP on the uplands. In contrast to these existing studies, our paper examines the impacts of the decoupling across a range of farm types in a marginal upland setting, in the context of reforms to agri-environmental schemes for an upland area where farming and biodiversity are closely inter-linked. The key outcomes presented here are in terms of changes in farm incomes, land use and ecological pressures, and are related to current biodiversity levels on case study farms. We also cast light on the likely problems due to the partial abandonment of upland livestock enterprises which would appear to follow both from decoupling and from the complete removal of core income support for upland farmers.

2. Methodology

Several techniques can be used to analyse the relationship between agricultural policy and land use decisions at the farm level, including normative and econometric approaches. Mathematical models, such as Linear Programming (LP) and agent-based models, have frequently been used for policy analyses for previous CAP reforms (Donaldson *et al*., 1995; Bos, 2002; Pacini *et al*. 2004; Veysset *et al*. 2005). For present purposes, a mathematical programming approach would seem to be preferable, since we are interested in micro-level predictions of long-run behaviour by rational agents across a range of enterprise types. Econometric models would not allow such a precise spatial or small-scale focus, and are more data-demanding. Agent-based models emphasise the interaction between the agents, however this is not the main focus of this study. Whilst the limitations of LP-type models are well-known[1], the technique has proved to be a robust approach to policy analysis in issues of land use in marginal areas (Hanley *et al.*, 1998) and in the examination of agricultural and environmental trade-offs (Gibbons *et al.,* 2005). In this paper, we therefore construct LP models for a series of representative farm types.

[1] For example, the exogeneity of prices for outputs and inputs.

Socio-economic farm survey

The initial step in the research was a farm survey to investigate how land is managed on hill farms in the Peak District, and to provide inputs to the LP models. The survey was designed and carried out with the help of experienced farm business researchers through the winter months of 2006/2007. It comprised 44 farm visits. Farms were chosen on the basis of their location and their access to moorland grazing (defined as livestock farms within two km of the moorland line). The survey included questions on land area, land types and use, production activities and subsidy payments received during the reference period of 2006.

Main farm types identified are shown in Figure 1, whilst the types of subsidies that farmers in the survey receive are shown in Figure 2. Sheep, dairy and beef cattle production were found to be the dominant activities in the uplands of the Peak District. Two types of land can be distinguished: moorland and inbye land. “Moorland” is defined as unimproved, semi natural rough grazing, situated at higher altitude, providing the poorest grazing. The “inbye” land is agriculturally improved, more productive land situated at lower altitude. Based on the survey results, six types of typical upland farms can be distinguished depending whether a part of the farm has moorland coverage or not[2]: Moorland Sheep & Beef (MSB), Moorland Sheep & Dairy (MSD), Moorland Sheep (MS), Inbye Sheep & Beef (ISB), Inbye Sheep & Dairy (ISD) and Inbye Beef (IB). In terms of subsidy payments, the SFP and HFA are received by most farmers. However, in addition, many farmers participate in different agri-environmental schemes.

[2] This distinction was important for ecological measurement and modelling purposes.

2.2 Farm modelling

2.2.1 General approach

The general structure of the mathematical models is shown in Table 1 and has the form of the standard linear programming model (Hazell & Norton, 1986):

Maximise $\{Z= c'x\}$

Subject to $Ax \leq b$

and $x \geq 0$

where:

Z =gross margin at farm level

x = vector of activities

c = vector of gross margins or costs per unit of activity

A = matrix of technical coefficients

b = vector of resource endowments and technical constraints

The group of activities, based on typical upland farming practices, are shown at the top of the Table 1 under 14 headings: activities for different land types, production activities representing several fodder crops and animal production systems, seasonal labour, purchase of fertilizer and feed, and activities for sold animal products and subsidy payments. The rows of the matrix indicate the type and form of the constraints included: land availability, supply and demand of fixed and seasonal labour, feeding and housing requirements for livestock, fertilizing requirements per land type, constraints on organic manure use in Nitrate Vulnerable Zone, constraints on subsidies for headage and Single Farm Payment based on production and land type, respectively; and restrictions for payments from Hill Farm Allowance and different agri-environment schemes. The objective function of the LP model is to maximise the gross margin, i.e. total returns from animal production and subsidy payments minus variable costs, including variable operations, fertilizer and seasonal labour. The output of the model includes the corresponding production plan with optimal land use, labour use and fertilizer application. To obtain the optimal solution for the LP models, the CONOPT solver was used in GAMS (General Algebraic Modelling System).

2.2.2 Production elements

The central element in the LP models is animal production, comprising sheep, beef and dairy. The production and the feeding requirements for each of these types are described below.

The sheep production model is based on an upland crossbreed ewe with finished and store lamb production with lambing in March-April. The feeding requirements for ewe and lambs are taken from The Farm Management Handbook 2006/07 (Beaton, 2007). The feeding requirement consists of grass grazing, silage, hay and ewe concentrate. We assumed that 1.5 lambs are born per average ewe with a 4% mortality rate. Due to voluntary and involuntary disposal of ewes, we assume that each year 25% of the ewes are replaced by gimmers raised on the farm. The ram requirement is also included, 2.5 per 100 ewes. Housing sheep is very unusual in the study area, and thus no housing requirement for sheep was specified. The returns from ewe production come from finished and store lambs, cull ewes and wool sales. The costs per ewe include those of health care, feed additives, shearing, and other costs (commission, levies, haulage and tags).

The beef cattle production model is based on a suckler cow calving in February-April and sold either young (6-12 months) or fat (12-24 months)). This includes 10% calf mortality and 1% cow mortality. The bull ratio is 1 to 35 cows. The suckler cow replacement is 7 years, which comes from purchased heifers. In winter the suckler cows are kept inside. The feeding requirement of cows and calves in winter consists of silage, straw, cow concentrates, cow cobs and some grazing. In summer the cows with calves are kept outside and fed by silage and grazing. The returns from beef production come from calf sales, minus the cost of replacements. The cost per suckler cow include those of concentrate and cow cobs, health care, straw bedding and other costs (commission, haulage and tags).

The dairy cattle production model is based on a 650kg Friesian Holstein dairy cow with a calving interval of 390 days and 6500 litre average milk production per year is used. The calves are sold either young (1 month) or fat (15-20 months). Calf mortality is 10% and the cow mortality is 1%. A 25% replacement rate is assumed with purchased heifers entering the dairy herd. Cull cows are sold for £300/head. The cows are kept inside in winter for 180 days and fed with silage and concentrates. In summer they are grazed outside and get additional forages and concentrates. The returns from dairy production come from milk production and calf sales. The costs per cow include those of concentrate, AI, vet and medicines, and other livestock expenses.

The output prices and input costs used for sheep, beef and dairy production are based on averages from the survey results across all the farm types and on The Farm Management Handbook (SAC 2006).

Feed production and purchase

The land on the farm can be used for growing grass for grazing and fodder production purposes. On inbye land, grass can be grown for grazing or fed in the form of silage or hay to sheep and to cattle. On moorland and rough grazing, only sheep can be kept for grazing, which fulfils part of their feeding requirement. Silage can be fed in winter and in summer. In addition to home-grown feed, concentrates can be purchased. Dry matter production of grass, silage and hay makes the link between the feeding requirements of sheep and cattle and supply by each land type. The dry matter production of grassland per year depends mainly on the amount of water and nutrients as well as on growing conditions. The effect of nutrients in the model is distinguished through different levels of nitrogen (N) use. The most commonly used combination of nitrogen use and cutting frequencies (1-3 cuts for silage and 1 cut for hay) were represented with separate activities ranging from 0 to 375kg N/ha (Beaton, 2007). The following main types of land use were distinguished: grass used only for grazing (N: 75, 125, 175, 250 or 375 kg/ha), grass used for silage with aftermath grazing (1, 2 or 3 cuts; N: 0, 125, 220, 250, 275, 300 or 375 kg/ha) and grass used for hay with aftermath grazing (1 cut; N: 0, 70, 125, 200). The costs of grassland include costs of renewal and sprays. On moorland no cutting or fertiliser use is specified.

Labour

Sheep and beef cattle require labour inputs. Throughout the year a particular amount is necessary for each period. Therefore the year is divided into months. Based on the survey, the amount of available unpaid family labour is assumed to be 0.8-1.7 full-time labour units (1 labour unit = 2600 hours/year) depending on the farm type. Apart from family labour there is the option of hiring seasonal labour. Labour can be hired at any time of the year at a cost of £5, £6.25, £7.5 and £6 per hour for sheep, beef, dairy and grass production, respectively. Information about the labour requirement per head (ewe or cattle) and per hectare (hay, silage making) is derived from the Farm Management Pocketbook (Nix, 2007).

Fixed costs

Fixed costs are calculated separately from the LP-model based on the socio-economic survey and data for Peak District hill farms from the Farm Business Survey given input factors such as the main production activity, the farm size, basic machinery and buildings, land rent and rental value and other miscellaneous costs (i.e. electricity, insurances, professional fees, farm maintenance).

2.2.3 Agri-environment and income support schemes for upland farmers.

Farmers in the uplands can take part in many different schemes. Payments under the CAP (in terms of the former headage payment and the Single Payment Scheme) are taken into account, along with other important schemes for the uplands such as the Hill Farm Allowance and the new agri-environmental schemes (Environmental Stewardship Schemes). The old agri-environmental schemes were not taken into account, since they are gradually being replaced with the new schemes, and most of them will be phased out by 2012. Headage payments have long been used to support sheep and cattle farming in the uplands. These historic direct subsidy schemes for sheep, beef and dairy production can be seen in Table 2. Most have now been phased out as part of the de-coupling process, but underlie the calculation of the Single Farm Payment in terms of historic payment rates.

The Single Farm Payment scheme replaced most crop and livestock payments from 2005, including those mentioned in Table 2. To comply with this scheme, farmers need to keep their land in good agricultural and environmental condition and comply with specified legal requirements relating to the environment, public and plant health and animal health and welfare ("cross-compliance"). In England, the payment consists of two elements: historical and flat-rate regional average payments. The historical payment is additional to the flat-rate payment, the amount of which is based on producers' historical claims during the 2000-2002 reference period. During the period of 2005-2012 the scheme will move from low percentage flat-rate and high percentage based on historical payments to a simple flat rate across all eligible land in England. The proportion of these payments can be seen in Table 3. The flat rate payments per land type for 2005 and the estimated flat rate payment in 2012, when it will account for 100% of payments, can be seen in Table 4. For the model, estimated payments for 2012 were included after deductions due to modulation. To receive SFP, a unit of land is required regardless of any activity on the farm. Thus, the payment is connected to the eligible land types and quantity on the farm. The payment also incurs costs of compliance, which was estimated based on the costs per hectare required to maintain grassland in "good agricultural condition". This amounted to approximately £13 per hectare for natural regeneration (SAC, 2006). In the model this was represented by the constraint that all land must be used for at least some agricultural activity, including maintenance of the land without using it for production. The constraint was set separately for the inbye land types (rough grazing and grassland). For moorland no restriction was made.

The Hill Farm Allowance is a compensatory allowance for cattle and sheep farmers in the English Less Favoured Areas (LFAs) in recognition of the difficulties they face and the vital role they play in maintaining the landscape and rural communities of the uplands. In our analyses we included the current form of the HFA payment. However, the HFA scheme will itself be revised. Currently HFA is based on area payments, which are made at different rates for different types of land and size of holding (Table 5). These payments are included in the model attached to the corresponding land types. For compliance with this allowance a minimum (0.15 LU/ha) and a maximum (1.4 LU/ha) constraint is set for the stocking density in order to avoid under- and overgrazing.

Agri-environment payments are intended to compensate or provide an incentive for farmers to undertake measures which go beyond Good Farming Practice. The Entry Level (ELS) and Higher Level Stewardships (HLS) were added to the model as payment for achieving the "Target point", which can be collected by certain management activities ("options") on the farm. The most frequently used options of ELS and HLS in the upland area of PDNP were selected and added to the model (Table 6). The ELS payments are £8/ha for LFA and £30/ha for non-LFA land types. The payments for selected HLS options can be seen in Table 6. These options can be taken up, with restrictions on fertiliser use and livestock density, as part of the maximisation of gross margin. Finally, most of the farms in the uplands in this region are situated within a Nitrate Vulnerable Zone, which imposes a limit on organic manure applications. The maximum is at 250kg/ha of total nitrogen each year averaged over the area of grass on the farm. This limit is also included in the model as a constraint.

2.3 Calibration of the farm models

The models incorporate all livestock and grass production activities carried out on the upland farms and can thus be calibrated to represent any particular farm situation in terms of basic resource endowments. Based on our survey the six typical farm types for the uplands are represented by the averages of these farm types. The six different models included calibration on the main production category (sheep, beef, dairy), on different land types, housing capacity for livestock and household labour availability (Table 7). We assumed no switching between the farm types, but allow for switching between livestock production activities within the same farm type. In order to ensure that the models provided an accurate simulation of current farming activity for representative farm types, each model calibration was completed and the output from the model (by using the same livestock numbers as in the survey averages), in terms of returns to enterprises and input costs, was compared with the survey data. Since the model is to be used to assess impacts upon the relative balance of different enterprises and associated changes in resource use, the key parameters of interest in this validation process are i) the proportion of revenue from livestock (% of total revenue from sheep, beef, dairy), ii) the proportion of variable costs (feed, seed, fertiliser, hired labour) of total costs and iii) the total net farm income (NFI). Table 8 provides a summary for these items for each farm type, for both the model and the observed survey data of 2006. Although there are inherent weaknesses in LP modelling due to factors such as assumed maximising behaviour and the explicitly linear technology (constant input-output coefficients), the models provide a reasonably accurate simulation of both farm revenue, production and cost structures.

2.4 Policy scenarios

The aim of this paper is to investigate the impacts of agricultural policy reform in marginal upland areas, in the context of on-going reforms to agri-environmental policy. The main impacts to be considered are those on farm incomes, land use and ecological pressures. The policy scenarios therefore chosen were: "Headage Payment"(HP), "Single Farm Payment"(SFP) and "No Payment" (NP) scenarios. This choice was based on focusing on three different points in time: the situation before de-coupling (HP scenario), after de-coupling (SFP scenario) and when the SFP disappears (NP scenario). These core agricultural policy scenarios are considered in interaction with additional upland supports: the HFA as currently implemented, since its reformed status is unsure at present – although as explained above this will probably become a new agri-environment scheme just for the uplands - and Environmental Stewardship options as the main agri-environmental schemes (AES). This generates three additional scenarios: (HP & AES/HFA, SFP & AES/HFA, NP & AES/HFA), giving a total of 6 policy scenarios in all[3]. The model was set to 2006 output price and input cost levels for all farming activities; whilst recent price movements in both agricultural output and input price markets have occurred, the modelling approach centres upon gross margin analysis and it is argued that the 2006 gross margin levels are an appropriate base-level for the analysis. Sensitivity analysis was then undertaken for key output and input prices.

In the "Headage Payment" scenario we model the policy situation as it existed before the introduction of the SFP. For the "Single Farm Payment" scenario we use a situation where the flat rate payment will account for 100% of payments (as planned for 2012: Table 4)[4]. In the "No Payment" scenario we assumed the loss of the SFP but also the relaxation of cross-compliance constraints which go along with this.

3. Results

Optimal production plans

From the perspective of upland biodiversity, the most important impacts of policy reform are those on land use, livestock density and fertiliser use: this section thus focuses solely on these variables. The changes in predicted land use for each farm type across the six policy scenarios can be seen in Table 9. The land that is used for livestock production or maintenance - under SFP and AES - is taken as a proportion of the total land availability per farm type. "Unused land" is land that is left as fallow.

[3] For brevity, the "AES/HFA" treatment is henceforth referred to simply as "AES".
[4] The historical payments differ considerably between the farms and farm types and this is the year when all farm payments will be completely detached from historical production and based only on their current eligible land types. These estimated payments for all three land categories, after deductions from modulation, were used for this scenario analysis, including the compliance constraints discussed above.

Under the HP scenario all land is used for livestock production. Under the SFP scenario, all inbye land continues to be used for production or maintenance, since the payment is based on the land used for agricultural purposes. On moorland farms, however, not all moorland is used. In the case of the NP scenario even more land is left fallow, including both moorland and inbye land types. The difference between the land area used in SFP and NP scenarios comes from the compliance obligation on farmers to obtain the SFP. The optimal solution balances the marginal cost and revenue coming from production and that coming from the cross-compliance obligation and payments from the SFP. The three scenarios with AES payments show similar results to those without AES: however, with new restrictions resulting from AES contracts, in general more land is used. This is due to the adoption of more extensive production and more options for farmers to maintain their land and receive a payment for it. The ELS and HLS schemes that are taken up for each AES scenario and farm type can be seen in Appendix 1. In summary, the predicted uptake of AES schemes and the preferred options differ markedly among farm types and within farm types depending on the nature of core subsidy support (HP, SFP or NP). The loss of the SFP results in many more farms leaving their land fallow, since the constraints on maintaining land in Good Agricultural Condition are no longer binding. The largest fallowing of land occurs in the MSD farm type, where only 53% and 13% of the land is used with and without AES, respectively, after loss of the SFP. The ISD and IB farm types also have more than half of the land fallow without AES. This means that not only the SFP but also the AES are important for keeping the land in production, or for maintaining it in "good condition".

The optimal livestock production for the six policy scenarios and the six typical farm types can be seen in Table 10. The results show that under the historic HP scenario, beef and dairy is preferred to sheep production. This means that in the case of all farm types the maximum amount of beef and dairy production occurs, given the cattle housing capacity constraints of the farm, with the remainder of the land being used for intensive sheep production. By switching from the HP to the SFP and NP scenarios, livestock numbers decrease, as do grazing livestock units (LU) (Figure 3). In general, livestock densities on the moorland farms are quite low, between 0.2 and 0.8 LU/ha for all the scenarios. This figure is higher for inbye farm types, at between 0.4 and 1.5 LU/ha. Besides extensification, decoupling leads to structural change within farm types. There is a large predicted fall in beef cattle numbers under the SFP and NP scenarios for some farm types: this dramatic cut is not prevented by the availability of AES. In general, beef production is declining, and in certain farm types it disappears entirely. This is due to the lower profitability from beef production after decoupling compared to that of sheep. A structural change can also be seen in sheep and dairy farms, where dairy activity is preferred to sheep from an economic point of view. This means on the MSD farm type sheep numbers are declining, while on the ISD farm type sheep production completely disappears.

The higher livestock units on farms under the HP scenario requires more fodder which leads to more intensive grass production for grazing, silage and hay. This is supplied by higher amounts of fertiliser use per hectare on grassland. For all farm types fertiliser use declines considerably after decoupling, except for the dairy farm types MSD and ISD (see Table 12 for details).

Financial results

Prior to the inclusion of AES/HFA payments, the results show positive gross margins in the case of all scenarios for all farm types (Figure 3). However, the net farm income (NFI) is negative for five out of six farm types, with the exception of the ISD farm type (Figure 5a), which is the most profitable in the Peak District as milk production generates the highest income in the uplands. In switching from HP to SFP or NP, the greatest losses are in beef farming. However, all farm types lose income after the switch from HP to either SFP or NP. The IB farm type shows the most negative net farm income due to relatively high fixed costs, which comes from the high rental costs for land and the large amount of machinery kept on the farm. Figure 5b shows equivalent results for net farm income once the option to receive AES/HFA payments is included. The major impact is to moderate income losses in the move away from HP to either SFP or NP.

Farmers in the uplands also get income from other sources, such as from diversification and off-farm sources. Actual levels of NFI under the policy scenarios considered will thus likely be higher (Franks *et al*,. 2008). Results not reported in detail here showed that once estimates of these income streams are included, all the farm types will have positive NFI under all scenarios, except the MSB and MS farm types under the NP scenario. This result shows that many farmers depend not only on AES schemes but also on the other income sources coming from off-farm and diversification for their long-term financial sustainability (Figure 5c).

Sensitivity Analysis

We investigated the implications for key outcomes (farm income, stocking rates and land abandonment) of increases in certain output and input prices above the base case of the most common sheep and beef farm types. 25% rise in lamb, calf and concentrate prices were modelled. This showed that, in the case of MSB farm type, higher input prices would lead to lower NFI with lower stocking density and more land abandonment of 28% and 26% for the SFP&AES and NP&AES scenarios, respectively. Higher output prices would lead to 95% and 100% land use and higher stocking density for the latter scenarios. In the case of HP&AES

there is no change on the production structure only on the income of the farmer. Similar results can be drawn for ISB farm type concerning the NFI and stocking density, however all the land area would be used for production in all these cases.

4. Discussion

The key results that emerge from the analysis described above is that the effects of policy reform vary substantially across farm type, but some general trends can be discerned. Our discussion of these findings is organised according to (i) the effects of de-coupling itself, (ii) the mediating effects of agri-environment scheme payments (including the HFA), (iii) the effects of loss of the Single Farm Payment, and (iv) ecological implications. For all cases, the base level is the HP scenario (Table 12). Absolute levels for income are shown in Table 11.

4.1 What are the impacts of decoupling?

The most relevant comparison here is the (HP&AES) scenario with the (SFP&AES) scenario.

i) Effects on net farm income are slight. Two farm types see a small decrease in net farm income, and one a small increase. The magnitude of the change in overall NFI is typically less than the magnitude of the change in subsidy, because it is modified by behavioural changes.

ii) Decoupling has mixed effects on the amount of land being used for agricultural production, ranging from 18% coming out of production for one farm type to 11% more going into production for another. On the whole, though, the amount of land used or maintained changes little.

iii) The major effect of decoupling is reductions in stocking densities (Figure 3), but these vary by a factor of three across farm types as a percentage rate (from -27% to -79%).

iv) The aggregate pattern regarding stocking densities masks a lot of what is going on. Suckler cow numbers are greatly reduced and abandoned altogether on moorland sheep and beef farms. The effect on sheep varies from minimal on some farm types to abandonment of sheep production on others. Decoupling has no effect on dairy production, which is operated at a capacity dictated by animal housing constraints.

v) Decoupling also results in less fertiliser application, but again how this plays out depends on farm type, with no change on some and 80-100% reductions on others. However, in general fertiliser use is relatively low in these upland areas for all farm types.

4.2 What are the moderating effects of agri-environmental policies on decoupling?

Agri-environmental schemes offer income earning opportunities for farmers, but also constrain their operations. The relevant comparison here is (HP&AES to SFP&AES) compared with (HP to SFP).

i) AES schemes play a major role in changing the overall economic impact of decoupling (Figure 5a, Figure 5b, Table 11). Instead of facing large losses, the various farm types face either much smaller losses or in some instances actually stand to gain from decoupling. This is because the two policy instruments are now pulling in the same direction rather than pulling against one another. However, we have to note that the models predict the maximum uptake of the most commonly used AES schemes for the given land types. This means that the uptake can differ based on farm specific circumstances, where a broader range of these schemes are available, and for some schemes (HLS) competition does not always lead to success in getting the desired payment, which can result in a slightly different economic outcome.

ii) Moderation of the effect of decoupling by AES has mixed implications for the amount of fallowing. Some farm types fallow more than they would otherwise have done and some less.

iii) AES leads to a greater losses of suckler cow production than would otherwise have resulted, which may lead to unfavourable ecological outcomes (for example, with regard to some bird populations such as lapwing). For sheep, decoupling and AES are sometimes pulling in the same direction resulting in greater losses than under decoupling alone (due to extensification requirements of AES) and sometimes in opposing directions meaning smaller reductions in sheep numbers because of AES payments.

iv) AES schemes have little effect on the outcome of decoupling for fertiliser application rates.

4.3 What would be the effect of loss of the Single Farm Payment?

Here the relevant comparisons are of (SFP & AES) with NP; and of (SFP & AES) with (NP & AES). The former shows the effects of removing all subsidy; the latter shows the more realistic outcome of the removal of direct income support with the retention of agri-environmental payment schemes.

Taking the extreme case first (removal of all subsidy), we see that this results in considerable land abandonment (Table 9) on three farm types, including two inbye farm types. The loss of all subsidy support would also result in five out of six farm types having a negative net farm income, and thus being financially unsustainable. Four would have a negative income even when including revenue from off-farm sources and diversification activities. The fifth farm type, ISB, that becomes financially sustainable when including these sources changes livestock production to sheep only, and intensifies land use. Relatively little change happens to moorland sheep production, except on the MSD farm type where sheep production ceases entirely.

Turning to the more realistic case where AES (and, one presumes, the replacement for HFA) carries on after the loss of the SFP, we can see that the loss of SFP alone causes a number of important changes. First, net farm income falls considerably on all farm types, and becomes negative in 5 out of 6 cases, if we ignore income from off-farm sources and diversification. For moorland sheep and moorland sheep and beef, income becomes negative even with these other sources. The main conclusion is that loss of SFP will have a serious effect on the long-term viability of hill farms in the Peaks. The intensity of livestock production also falls in most cases, whilst land abandonment increases, especially on mixed moorland farms.

4.4 Comparison to other studies

Our results show that it is likely that there will be a move away from beef production towards sheep, although for both categories of livestock, total numbers are likely to fall. This extensification, lower fertiliser use and shift from beef to sheep production in the uplands has been noted by others for the UK (Revell and Oglethorpe, 2003; Oglethorpe, 2005; Matthews *et al*., 2006) and in the EU-15 as a whole (Balkhausen *et al*., 2008). Moss *et al.* (2005) predicted a reduction of 16.7% in beef animal numbers and a 9.5% reduction in sheep. Our results show no decline is expected in the dairy enterprise in the uplands, given current price levels. However, some EU studies have forecast that the prices will fall after CAP reform which will reduce gross margins of the dairy enterprise due to the reduction in the price of milk. Fewer but larger dairy herds were also predicted after this change in the uplands (Shrestha *et al*., 2007).

Land abandonment after decoupling is limited in our results by the requirement to keep the land in good agricultural and environmental condition under SFP. Similar results were found in other studies (Defra, 2004; Oglethorpe, 2005; IEEP, 2007; Revell and Oglethorpe, 2003). However, in marginal areas like moorland, abandonment might take place sooner due to the lower productivity of the land (Primdahl *et al.,* 2003; Defra, 2004). With regard to predicted changes in income, Oglethorpe (2005) found that decoupling would lead to net farm income becoming negative, other than for dairy. This result is also supported by the findings of this study for all the farm types except for inbye sheep & dairy, which currently is the most profitable enterprise in the uplands.

4. 5 Ecological implications

The land use changes predicted under these different policy scenarios will have important implications for upland ecosystems. To illustrate, we focus on the implications for biodiversity using the number of different bird species as an indicator. The bird community was surveyed on the same farms from which farm management data had been collected for the LP models in the following breeding season (2007; Dallimer *et al. ms*). The average number of different species ("species richness") for each farm type categorised into moorland and inbye land when appropriate are shown in Table 13, column 2. We also identified two subgroups of species of particular conservation interest. First, we identified the subset of species with an upland breeding distribution in the UK. These species include particularly emblematic examples of upland wildlife, such as the curlew (*Numenius arquata*) and ring ouzel (*Turdus torquata*), and could form local conservation priorities for these habitats: these numbers are shown in column 3. Then, we identified a second subset of species that are of national or international conservation concern, including red and amber listed species, UK Biodiversity Action Plan species and species listed in the European Community's designation of part of our study area as a Special Protection Area for wild bird conservation. These are shown in column 4.

Inbye habitats contained more species overall and more of national conservation concern, however, moorland habitats held a greater richness of upland specialist species. Farms that were composed of both moorland and inbye, had higher species richness in their inbye areas than the more intensive inbye-only operations. As such the prediction that farming will generally become less intensive under CAP reform on these inbye-only operations (with the one exception being ISB in the extreme case of no subsidies) may help biodiversity. MSB farms are richest in overall species and in upland specialists on either habitat type. As such, the loss of suckler cows and conversion of these operations just to sheep production (MS), along with the worsening economic circumstances of this sector, could pose particular problems for upland ecosystems. Such a prediction is supported by more detailed ecological analyses, where species richness was higher on farms where cattle were grazing (Dallimer *et al., ms;* Evans *et al.,* 2006). Land abandonment has been shown, historically, to lead on average to a loss of biodiversity in upland grazed systems (Hanley *et al*, 2008), so that any policy changes which increases abandonment will likely have adverse consequences for biodiversity.

5. Conclusions

In this study the aim was to investigate how policy changes under CAP reform affect farmers' income and land use in marginal upland farming systems, and to relate these to likely ecological impacts. Different policy scenarios were analysed and compared using linear programming models developed for six representative farm types in the Peak District. Results show that the change from headage-based payments to the Single Farm Payment motivates farmers to operate more extensively with part of the moorland left unused, although there is little real risk of land abandonment due to the contract requirements of the SFP. Removal of the SFP results in still lower livestock numbers, negative net farm incomes in most cases, and a rise in land abandonment. Agri-environment schemes moderate the impacts of decoupling, and play a vital role in supporting hill farm incomes. Indeed, an interesting side-effect of decoupling is predicted to be a rise in desired uptake of agri-environmental schemes, and thus an increase in competition for limited-fund schemes such as Higher Level Environmental Stewardship. This should promote increased cost-effectiveness in the delivery of public environmental goods on upland farms so long as the contract rationing scheme rewards both supply price and expected environmental delivery.

Acknowledgements

This study would not have been possible without the generous time commitment and interest of the hill farmers of the Peak District. Help identifying suitable farms was provided by: NFU; Catherine Gray and other staff at the Peak District National Park; Aletta Bonn of the Moors For the Future Partnership; Mike Innerdale and Russell Ashfield of the National Trust; Chris Thomson of the RSPB; and Andrew Critchlow. Socio-economic surveys were performed by Helen McCoul, Richard Darling, John Farrar, Nick Harpur and Robert Yates of the Rural Business Research Unit at the University of Nottingham. Funding was provided by the RELU programme of the UK Research Councils. K.J.G holds a Royal Society Wolfson Research Merit Award. We thank David Oglethorpe for his advice on construction of the farm models used here.

References

Anderson, P., Yalden, D.W. 'Long-term changes in the extent of heather moorland in upland Britain and Ireland: palaeoecological evidence for the importance of grazing', *Biological Conservation,* Vol. 20, (1981) pp. 195-213.

Banse, M., Gerthe, H. and Nolte, S. *Documentation of ESIM Model Structure, Base Data and Parameters* (Berlin, Göttingen, 2005)

Beaton, C. *The Farm Management Handbook 2006/07* (Edinburgh, SAC, 2007, 27th Edition, pp. 520)

Binfield, J., Donnellan, T., Hanrahan, K. and Westhoff, P. *CAP Reform and the WTO: Potential Impacts on EU Agriculture* (Selected Paper for presentation at the American Agricultural Economics Association Annual Meeting, Denver, CO, USA, 1-4 July 2004).

Balkhausen, O., Banse, M. and Grethe, H. 'Modelling CAP Decoupling in the EU: A Comparison of Selected Simulation Models and Results**',** *Journal of Agricultural Economics*, Vol. 59, (2008) pp. 57-71.

Britz, W. *CAPRI Model System Documentaion. Common Agricultural Policy Regional Impact Analysis* (Bonn, 2004)

Pacini, C., Wossink, A., Giesen, G. and Huirne, R. 'Ecological-economic modelling to support multi-objective policy making: a farming systems approach implemented for Tuscany', *Agriculture, Ecosystems & Environment,* Vol. 102, (2004) pp. 349-364.

Chantreuil, F., Hanrahan, K. and Levert, F. 'The Luxembourg agreement reform of the CAP: An analysis using the AG-Method composite model', in *Balkhausen et al. Journal of Agricultural Economics, Vol.* 59, (2008) pp. 57-71.

DEFRA (2004) 'An assessment of the impacts of hill farming in England on the economic, environmental and social sustainability of the uplands and more widely', *A study for Defra by the Institute for European Environmental Policy, Land Use Consultants and GHK Consulting, February 2004.* (available at: http://statistics.defra.gov.uk/esg/reports/hillfarming/default.asp ; 2004; last accessed November 2007)

DEFRA. *Entry Level Stewardship Handbook. Terms and Conditions and how to apply*. (2005a) pp 113.

DEFRA. *Higher Level Stewardship Handbook. Terms and Conditions and how to apply.* (2005b) pp. 120.

Defra, *Rural Development Programme for England: 2007- 2013 - uplands steward structure* (2006)

Dennis, R. The importance of extensive livestock grazing for woodland biodiversity: traditional cattle in the Scottish Highlands (1999) in Defra 2004

Donaldson, A.B., Flichman, G. and Webster, J.P.G. 'Integrating agronomic and economic models for policy analysis at the farm level: the impact of CAP reform in two European regions', *Agricultural Systems,* Vol. 48, (1995) pp. 163–178.

English Nature *Sites of Special Scientific Interest* (available at: http://www.english-nature.org.uk/special/sssi/; 2005)

Evans, D.M., Redpath, S.M., Evans, S.A., Elston, D.A., Gardner, C.J., Dennis, P. & Pakeman, R.J. 'Low intensity, mixed grazing improves the breeding abundance of a common insectivorous passerine'. *Biology Letters 2*, (2006) pp. 636-638.

Franks, J, Harvey, D. Scott, C. (2008). Farm Business Survey 2006/07 Hill Farming in England (available at http://www.ruralbusinessresearch.co.uk/) accessed 8 July 2008.

Schmid, E. and Sinabell, F. ‚On the choice of farm management practices after the reform of the Common Agricultural Policy in 2003', *Journal of Environmental Management,* Vol. 82, Issue 3, (2007) pp. 332-340

Gibbons, J.M., Sparkes, D.L., Wilson, P. and Ramsden, S.J. Modelling Optimal Strategies for Decreasing Nitrate Loss with Variation in Weather- A Farm-Level Approach, *Agricultural Systems*, Vol 83 (2), (2005) pp 113-134.

Gohin, A. 'Assessing the CAP reform: Sensitivity of modelling decoupling policies', *Journal of Agricultural Economics*, Vol. 57, (2006) pp 415-440.

Hanley, N., Kirkpatrick, H., Oglethorpe, D. and Simpson, I. "Paying for public goods from agriculture: an application of the Provider Gets Principle to moorland conservation in Shetland". *Land Economics*, 74 (1), (1998) 102-113.

Hanley, N., Colombo, S., Mason, P. and Johns, H. 'The reform of support mechanisms for upland farming: paying for public goods in the Severely Disadvantaged Areas of England', J*ournal of Agricultural Economics*, 58 (3), (2007) pp. 433-453.

Hanley, N., Tinch, D., Angelopoulos, K., Davies, A., Barbier, E. and Watson, F. 'What drives long-run biodiversity change? New insights from combining economics, paleoecology and environmental history' *Journal of Environmental Economics and Management*, (2008) forthcoming.

Happe, K., Balmann, A., Kellermann, K., Sahrbacher, C. 'Agent-based modelling and policy analysis – the impact of decoupling on farm structures', Institute of Agricultural Development in Central and Eastern Europe (IAMO), Halle (available at: http://www.kathrin-happe.de/; 2005; last accessed: 5 May 2008)

Hazell, P.B.R and Norton, R.D. *Mathematical Programming for Economic Analysis in Agricutlure* (Macmillan Publishing Company, New York, 1986)

Hertel, T.W. *Global Trade Analysis: Modeling and Applications* (Cambridge: Cambridge Uniersity Press, 1997)

HM Treasury and Defra. *A Vision for the Common Agricultural Policy* (available at: www.defra.gov.uk ; 2005 pp. 69; last accessed: 7 September 2007.)

IEEP. *An assessment of the impacts of hill farming in England on the economic, environmental and social sustainability of the uplands and more widely.* (A study for Defra by the Institute for European Environmental Policy, Land Use Consultants and GHK Consulting, February 2004)

Breen, J. P., Hennessy, T.C. and Thorne, F.S. 'The effect of decoupling on the decision to produce: An Irish case study', *Food Policy,* Vol. 30, Issue 2, (2005) pp. 129-144

Bos, J.F.F.-P. *Comparing specialised and mixed farming systems in the clay areas of the Netherlands under future policy scenarios: an optimisation approach* (Ph.D. Thesis; Wageningen: Wageningen University, 2002)

Latacz-Lohmann U. and Hodge I. 'European agri-environmental policy for the 21st century', *Australian Journal of Agricultural and Resource Economics*, Vol. 47, (2003) pp.123-139

Matthews, K.B., Wright, I.A., Buchan, K., Davies D.A. and Schwarz, G. 'Assessing the options for upland livestock systems under CAP reform: Developing and applying a livestock systems model within whole-farm systems analysis', *Agricultural Systems*, Vol. 90, (2006) pp. 32-61.

Moss, J., Binfield, J., Westhoff, P., Kostov, P., Patton, M., Zhang, L., *Analysis of the impact of the Fishler Reforms and potential trade liberalisation* (Food and Agricultural Policy Research Institute (FAPRI), 2005)

NCC *Changes in the Cumbrian Countryside* (NCC, Peterborough, 1987)

Nix, J. *Farm Management Pocketbook* (37th Edition, The Andersons Centre, 2007)

Oglethorpe, D.R. 'Livestock production post CAP reform: implications for the environment', *Animal Science*, Vol. 81, (2005) pp. 189-192.

PDRDF. *Hard Times – a report into hill farming and farming families in the Peak District. (*Peak District Rural Deprivation Forum, Hope Valley, Derbyshire; available at: http://www.pdrdf.org.uk/hillfarmingreport.htm; 2004; last accessed: 15 November 2007)

Primdahl, J., Peco, B. Schramek, J. Andersen, E. Onate, J.J. 'Environmental effects of agri-environmental schemes in Western Europe', Journal of Environmental Management, Vol. 67, Issue 2, (2003) pp. 129-138.

Ratcliffe, D.A. & Thompson, D.B.A. 'The British uplands: their ecological character and international significance', In *Ecological Change in the Uplands* ed. by M.B. Usher & D.B.A. Thompson (Blackwell Scientific Publications, Edinburgh, 1988, pp. 9-36)

Revell, B. and Oglethorpe, D. 'Decoupling and UK Agriculture: A Whole Farm Approach', (Study Commissioned by Department of the Environment, Food and Rural Affairs, 2003)

Rodwell, J.S., *British Plant Communities* V. 2. (Mires and Heaths. Cambridge University Press, Cambridge, 1991)

SAC, *The Farm Management Handbook 2006/07* (Scottish Agricultural College, Edinburgh 2006)

Shrestha, S., Hennessy, T. and Hynes, S. 'The effect of decoupling on farming in Ireland: A regional analysis', *Irish Journal of Agricultural and Food Research,* Vol. 46, (2007) pp. 1–13.

Tudor, G., Mackey, E.C. 'Upland land cover change in post-war Scotland', In: *Heaths and Moorlands: Cultural Landscapes*, Thompson, D.B.A, Hester, A.J., Usher, M.B. (Eds.) (HMSO, Edinburgh, 1995.)

Veysset, P., Bebin, D. and Lherm, M. 'Adaptation to Agenda 2000 (CAP reform) and optimisation of the farming system of French suckler cattle farms in the Charolais area: a model-based study', *Agricultural Systems,* Vol. 83, Issue 2, (2005) pp. 179-202.

Witzke, H.P. and Zintl, A. *CAPSIM Documentation of Model Strucutre and Implementation* (Eurostat Working Papers and Studuies. Eurostat, Luxembourg, 2005)

Table 1. The general structure of the linear programming farm models for sheep, beef and dairy production

Activities	Moorland	Inbye land	Fodder production for own use	Sheep production	Beef production	Dairy production	Seasonal labour	Purchase of fertilizer	Purchase of feed	Animal production for sale	Headage payment	Single Farm Payment	Hill Farm Allowance	Agri-Environ-ment Payments	Resource endowments and technical constraints
Constraints															
Land requirements	1	1													≤ available hectares
Land types for fodder production	-1	-1	1												≤ 0
Animal production for sale				-aij	-aij	-aij				+aij					≤ 0
Labour requirements			+aij	+aij	+aij	+aij	-1								≤ available fixed labour in hours
Housing requirements					+aij	+aij									≤ avaible cattle places
Feeding requirements			-aij	+aij	+aij	+aij			-aij						≤ 0
Fertilizing requirements			+aij		-aij	-aij		-aij							≤ 0
Nitrate Vulnerable Zone		+aij		-aij	-aij	-aij									≤ max. manure application
Headage Payment				+aij	+aij	+aij					-aij				≤ 0
Single Farm Payment	+aij	+aij										-aij			≤ 0
Hill Farm Allowance	+aij	+aij											-aij		≤ 0
Agri-Environment Schemes	+aij	+aij												-aij	≤ 0
Livestock constraints for HFA & AES				+aij	+aij	+aij									≤ max. and ≥ min. livestock unit
Objective function	Costs (£/ha)	Costs (£/ha)	Costs (£/ha)	Gross margin (£/head)	Gross margin (£/head)	Gross margin (£/head)	Costs (£/hour)	Costs (£/kg)	Costs (£/unit)	Revenue (£/head)	Revenue (£/head)	Revenue (£/ha)	Revenue (£/ha)	Revenue (£/ha)	

aij - the technical coefficient that relates activity i to the constraint j

Table 2. Headage payments for sheep, beef and dairy cattle production in 2004 (Nix 2007)

Headage payment	£/head
Suckler Cow Premium	161.50
Beef Special Premium (steer)	102.00
Beef Special Premium (bulls)	142.80
Sheep Annual Premium	14.82
Sheep Annual Premium Suplement (LFA)	4.76
Dairy (2006) £/liter	0.0248

Table 3. Percentage of historical and flat-rate payment over the years (Nix 2007)

Year	2005	2006	2007	2008	2009	2010	2011	2012
Historical (%)	90	85	70	55	40	25	10	0
Flat-rate (%)	10	15	30	45	60	75	90	100

Table 4. Flat rate payments for 2005 and estimated for 2012 for Single Farm Payment

Year	2005	2012	
		before deduction	after deduction*
Moorland SDA	2.29	24	18
Non-Moorland SDA	16.09	175	131
Non SDA	19.23	215	161

* estimated 25% deduction after EU and National modulation

Source: SAC 2006/07, Nix 2007.

Table 5. Hill Farm Allowance payments per land type in 2006

Land type	0-350 ha	351-700 ha
Moorland & common land	11.66	5.83
SDA Non-Moorland	30.82	15.41
DA	16.66	8.33

Source: Nix 2007

Table 6. Management options for Entry Level and Higher Lever Stewardship schemes

	Code	Points	Unit	Fertiliser	LU/ha
ELS options					
Stone wall protection and maintenance	EB11	15	100 m	-	-
Manage permanent in-bye grassland with low inputs	EL2	35	ha	< 50kg N/ha	< 1.0
Manage in-bye pasture and meadows with very low input	EL3	60	ha	< 12.5 t/ha FYM	< 1.0
Enclosed rough grazing (<15ha parcel)	EL5	35	ha	none	< 0.75
Moorland and rough grazing (≥15 ha parcel)	EL6	5	ha	none	< 0.4
Genaral constraints for ELS at farm level					0.15 - 1.4
HLS options					
Maintenance of species-rich, semi-natural grassland	HK6	£200	ha	none	< 0.4
Suplement for hay making	HK18	£75	ha	none	none
Maintenance of rough grazing for birds	HL7	£80	ha	none	< 0.7

Source: DEFRA 2005a, DEFRA 2005b

Table 7. LP model predictions in base case for six farm types

	Units	Moorland Sheep & Beef	Moorland Sheep & Dairy	Moorland Sheep	Inbye Sheep & Beef	Inbye Sheep & Dairy	Inbye Beef
Moorland	%	86	64	85	-	-	-
In-bye	%	14	36	15	100	100	100
rough grazing	%	5	3	3	20	11	6
grassland	%	9	33	12	80	89	94
LFA	%	98	78	93	92	83	62
DA	%	1	0	1	29	45	16
SDA moorland	%	86	48	82	0	0	0
SDA in-bye	%	11	31	9	63	39	46
Non LFA	%	2	22	7	8	17	38
Nitrate Vulnerable Zone	%	53	56	18	52	44	76
Stone wall length	m	1092	1214	814	0	254	0
Housing capacity for cattle	head	151	94	-	83	100	164
Household labour availability	labour unit*	1.7	1.6	1.5	1.3	1.6	0.8

* labour unit = 2600 hours/year

Table 8. Economic comparison of the model and the observed survey data for each farm type

	Moorland Sheep & Beef		Moorland Sheep & Dairy		Moorland Sheep	
	Model	Observed	Model	Observed	Model	Observed
Revenue from sheep (%)	59	55	19	17	100	100
Revenue from beef (%)	41	45	0	0	0	0
Revenue from dairy (%)	0	0	81	83	0	0
Variable costs (% of total costs)	38	37	47	50	16	20
Net Farm Income (£/ha)	-85	-90	-86	-142	-111	-119

	Inbye Sheep & Beef		Inbye Sheep & Dairy		Inbye Beef	
	Model	Observed	Model	Observed	Model	Observed
Revenue from sheep (%)	46	53	10	10	0	0
Revenue from beef (%)	54	47	0	0	100	100
Revenue from dairy (%)	0	0	90	90	0	0
Variable costs (% of total costs)	46	52	60	57	39	44
Net Farm Income (£/ha)	-178	-252	62	90	-371	-437

Table 9. Land used for production and maintenance in different policy scenarios per farm type in % of farm area

Farm types	HP	SFP	NP	HP&AES	SFP&AES	NP&AES
Moor Sheep & Beef	100	87	89	100	82	77
Moor Sheep & Dairy	99	52	13	99	86	53
Moor Sheep	99	100	93	99	96	99
Inbye Sheep & Beef	100	100	100	100	100	100
Inbye Sheep & Dairy	100	100	42	100	100	100
Inbye Beef	93	100	43	100	100	92

Note: “AES” includes both AES and HFA schemes.

Table 10. Livestock numbers for different policy scenarios per farm type

Farm types	HP	SFP	NP	HP&AES	SFP&AES	NP&AES
Moor Sheep & Beef						
sheep	1741	1727	1727	1712	1617	1319
beef	151	0	0	151	0	0
Moor Sheep & Dairy						
sheep	995	32	0	975	272	108
dairy	94	94	94	94	94	94
Moor Sheep						
sheep	1529	1427	1155	1519	1123	1123
Inbye Sheep & Beef						
sheep	492	428	815	482	186	173
beef	83	44	5	83	38	28
Inbye Sheep & Dairy						
sheep	410	0	0	332	0	0
dairy	100	100	100	100	100	100
Inbye Beef						
beef	164	56	56	164	35	35

Note: “AES” includes both AES and HFA schemes.

Table 11. Economic results for different scenarios and farm types (£/ha).

	HP	SFP	NP	HP&AES	SFP&AES	NP&AES
Moor Sheep & Beef						
Revenue	156	89	89	154	84	68
Subsidy	65	36	0	98	73	44
Variable costs	154	71	70	157	71	59
Gross margin	67	55	19	96	86	53
Fixed costs	98	98	98	98	98	98
NFI	-31	-43	-79	-2	-12	-45
Other income	22	22	22	22	22	22
NFI with other income	-9	-21	-57	20	9	-23
Moor Sheep & Dairy						
Revenue	543	377	371	540	418	390
Subsidy	114	96	0	170	186	90
Variable costs	403	232	222	406	300	271
Gross margin	254	241	150	303	305	209
Fixed costs	235	235	235	235	235	235
NFI	19	6	-85	69	70	-26
Other income	64	64	64	64	64	64
NFI with other income	83	70	-21	133	134	38
Moor Sheep						
Revenue	126	118	95	125	93	93
Subsidy	47	44	0	80	84	42
Variable costs	103	93	70	104	73	74
Gross margin	70	68	25	101	103	61
Fixed costs	126	126	126	126	126	126
NFI	-55	-58	-101	-25	-22	-65
Other income	41	41	41	41	41	41
NFI with other income	-15	-17	-60	16	18	-24
Inbye Sheep & Beef						
Revenue	520	350	377	515	222	180
Subsidy	226	162	0	337	330	197
Variable costs	468	277	296	485	200	161
Gross margin	279	235	81	368	353	216
Fixed costs	242	242	242	242	242	242
NFI	37	-7	-161	126	111	-26
Other income	199	199	199	199	199	199
NFI with other income	236	192	38	325	310	173
Inbye Sheep & Dairy						
Revenue	1331	1128	1128	1292	1128	1128
Subsidy	227	185	0	327	357	171
Variable costs	906	692	692	873	738	737
Gross margin	652	622	437	746	747	562
Fixed costs	377	377	377	377	377	377
NFI	275	245	60	369	370	186
Other income	59	59	59	59	59	59
NFI with other income	334	305	119	429	430	245
Inbye Beef						
Revenue	783	268	268	783	167	167
Subsidy	375	175	0	469	332	156
Variable costs	917	254	247	922	155	154
Gross margin	241	189	21	330	344	169
Fixed costs	392	392	392	392	392	392
NFI	-151	-203	-371	-62	-48	-223
Other income	261	261	261	261	261	261
NFI with other income	110	59	-109	199	213	39

Table 12. Changes in production, resource use and income compared to the HP scenario.

% Change	HP	SFP	NP	HP&AES	SFP&AES	NP&AES
Moor Sheep & Beef	base					
Sheep nos.	100	-1	-1	-2	-7	-24
Beef nos.	100	-100	-100	0	-100	-100
LU	100	-31	-31	-1	-35	-47
Fertiliser use	100	-100	-100	0	-100	-100
Land used	100	-13	-11	0	-18	-23
Gross margin	100	-18	-72	43	28	-21
Subsidy	100	-44	-100	51	12	-33
Net Farm Income	100	-39	-156	94	61	-46
Moor Sheep & Dairy						
Sheep nos.	100	-97	-100	-2	-73	-89
Dairy nos.	100	0	0	0	0	0
LU	100	-59	-61	-1	-45	-55
Fertiliser use	100	1	1	0	1	1
Land used	100	-47	-87	0	-14	-47
Gross margin	100	-5	-41	20	20	-18
Subsidy	100	-15	-100	49	64	-21
Net Farm Income	100	-66	-547	260	268	-236
Moor Sheep						
Sheep nos.	100	-7	-24	-1	-27	-27
LU	100	-7	-24	-1	-27	-27
Fertiliser use	100	-100	-100	-1	-100	-100
Land used	100	1	-6	0	-3	0
Gross margin	100	-3	-64	43	47	-13
Subsidy	100	-7	-100	70	79	-10
Net Farm Income	100	-4	-82	55	60	-17
Inbye Sheep & Beef						
Sheep nos.	100	-13	65	-2	-62	-65
Beef nos.	100	-47	-93	0	-54	-66
LU	100	-28	-7	-1	-58	-65
Fertiliser use	100	-47	-5	0	-54	-66
Land used	100	0	0	0	0	0
Gross margin	100	-16	-71	32	27	-23
Subsidy	100	-28	-100	49	46	-13
Net Farm Income	100	-119	-535	241	200	-170
Inbye Sheep & Dairy						
Sheep nos.	100	-100	-100	-19	-100	-100
Dairy nos.	100	0	0	0	0	0
LU	100	-38	-38	-7	-38	-38
Fertiliser use	100	0	0	0	1	1
Land used	100	0	-58	0	0	0
Gross margin	100	123	57	168	168	102
Subsidy	100	-18	-100	44	57	-24
Net Farm Income	100	-11	-78	34	35	-32
Inbye Beef						
Beef nos.	100	-66	-66	0	-79	-79
LU	100	-66	-66	0	-79	-79
Fertiliser use	100	-66	-66	0	-79	-79
Land used	100	8	-53	8	8	-1
Gross margin	100	-21	-91	37	43	-30
Subsidy	100	-53	-100	25	-12	-58
Net Farm Income	100	-34	-145	59	68	-47

Table 13. Average number of bird species encountered on each farm type. I indicates inbye areas, and M moorland areas.

Farm type	Total species		Upland species		Conservation concern	
Moorland Sheep & Beef	I: 33.0	M: 12.2	I: 5.9	M: 6.1	I: 13.7	M: 7.7
Moorland Sheep & Dairy	I: 31.2	M: 14.2	I: 3.2	M: 5.0	I: 10.0	M: 9.2
Moorland Sheep	I: 30.3	M: 13.8	I: 3.8	M: 5.8	I: 11.3	M: 8.2
Inbye Sheep & Beef	I: 31.3		I: 3.3		I: 12.1	
Inbye Sheep & Dairy	I: 28.2		I: 2.6		I: 11.6	
Inbye Beef	I: 25.4		I: 2.2		I: 10.2	

Figures

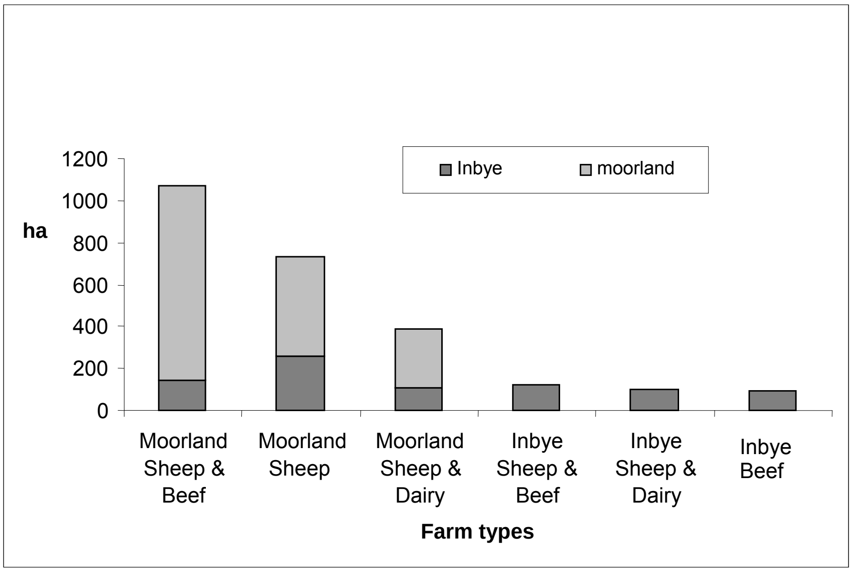


Figure 1. Average farm size of different farm types

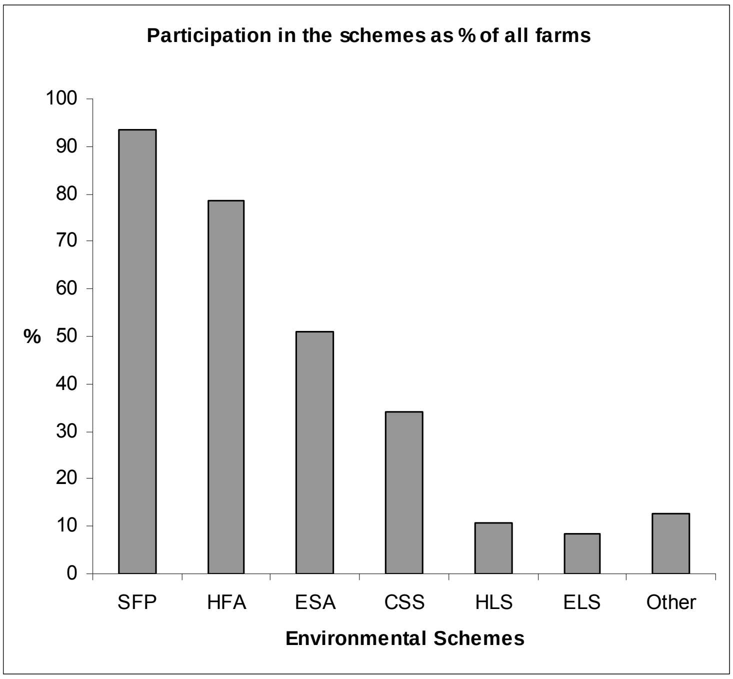
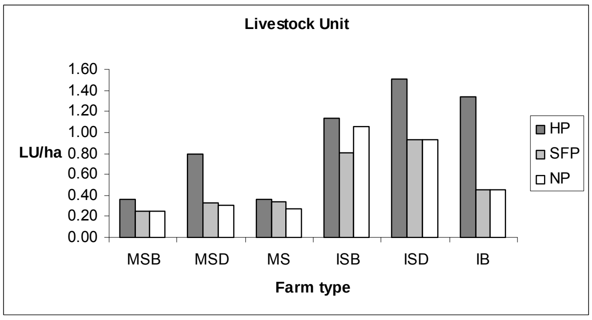


Figure 2. Participation in different schemes as a % of all farms in the survey



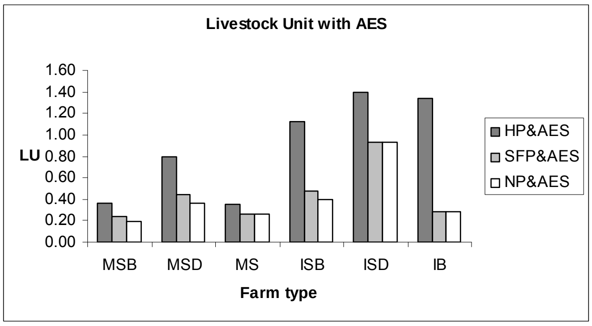


Figure 3. Livestock unit per farm type for different policy scenarios

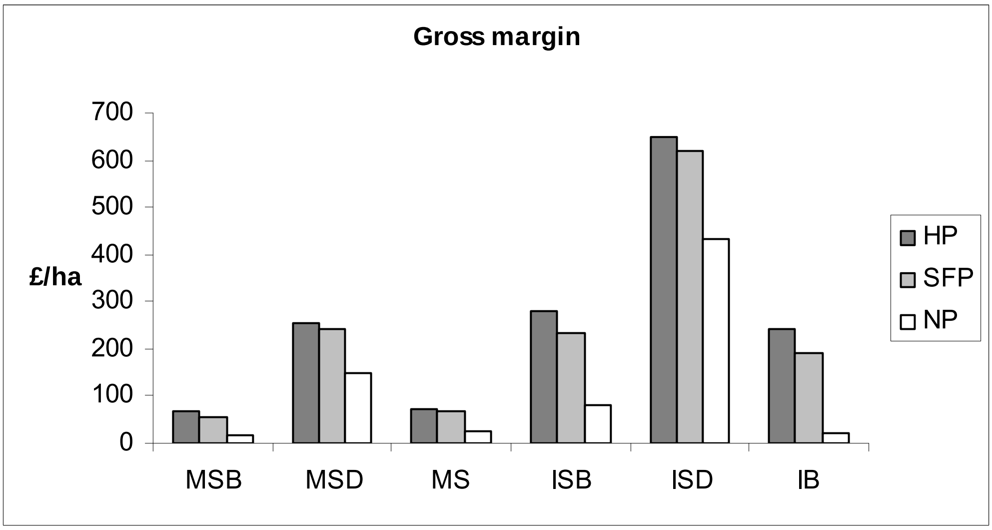


Figure 4.Gross margin per farm type for different policy scenarios.

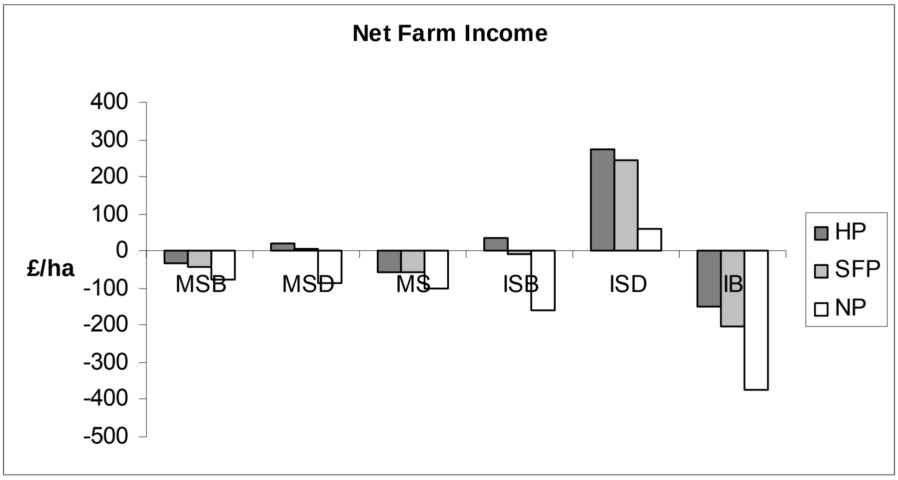


Figure 5a. Net farm income for different policy scenarios per farm type

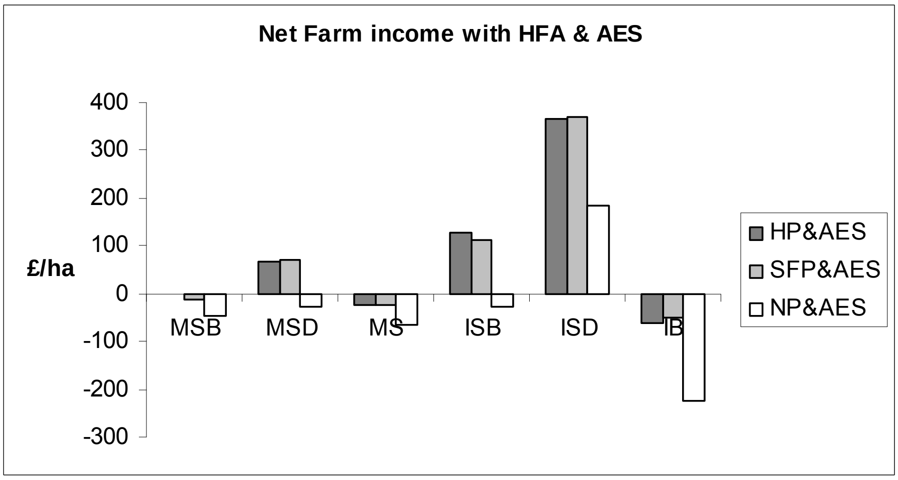


Figure 5b. Net farm income with HFA and AES payments for different policy scenarios per farm type

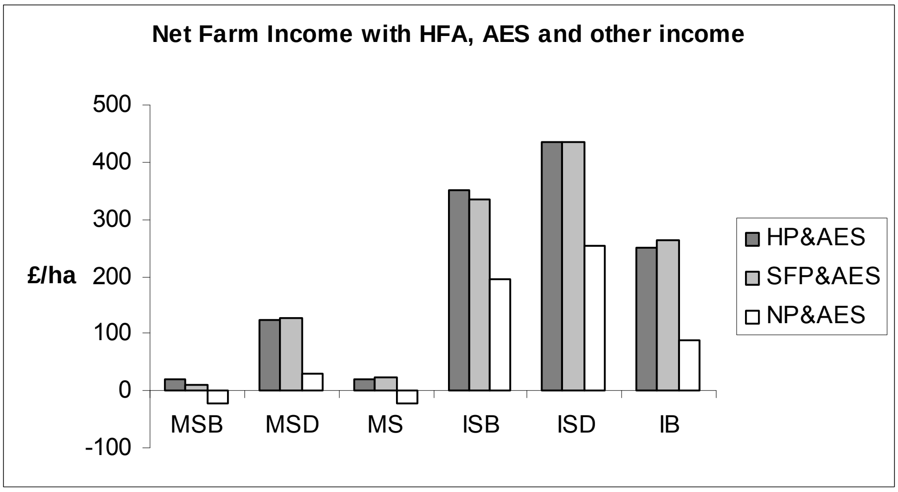
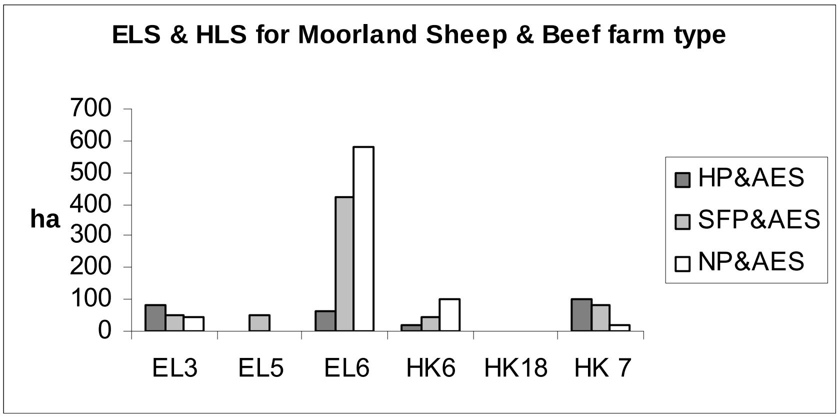
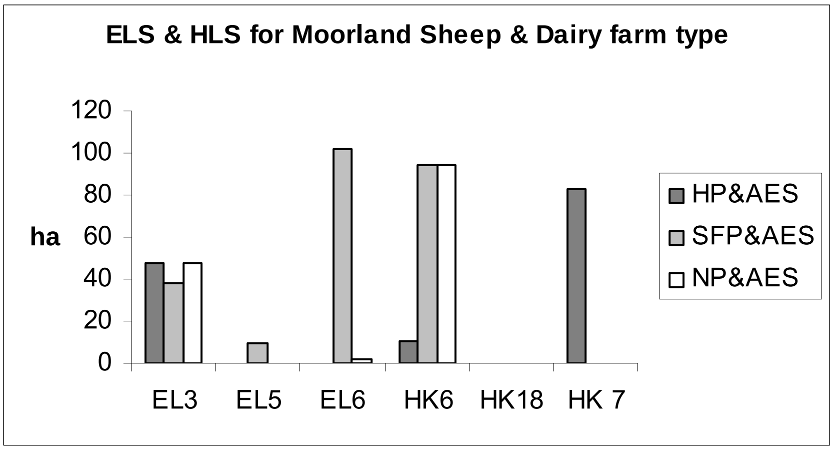


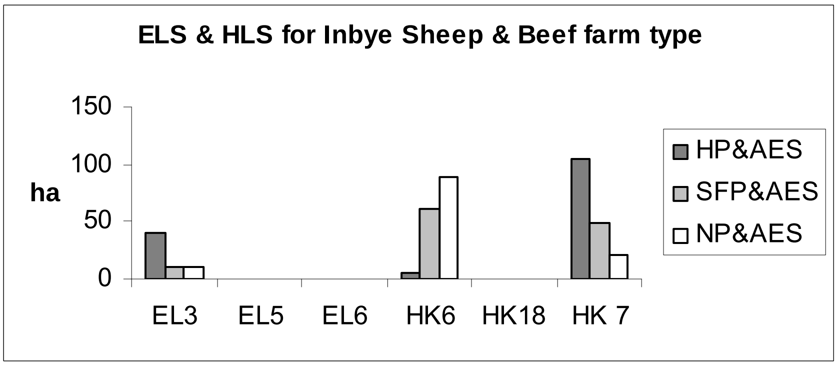
Figure 5b. Net farm income with HFA, AES payments and other income (diversification, off-farm) for different policy scenarios per farm type

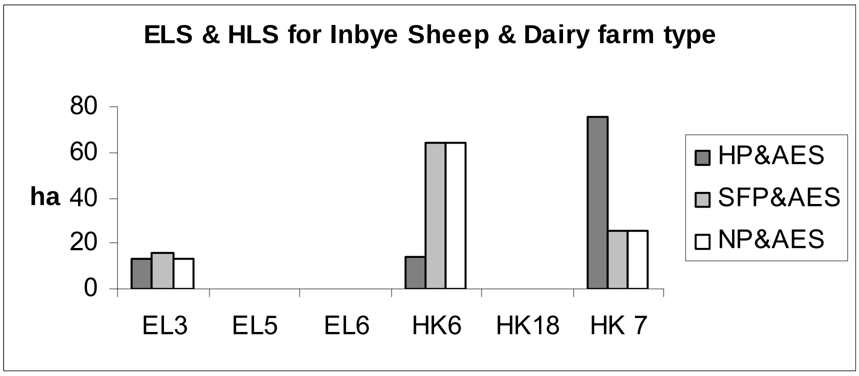
Appendix 1.

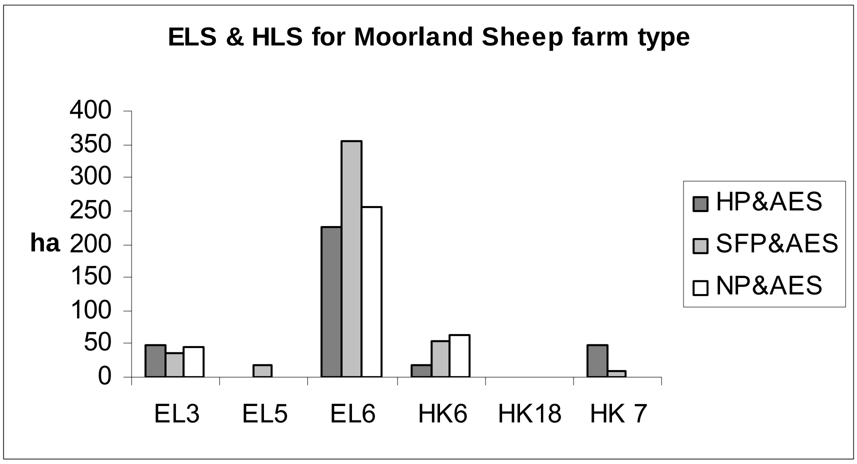
Optimal Entry Level and Higher Level Stewardships options for different scenarios for each farm type

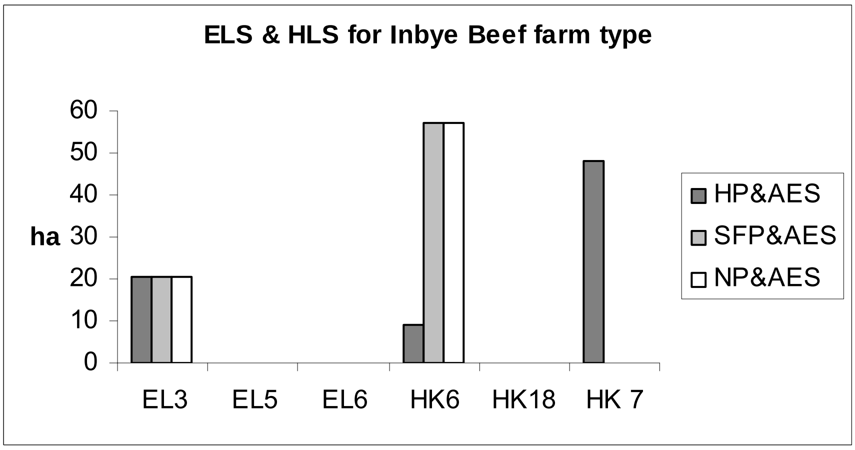







ELS & HLS for Inbye Sheep & Dairy farm type
80
60
ha 40
20
0
EL3
EL5
EL6
HK6
HK18
HK 7
HP&AES
SFP&AES
NP&AES


ELS & HLS for Moorland Sheep farm type
400
350
300
250
ha 200
150
100
50
0
EL3
EL5
EL6
HK6
HK18
HK 7
HP&AES
SFP&AES
NP&AES


ELS & HLS for Inbye Beef farm type
60
50
40
ha 30
20
10
0
EL3
EL5
EL6
HK6
HK18
HK 7
HP&AES
SFP&AES
NP&AES

ACTIVITIES AND ACHIEVEMENTS QUESTIONNAIRE

1. Non-Technical Summary

A 1000 word (maximum) summary of the main research results, in non-technical language, should be provided below. The summary might be used by the Research Councils to publicise the research. It should cover the aims and objectives of the project, main research results and significant academic achievements, dissemination activities and potential or actual impacts on policy and practice.

SEE ALSO RELU POLICY AND PRACTICE NOTE IF LOOKING FOR TEXT TO PUBLICISE THE RESEARCH TO THESE CONSITITUENCIES.

Upland ecosystems support traditional rural industries like hill farming, are home to emblematic species and habitats of conservation concern, and provide a wealth of ecosystems goods and services. Upland ecosystems that we see today have been shaped by land management practices by farmers and others. However, policies affecting hill farming are in a state of flux. Policy-makers need to understand how ongoing policy changes are likely to affect hill farming communities and ecosystems and whether they can deliver what the public want from the hills. This project examined hill farming in the Peak District National Park as a case study into what is happening in the uplands.

Objectives (from original proposal) **and Relevant Results**
Primary Priority

1. To develop coupled ecological-economic models that predict how representative hill farms will respond to changing framework conditions.

A range of coupled farm-scale ecological and economic models have been constructed that are parameterised with socioeconomic and ecological survey data on a panel of Peak District hill farms. These models have been used to examine the effects of particular policy shifts on hill farms.

For example, one set of analyses, which is published in *Land Use Policy*[1], examines the economic incentives provided to hill farmers by decoupling, finding that the economic incentives this policy provides to farmers encourages:

- a reduction in stocking densities with a shift away from beef cattle.
- a concomitant reduction in the amount of additional labour employed on the farm.
- further specialisation by farms in what they produce.
- but little abandonment of land, with farming likely to continue in a way that keeps the land in “good agricultural condition”.
- little change to farm incomes on average with some farms seeing slight increases in income and others slight losses.

In a second example, we published a discussion of the differences in statistical modelling approaches in ecology and economics and how these might be overcome in *Journal of Applied Ecology*[2] in April.

2. To design modelling techniques that account for economic and ecological interactions among farms:

Measuring spatial ecological and economic interactions among farms and designing policies that encourage farmers to internalise these interactions is a very significant empirical and theoretical challenge that we have begun to address through multiple different elements of the work programme. For example, we have developed a collaboration with RELU Exchange Fellow Professor Jim Shortle in Penn State University and his student, Simanti Bannerjee, which has shown how agrienvironment policy designs (the agglomeration bonus) intended to encourage farmers to cooperate to provide spatial ecological benefits (see below for how these are measured) can be adjusted to overcome technological externalities (sheep trespass) that act in direct opposition to the positive externality. Bannerjee and Shortle are currently testing these policies in a lab setting. The collaboration has also aided the development of additional grant proposals to answer new questions raised by the work.

3. To estimate public understanding of and preferences for contrasting moorland futures…

We have used choice experiments and valuation workshop methodologies to assess what people wanted from the hills and whether they would be willing to pay to achieve that vision. Key findings include:

- Visitors to the Peak District National Park would be willing to pay an additional parking fee to support conservation of key habitats, especially for moorlands, where people would be willing to pay an average of £4 per visit.
- However, residents of towns surrounding the National Park would not be willing for local taxes to increase in order to support further conservation efforts.
- That estimates of people's willingness to pay for environmental goods are affected when respondents are taken to visit exemplar sites, given time to reflect on their choices, or provided with expert witness testimony.

A first manuscript presenting the valuation results is in preparation for publication as a book chapter in International Handbook on Non-Market Environmental Valuation. Future manuscripts examining other elements of these results are also planned.

4. To assess whether alternative policy interventions can deliver a sustainable hill farming economy compatible with moorland conservation

The ecological economic models let us examine how agricultural subsidy schemes can be designed more effectively to provide environmental benefits. In this work, we have been able to derive an estimate of the "true" private costs of providing environmental benefits and from it of the most cost effective policy design for delivering particular conservation benefits. These results are currently in the process of being written up.

Secondary Priority

- To demonstrate whether and how moorland bird species respond to land management practices and landscape features,…

Ecological survey results for moorland fringe habitats were published in *Journal of*

Applied Ecology[3] in June 2009 and demonstrate an important role for socioeconomic characteristics of farms in influencing species richness patterns for birds across properties.

- To describe long-term spatio-temporal patterns in farm production decisions and evaluate how well historical changes in production explain changes in habitat condition and cover.

An analysis of historical data sources for the Peak District was published in *Journal of Applied Ecology*[4] in April 2009 and relates the history of intensification and specialisation of agriculture in the region to very dynamic patterns of habitat change and to stakeholder perceptions of historical changes (a more detailed analysis of the latter and its implications for valuation and policy setting was published as a book chapter[5] in March 2009).

- To quantify the extent to which environmental factors constrain present-day farm production decisions and profitability …

The farm models, ecological and economic data all demonstrate strong subregional environmental signals. We have shown that, as a consequence, policy impacts will be different in different areas and are analysing how policies can be designed to reflect heterogeneous conditions experienced by farms.

Peer Reviewed Publications:

1. Acs, S., Hanley, N., Dallimer, M., Gaston, K.J., Robertson, P., Wilson, P., Armsworth, P.R. 2009. The effect of decoupling on marginal agricultural systems: Implications for farm incomes, land use and upland ecology. Land Use Policy, in press. Published online August 2009 doi:10.1016/j.landusepol.2009.07.009
2. Armsworth, P.R., Gaston, K.J., Hanley, N.D. & Ruffell, R.J. 2009. Contrasting approaches to regression in ecology and economics. Journal of Applied Ecology, 46, 265-268.
3. Dallimer, M., Acs, S., Hanley, N., Wilson, P., Gaston, K.J. & Armsworth, P.R. 2009. What explains property-level variation in biodiversity? Taking an inter-disciplinary approach. Journal of Applied Ecology, 46, 647-656.
4. Dallimer, M., Acs, S., Tinch, D., Hanley, N., Gaston, K.J. & Armsworth, P.R. 2009. 100 years of change: examining agriculture, habitat change and stakeholder perceptions through the 20th century. Journal of Applied Ecology, 46, 334-343.
5. Tinch, D., Hanley, N., Dallimer, M., Posen, P., Acs, S., Gaston, K.J. & Armsworth, P.R. 2009. Historical perspectives on the development of multifunctional landscapes: a case study from the UK uplands. In: Multifunctional Rural Land Management: Economics and Policies. Brouwer, F. & van der Heide, M. (eds.). Earthscan, London, UK, pp. 277-294.

Examples of other Dissemination activities

- More publications in preparation.
- Over 30 conference presentations,
- Project website.

1.6 RELU Research Report

A full report on the research should accompany the completed report form. The report should not exceed 7,000 words in length and should be a succinct, self-contained document, giving a straightforward and critical appraisal of the research in, as far as possible, non-technical language.

Peer reviewed publications

Journal Articles

1. Armsworth, P.R., Gaston, K.J., Hanley, N.D. & Ruffell, R.J. 2009. Contrasting approaches to regression in ecology and economics. *Journal of Applied Ecology*, 46, 265-268.
2. Dallimer, M., Acs, S., Hanley, N., Wilson, P., Gaston, K.J. & Armsworth, P.R. 2009. What explains property-level variation in biodiversity? Taking an inter-disciplinary approach. *Journal of Applied Ecology*, 46, 647-656.
3. Dallimer, M., Acs, S., Tinch, D., Hanley, N., Gaston, K.J. & Armsworth, P.R. 2009. 100 years of change: examining agriculture, habitat change and stakeholder perceptions through the 20th century. *Journal of Applied Ecology*, 46, 334-343.
4. Acs, S., Hanley, N., Dallimer, M., Gaston, K.J., Robertson, P., Wilson, P. & Armsworth, P.R. 2009. The effect of decoupling on a marginal agricultural system. *Land Use Policy*, in press. Published online: August 2009

Book Chapter

5. Tinch, D., Hanley, N., Dallimer, M., Posen, P., Acs, S., Gaston, K.J. & Armsworth, P.R. 2009. Historical perspectives on the development of multifunctional landscapes: a case study from the UK uplands. In: *Multifunctional Rural Land Management: Economics and Policies*. Brouwer, F. & van der Heide, M. (eds.). Earthscan, London, UK, pp. 277-294.

Manuscripts currently in preparation

Currently in manuscript form or being written up

i) Dallimer, M., et al. 2009. Multiple habitat associations: the role of off-site habitat in determining on-site avian species density. Submitted.

ii) Dallimer, M. et al. 2009. The ecological effectiveness of agrienvironment schemes at field and landscape-scales. In development.

iii) Acs, S. et al. 2009. Linking biodiversity, land-use and incomes at the farm level: an interdisciplinary modelling approach. In development.

iv) Armsworth, P.R. et al. 2009 Failure to account for farmers' behavioural responses undermines incentive payments for biodiversity conservation. In development.

v) Banerjee, S. et al. 2009. Effectiveness of the Agglomeration Bonus in the presence of technological interdependencies: A case study of the Peak District (UK). In development.

vi) Tinch, D., Hanley, N. 2009. Decision versus experienced utility: an investigation using the choice experiment method. Invited book chapter contribution for International Handbook on Non-Market Environmental Valuation. In development.

Additional analyses are still under way and planned and will be developed into publications in due course.

Presentations and Seminars

1. Project Team 18/01/06. Poster presentation. A Landscape-scale Analysis of the Sustainability of the Hill Farming Economy and Impact of Farm Production Decisions on Upland Landscapes and Biodiversity. Rural Economy and Land Use: Enabling Knowledge Exchange. Manchester.
2. Armsworth 19/01/06. Discussant. Constructing Evidence for Public Policy. Rural Economy and Land Use: Enabling Knowledge Exchange. Manchester.
3. Project Team 20/01/06. A Landscape-scale Analysis of the Sustainability of the Hill Farming Economy and Impact of Farm Production Decisions on Upland Landscapes and Biodiversity. Rural Economy and Land Use: Enabling Knowledge Exchange. Manchester.
4. Hanley 16/03/06. Debate. Farming's no place for wildlife. Rural Economy and Land Use Debates. London.
5. Armsworth and Dallimer 09/10/06. Hill Farm Economics, Landscapes and Biodiversity in the Peak District. Breeding Birds of the Peak District Moorlands. Edale.
6. Hanley and Colombo 09/11/06. Valuing the Uplands. Moors for the Future: Upland Ecosystem Services. Castleton.
7. Project Team 10/11/06. Hill Farm Economics, Upland Landscapes and Biodiversity. Moors for the Future: Upland Ecosystem Services. Castleton.
8. Acs S, 16th May 2007. "Impacts of Policy Reform on Sustainability of Hill Farming", RELU Conference - Research on Rural Resource Management and the Rural Economy: Addressing the Local Dimension, Edinburgh.
9. Dallimer M, 10th September 2007 "The Impact of Hill Farming on Upland Bird Communities in the Peak District", BES Annual Conference in Glasgow.
10. Acs S, 1st October 2007 "Sustainability of Hill Farming in the Uplands" RELU Workshop - Farm Production Modelling, Sheffield.
11. Acs S, Dallimer M, 20th Nov 2007 "The Economics of Hill Farming and its Contribution to Supporting Biodiversity", Moors for the Future Annual Conference - Climate Change and Upland Management, Castleton.
12. Hanley N, November 2007. Seminar, CEMAGREF, Montpellier.
13. Hanley N, December 2008. Seminar, Resource and Agricultural Economics Department, UWA, Perth.
14. Acs S, 3-6th December 2007 "Impacts of Policy Reform on Sustainability of Hill Farming in UK", Tradition and Innovation International Conference, Gödöllö, Hungary
15. Presentation: Acs S, 16th May 2007. "Impacts of Policy Reform on Sustainability of Hill Farming", RELU Conference - Research on Rural Resource Management and the Rural Economy: Addressing the Local Dimension, Edinburgh.
16. Poster: Tinch D, 16th May 2007. "Historical Drivers of Change in the Peak District National Park" ", RELU Conference - Research on Rural Resource

Management and the Rural Economy: Addressing the Local Dimension, Edinburgh.

17. Presentation: Acs S, Dallimer M, 20th Nov 2007 "The economics of hill farming and its contribution to supporting biodiversity", Moors for the Future Annual Conference - Climate Change and Upland Management, Castleton.
18. Workshop participation: Armsworth, P 11th Dec 2007 RELU Land Use Commission, London
19. 01/08. Impacts of policy reform on sustainability of hill farming in UK by means of bio-economic modelling. 107th Seminar of the EAAE, Modelling Agricultural and Rural Development Policies, Sevilla, Spain.Presenter: Acs.
20. 01/08. Valuing an upland ecosystem using choice experiments. Scottish Graduate Programme in Economics, Edinburgh. Presenter: Tinch.
21. 06/08. Effectiveness of the Agglomeration Bonus in the presence of technological interdependencies: A case study of the Peak District (UK). Presented at the Annual NAREA/ CAES meetings.Presenter: Bannerjee.
22. Moors for the Future's 5th Research Day, 20 June 2008, Bakewell. Title: Effects of subsidy changes on hill farm production decisions, income and biodiversity. Authors: Acs et al.
23. Moors for the Future's 5th Research Day, 20 June 2008, Bakewell. Title: Valuation of upland landscapes and biodiversity. Authors: Tinch et al.
24. NE Board Workshop on Ecosystem Services, 24/06/08, Sheffield. Title: Ecosystem Services. Authors Armsworth et al.
25. RELU / CCF The Future of Farming, 03/07/08, Cambridge. Title: The Future of the Uplands. Authors: Armwsorth et al.
26. 09/08 Incentive mechanisms for landscape management: the Agglomeration Bonus with technological externalities in different neighborhoods. Presented at 10th Annual Bioecon Conference, Cambridge. Presenter Bannerjee.
27. 09/08. Incentive mechanisms for landscape management and habitat conservation: the Agglomeration Bonus and the Agglomeration Reverse Auction. Department of Economics, University of Stirling. Presenter: Bannerjee. (Authors: Bannerjee, Shortle, Kwasnica, Armsworth, and Hanley).
28. 09/08. Incentive mechanisms for landscape management and habitat conservation: the Agglomeration Bonus and the Agglomeration Reverse Auction. Department of Animal and Plant Sciences, University of Sheffield. Presenter: Bannerjee.
29. 10/08. Future impacts of agriculture on biodiversity and socio-economics in the UK uplands. Seminar, TEAGASC, Athenry, Ireland. Presenter: Hanley.
30. Moors for the Future, Upland Research Forum, 25/11/08, Castleton. Title: Hill Farm Economics and Biodiversity in the Peak District. Authors: Armsworth et al.
31. 03/09. Hill-Farming and Biodiversity: an analysis for the Peaks. Presented at RELU conference on Rural Land Use in the North: Future Challenges, York. Presenter: Nick Hanley.
32. 04/09. Linking biodiversity, land-use and incomes at the farm level: an interdisciplinary modelling approach. Presented at Agricultural Economics Society Conference, Dublin, Ireland. Presenter: Hanley.

33. Evidence to Commission on Rural Communities, 20/03/09, Alnwick. Presented by Philip Lowe on behalf of the project
34. Relu: The Future of Rural Land Use, 04/06/09, London. Title: The Future for the Uplands. Authors: Armsworth et al.
35. Moors for the Future's 6th Research Day, 07/07/09, Bakewell. Title: Sustainable hill farming. Authors: Armsworth et al.
36. European Congress of Conservation Biology, 03/09/09, Prague. Title: The implications of agricultural change on avian diversity and the economics of upland farming. Authors: Dallimer et al.

BACKGROUND

Uplands ecosystems contain many unique ecological community types and support many species of conservation interest (Thompson et al. 1995). For example, eight upland bird species are red-listed and thirty-one are amber-listed (BTO 2005). Despite their ecological value, large areas of upland habitat deteriorated throughout the last century, due in part to the steady intensification of hill farming (Anderson & Yalden 1981, Tudor & Mackey 1995) and these areas continue to experience widespread habitat change (Haines-Young et al. 2003). The ecological consequences of such a dramatic shift in land-use are marked, and substantial declines in upland breeding bird populations continue (Sim *et al*. 2005).

Many upland ecosystems are semi-natural and have been shaped by centuries of human exploitation. As such, the current condition and future of these ecosystems and the species that inhabit them depends in part on the land management actions of hill farmers and others. Production possibilities for farmers in the uplands are tightly constrained by climate, topography and soil productivity. Livestocking is the main farm enterprise Recently, hill farm incomes in the UK have fallen dramatically in response to lower lamb and beef prices (Defra 2005) and the viability of upland farms often depends on subsidy support (Peak District Rural Deprivation Forum 2004). The form of government subsidies has been changing. In 2005, the Single Farm Payment replaced previous headage payments and decoupled core support from production decisions. Hill farmers also depend on other subsidy schemes, notably agrienvironment schemes and the Hill Farm Allowance (HFA), which themselves are in flux. Over the longer term the future of agricultural subsidies depends on maintaining public support for these policies, which in turn will depend on the ability of the subsidy schemes to deliver what people want to see from upland areas.

We used the Peak District National Park as a case study to examine the impact of hill farming practices on upland biodiversity (using birds as an indicator group); how hill farms were responding to ongoing and future changes to policies and prices; what this would in turn imply for upland biodiversity; what the public wanted from upland ecosystems and how policies could be designed better to deliver public goods from hill farms.

To answer these questions, we conducted ecological and economic surveys on hill farms; used survey results to parameterise ecological and economic models of this farming system; developed new ways to integrate these into coupled ecological and economic models and paid particular attention to interactions across farm and habitat boundaries; used the models to evaluate the performance of existing policies and to test designs that could lead to more effective policies; and conducted a range of choice experiments with different cross-sections of the general public to evaluate their preferences for upland landscapes.

METHODS: DATA COLLECTION

Primary Data

Sample Farms:

Ecological and economic surveys were conducted on a panel of 44 farms, where the main landholding fell within 2 km of the Moorland boundary within the Peak District National Park. We know of no comparable published datasets that present a detailed micreconomic description of the state of farm businesses and the biodiversity on the same properties at the same time.

Economic Surveys

A questionnaire based survey was designed and carried out with the help of experienced farm business researchers through the winter months of 2006/2007. The survey included questions on land area, land types and use, production activities and subsidy payments received during the reference period of 2006.

Ecological Surveys

Walking transects and distance sampling were used to survey all bird species on farms and on 37 paired moorland areas nearby. On average, 95.0ha (SD = 66.7ha) of farmland was surveyed per property, with an average 1651m (SD = 561m) of transect walked. Moorland bird surveys were carried out by walking two parallel transects (total length 2km) on a 1x1km square (100ha) near to each farm. Birds were only included as present if they were seen or heard within the property, irrespective of the distance from the transect. Bird surveys were carried out on two separate visits in Spring-Summer 2007. Distance sampling allows estimates of bird densities to be obtained while controlling for differences in detectability of the different species.

We conducted habitat surveys within the farmland and moorland areas. In farmland, each surveyed field was characterised according to whether it was improved grassland, cut for silage or hay in the year of the survey, the proportion of the field boundaries that were vegetated with hedges or woodlands, the number of trees present in the surveyed fields, the proportion of rush cover and the proportion of fields with wet features. To assess moorland habitat, quadrats (50 x 50 cm) were placed every 100m along four parallel transects 200m apart (44 per survey square). In each quadrat, vegetation height, vegetation cover, and whether or not managed burning had been conducted, were recorded.

We also conducted intensive behavioural observations of a species of particular interest to upland conservation, the Eurasian curlew (*Numenius arquata*), during its 2008 breeding season. Vantage-point watches of focal individuals were carried out at five sites covering the eastern edge of the Peak District, noting movements and behaviour. Individual behaviour was recorded every minute for as long as the bird remained in view, for a minimum of ten minutes. For each movement (any flight or directional walk that did not involve foraging), the habitat type at the start and end points was recorded along with the six-figure grid references of each start and end point by reference to physical features using laser rangefinder and compass.

Valuation Workshops

We administered choice experiments through a workshop approach (Alvarez-Farizo and Hanley, 2006). In total 385 participants completed the choice experiment drawn from three different stakeholder groups (local residents, visitors and farmers). All policies under consideration were changes to agri-environmental schemes to reduce or increase management intensity, but not to abandon farmland. The choice experiment included five choice attributes: intensity of management in three habitat areas - moorland, moorland fringe and valley bottom farmland; footpath network quality; and a payment vehicle, (e.g., annual household tax increases for local residents). In relation to biodiversity impacts it was posited to participants that less intensive management would lead to a greater variety of habitats and species. Six levels were selected for the payment vehicle; other attributes had three levels (e.g., more intensive management, no change, less intensive).

Secondary Sources

Historical records on agricultural change and land cover change were collated to help put the results of our own data collection efforts and model predictions in context. Changes in agricultural practice were derived from the June Agricultural Census (JAC). Data were collected every 10 years from 1900 to 2000 and for the years 1914, 1932, 1966 (broadly relating to when habitat and land-use maps were available; see below) and 1988 (to ensure that the full time span of parish data were used). Data from 32 parishes (for 1900 to 1988, and 22 wards for 2000) were collated. The area of agricultural land ascribed to each parish changed between years, as JAC data include all agricultural activity registered to properties within a particular parish. Parish boundaries themselves also altered. To overcome the effect of shifting agricultural area, all variables were converted to a per-hectare basis, or as a proportion of the overall land area.

At the time this project component was undertaken, habitat maps were available from 1913 (Moss 1913), 1940 (Ordnance Survey 1952), 1978/1979 (Anderson & Yalden 1981; Anderson 1983), 1990 (Barr *et al.* 1993), and 2000 (Haines-Young *et al.* 2000). The complete area featured in all maps was 891 km^2 and covered the northern portion of the Peak District National Park. Each habitat map used a different set of vegetation types and definitions. However, these were assigned to new common categories that were consistent across the set of surveys (Dwarf Shrub Moor, Acid Grassland, Scrub, Urban, Inland Water and Woodland). All other land types, whether they were primarily agricultural or semi-natural, were not compatible across the habitat maps and were hence included in a single category 'All Other Land'. Although cotton grass represents a major semi-natural habitat type, it was not consistently mapped through the study period, and therefore, we were not able to consider it in detail. To assess habitat change, a 50 × 50 m grid was placed over the survey area. A random sample of 1% of these grid squares (3452 in total) was selected and examined for every map. Each grid square was ascribed a habitat category, based on the predominant habitat type for that cell. For every available year, the number and proportion of squares that belong to each habitat type were recorded.

OBJECTIVE 1

To develop coupled ecological-economic models that predict how representative hill farms will respond to changing framework conditions.

Methods: Economic models

The economic survey results were used to develop and to parameterise a set of linear programming models that estimates the economic incentives presented to farmers by different policy changes. Versions have been created that are tailored to different types of farm as measured by enterprise mix, different types of farm by region, and whole-region models.

Results: Economic models

One set of analyses of these economic models examines the economic incentives provided to hill farmers by decoupling and the switch to the Single Farm Payment. These analyses demonstrate that decoupling results in little change to farm incomes on average with some farms seeing slight increases in income and others slight losses, and that the economic incentives provided by the new policy encourages farmers to:

- reduce stocking densities
- shift away from beef cattle
- reduce the amount of additional labour employed on the farm
- further specialise in what they produce.
- but not abandon land, but rather to keep farming in a way that keeps the land in "good agricultural condition".

Moreover the analyses suggest that agrienvironment schemes and the Hill Farm Allowance played an important role in moderating the influence of decoupling, by lessening the impact on farm incomes and encouraging greater reductions in stocking raqtes of beef cattle than would otherwise have occurred. These core economic predictions are in press in *Land Use Policy* (**Acs et al. 2009**). The sensitivity of these results to price variation was also considered.

Methods: Ecological models

The ecological survey data were used to construct statistical regression based models relating land management changes (stocking rates, fertiliser application, etc.) to responses of the bird community and of individual bird species (**Dallimer et al. 2009a**). Throughout information theoretic approaches to model simplification and multi model inference were followed. Different study questions required differing degrees and types of non-linearity to be considered in these models.

Results: Ecological models

Summarised in response to Objective 5 below.

Methods: Coupled ecological and economic models

The two sets of models were combined to arrive at coupled ecological and economic models for exploring the implications of policy and price changes for hill farm businesses and upland biodiversity. Two different approaches were taken, each answering different questions. The first approach considers discrete policy or pricing scenarios changes. The second modelling approach focuses on decision-making at the margin and is better suited for studying incremental changes to policies or prices.

The first (discrete policy change) approach simply enters the changes in land management variables predicted under different policy and pricing scenarios into the statistical regressions predicting likely responses of the bird community.

The second marginalist, approach involved generalising the models using nonlinear programming techniques that allowed the biodiversity response function to be entered directly into the farm production decisions just like conventional agricultural inputs and outputs. In effect, it modelled farmers as producers of biodiversity just as they are producers of livestock and milk. With the relevant input data, the techniques developed in this part of the grant could readily be generalised to consider the production of other goods and services (improvements in water quality, changes to soil carbon storage, etc.) from farms.

Results

Analyses of both sets of coupled models is ongoing and two papers (one presenting each modelling approach) are currently in preparation. Analyses of discrete policy and pricing changes (like the switch from headage payments to the Single Farm Payment) make very apparent that simple generalities about the implications for biodiversity are unlikely to be obtainable. Rather a given policy change will likely benefit some species and community indices, but will negatively impact others, reflecting the differing ecological requirements that different species have. Moreover, the impacts also vary across farm types and regions adding further complexity to the results.

With the nonlinear programming models, we have been able to build trade-off curves that allow us to identify locations where biodiversity gains can be made in particular biodiversity measures at relatively little cost in terms of farm profitability, after accounting for adaptation on the part of farmers to any requirements to provide particular biodiversity benefits. One early lesson from the development of these trade-off curves however, is that trying to pursue multiple biodiversity targets simultaneously with a single policy, limits the prospects for finding such win-win scenarios. A second early lesson suggested by comparing the trade-off curves obtained when trying to buy improved conservation of individual species versus improvements to whole community measures is that low cost biodiversity gains are easier to come by when targeting individual species, whereas biodiversity gains are more costly when trying to improve whole community measures of biodiversity (such as species richness or the total density of birds).

As an interdisciplinary team, we have learned a great deal about different modelling approaches by bringing ecologists and economists together, an experience we have tried to share with other teams in the RELU program by organising cross-team meetings (see below). We have also published a perspective piece (**Armsworth et al. 2009**) in *Journal of Applied Ecology* that aims to open up a discussion of some of these difference in modelling philosophies and practices across the disciplines to the wider community.

OBJECTIVE 2

To design modelling techniques that account for economic and ecological interactions among farms.

Ecological interactions across the landscape

When examining ecological interactions across the landscape, we first focused on ecologically or geographically meaningful spatial units (e.g., habitat boundaries, circular buffers). The measurements we obtained from these spatial units can then be used to derive estimates of the importance of movements that cross property boundaries and the potential ecological pay-offs that can be obtained through spatially coordinated conservation actions among farmers.

Spatial Covariation in Bird Densities Across Habitats

Across both habitat types, 90 species were observed. Of these, 83 occurred on farmland, 50 on moorland and 43 species were shared between the two habitat types. We examined spatial covariation of bird abundance between habitats for three whole community measures (the density of all bird species, all upland specialist species and all species of conservation concern that were found in both habitats) and for nine individual species: three upland specialists (snipe *Gallinago gallinag*; Eurasian curlew *Numenius arquata* and meadow pipit *Anthus pratensis*), four species of conservation concern (willow warbler *Phylloscopus trochilus*, common linnet *Carduelis cannabina*, reed bunting *Emberiza schoeniclus* and skylark *Alauda arvensis*) and two widespread and common species (carrion crow *Corvus corone* and winter wren *Troglodytes troglodytes*).

For the individual species, a correlation between bird density on moorland and farmland sites ranged from -0.08 (ns) for skylark to 0.42 ($p<0.05$) for the carrion crow. Community-level (Total, Upland or Conservation Concern) densities were all negatively correlated between paired sites, although none of the relationships were significant.

We then tested how well on-site habitat variables explained variation in bird abundance (e.g., how well moorland habitat variables explained spatial variation in the density of linnet across moorland sites) relative to offsite habitat variables (e.g., how well farmland habitat variables explained spatial variation in linnet density on nearby moorland). We used information theoretic approaches to seek parsimonious explanations for variations in bird abundance.

When considering partial r^2 (a measure of the amount of variation in density that is explained) for farmland densities, between 0 (for the reed bunting) and 0.15 (Eurasian Curlew) of the total variation was explained by off-site moorland habitat characteristics. For a single species (common linnet) a greater proportion of their variation on farmland was explained by off-site than by on-site habitat characteristics. For birds on moorlands, between 0.03 (skylark) and 0.23 (linnet) of the total variation in moorland species densities was explained by off-site habitat characteristics. In five cases, more of the variation in density was explained by off-site variables than on-site variables.

Proportion of the surrounding landscape in agrienvironment schemes

Additionally in analyses that are currently in review, we examine how field-scale measurements of bird abundance (of individual species and of groups of species) are affected by the proportion of the surrounding landscape within a 500m buffer that is in a semi-natural state and is included in agrienvironment schemes. Results of these analyses indicate that the abundance of upland specialist species in fields increases with the proportion of the surrounding landscape that is covered by AES and that is semi-natural, effects are more marked for fields that are semi-improved. Early results also indicate that half of the species we have analysed to date are more abundant where the landscape has a high proportion of AES coverage, and all but two species are more abundant as the landscape was increasingly semi-natural.

Direct observations of curlew movements and behaviour

Twenty-five curlew pairs were identified across the study sites. Behavioural observations covered over 110 hours on 216 separate occasions. In total, 652 movements were recorded; a quarter of these were between inbye (improved and semi-improved fields) and moorland habitats. Movement length ranged from 4m to 1400m, and were significantly longer between habitat types than within. The proportion of time spent carrying out the four major activities varied between moorland and inbye habitats. A greater proportion of time was spent foraging on farmland than moorland (63% compared to 33%). While on moorland, curlew spent a greater proportion of time loafing (29%), being vigilant (19%) and carrying out reproductive behaviour (5%).

Modelling ecological and economic interactions among farms

To address economic interactions among farms, we have developed models in collaboration with RELU Exchange Fellow Professor Jim Shortle in Penn State University and his student, Simanti Bannerjee. The models are designed to be parameterised on the cost side from the results of the whole farm LP models described under objective 1 and the evidence for ecological benefits from landscape coordination across farms described above. In the models, the continuous control choices examined in the LP model are ‘packaged’ into discrete choices (e.g., enter AES on moorland or not), from which the relevant Nash pay-off matrices can be constructed. We have developed a stylized geometry of hill farms, which captures essential dynamics of a number of regions within the Peak District, while allowing sufficient simplification to enable computation of the many Nash equilibria involved in the spatial game.

The work we have undertaken with Shortle and Bannerjee to date examines how agrienvironment policy designs intended to encourage farmers to cooperate to provide spatial ecological benefits (the agglomeration bonus) must be adjusted to overcome technological externalities (sheep trespass) that act in direct opposition to the positive externality to be effective. The results of these models are written up in manuscript form and was presented at the BioEcon and NAREA conferences last year. Further analyses and model development are still ongoing

Bannerjee and Shortle are currently testing these policies in an experimental lab setting. The collaboration has also aided the development of an additional grant proposal. If funded, this follow up proposal would enable us to replicate these experimental economics in the field with our survey farmers and would also answer new questions raised by the work about the trade-off encouraging cooperation among farmers to capture spatial externalities and requiring competition among farmers to overcome adverse selection problems in scheme design.

Objective 3

To estimate public understanding of and preferences for contrasting moorland futures…

Methods: contrasting valuation estimates across stakeholder groups

We used the Choice Experiment technique to assess what people wanted from the hills and whether they would be willing to pay to achieve that vision. Similar experiments were conducted with 50 residents from villages surrounding the park, 305 visitors to the park and 30 farmers in order to determine if different user groups valued the park's environmental resources in divergent ways. Data were analysed using Error Component Logit Models from which implicit prices were estimated. It was necessary to adopt different payment vehicles for different groups, so comparison relied upon the relative weight placed on different choice features.

Results: contrasting valuation estimates across stakeholder groups
Key findings include:

- Different user groups have divergent preferences for management in the park
- Visitors to the Peak District National Park would be willing to pay an additional parking fee to support conservation of key habitats, especially for moorlands, where visitors would be willing to pay an average of £4 per visit.
- However, residents of towns surrounding the National Park would not be willing for local taxes to increase in order to support further conservation efforts.
- No user group (Local Residents, Visitor or Farmers) would like to see increased management intensity within the National Park boundaries with all groups stating a Willingness to Pay to avoid such management.

Methods: the role of experience and reflection in determining valuation estimates
We also tested methodological questions regarding the reliability and interpretation of valuation estimates derived through these approaches. Specifically, we tested the role of experienced versus anticipated utility and time for reflection on valuation estimates obtained using several experimental treatments with the same participants (**Tinch & Hanley, in prep.**).

<u>Treatment 1</u> (baseline) was run in a local hall prior to the visit to the National Park and represents the value derived in most choice experiments (and other stated preference techniques), since it is based on information given to participants through description, visual images and aurally.
<u>Treatment 2</u> (experienced utility) aims to identify the impact of the moment of experience of landscape on values, and was conducted on site where a representative series of landscapes could be seen. Participants were driven to the Park and shown the landscape characteristics which they were valuing in the choice experiment. Individuals could identify the impacts of management changes without needing to rely on their own anticipation of changes and (to some extent) anticipation of adaptation to landscape changes. Participants were shown landscape features characteristic of each proposed level for each attribute, and were asked to identify those features relevant to the combinations presented in the choice before them.
<u>Treatment 3</u> (Remembered 1) was conducted upon return to the village hall on the same day as the site visit.
<u>Treatment 4</u> (Remembered 2) was administered during a second workshop held four months after the first.

Results of the choice experiments were analysed using both the nested logit model and error component model. Complete Combinatorial Convolutions Methodologies and the Johnson and Duke Test for Transfer Errors were adopted to analyse differences in preference between treatments.

Results: the role of experience and reflection in determining valuation estimates
We found differences between treatments showing that preferences are impacted by both experience and memory. We found consistency in the results between an initial WTP (first treatment) and the final (fourth treatment) WTP which to all intents and purposes remained the same. However, upon visitation and experience of management in the National Park mean WTP values fell by almost half for current levels of management intensity over a general shift to more OR less intensively managed landscapes. This result suggests that experience has an impact on the preference for environmental goods. While memory led to a shift in mean willingness to pay to an intermediary level between the 2nd and 3rd treatments in the short term and between the 3rd and 4th treatments in the longer term. In our case, this seems to mitigate the impact of experience all together.

Objective 4

To assess whether alternative policy interventions can deliver a sustainable hill farming economy compatible with moorland conservation

The coupled ecological economic models described under Objective 1 that take a marginal approach to understanding policy changes are specifically designed to allow us to examine the effectiveness of alternative policy designs. From the trade-off curves between farm profit and particular biodiversity benefits that we construct, we can derive the theoretically optimal (i.e., most cost effective) incentive payment that one would need if trying to purchase a given level of improvement in biodiversity from a farmer. This optimal policy accounts for adjustment in the farm enterprise when setting incentive payment levels, which, if unaccounted for, allows farms to claw-back substantial revenue and leaves them over-compensated for actions that they undertake. The optimal policy varies by region, with the amount of a given biodiversity target provided on the farm, and with different choices of biodiversity target(s).

This most cost effective scheme design would be very hard to implement. However, with it, we are able to evaluate the cost incurred (either in terms of the overall economic cost of the scheme or the amount of biodiversity provided for a given budget) when employing simpler but more manageable scheme designs, such as spatially uniform payments, or fixed payments per unit biodiversity target produced on a given farm. These analyses are still under way, but early results suggest that some simplifications to scheme design can greatly reduce effectiveness (by up to 70 or 80%) and those that are most costly are those that preclude an agrienvironment scheme design from exploiting a low-cost biodiversity gain identified in the trade-off curves.

Secondary Priority: Objective 5

To demonstrate whether and how moorland bird species respond to land management practices…

Results that describe individual species and cross-habitat movements are summarised under Objective 2. Here we focus on the response of species richness based measures of bird diversity to land management practices within a given habitat type. Early this year, we published a first paper presenting ecological survey results that focused on what explained patterns of species richness (all species, upland specialist species, and species of conservation concern) across farms (**Dallimer et al. 2009b**)

Farm management variables, including many of the main prescriptions outlined in AES, accounted for 23% of the variation in the richness of species of Conservation Concern, but less than 10% for Total Richness. However, no farm management variable alone was shown to offer better predictive power of avian species richness than random. Importantly, Agri-Environment Scheme payments also did not play a significant role in predicting species richness.

Also Landscape context variables (proportion of different habitat types in a 500-m buffer around each property) offered little explanatory power for all three measures of species richness.

Instead within-property habitat quality explained 42% of the variation in richness of upland specialist species with fewer species where more fields were mowed for silage or hay, and more species with increasing numbers of cows and proportion of field with rush cover. But within-property habitat quality had no influence on Total or Conservation Concern Richness. Interestingly socio-economic circumstances of farms alone accounted for 24% of the variation in Total Richness, with land tenure and labour inputs important predictors of this measure of avian diversity.

Objective 6

To describe long-term spatio-temporal patterns in farm production decisions and … habitat condition and cover.

We published a study examining long-term changes in agricultural production and habitat change in the Peak District in the *Journal of Applied Ecology* in April 2009 (**Dallimer et al. 2009b**). In the paper, we also include a summary of discussion with stakeholder about their perspectives on historical changes in the region that are written up in more detail in a recent book chapter (**Tinch et al. 2009**).

Headline messages from these analyses include that since 1900:
- sheep numbers maintained by farms in the hill parishes increased five-fold.
- medium sized farms decreased in numbers as large farm businesses and hobby farmers emerged.
- farming simplified as traditional mixed enterprises disappeared (as evidenced by a loss of small oat fields, losses of horses kept on farm, etc,), resulting in increased specialisation in livestocking.
- the amount of labor employed on farms remained relatively constant, because the steady intensification of agriculture offset the labour reductions per unit output made possible by technological improvement.
- upland ecosystems are dynamic with high turnover rates among habitat types. E.g., despite a stable percentage of squares being occupied by dwarf shrub moor between

1913 and 2000, only 55% of the squares classified as dwarf shrub moor in 1913, retained this classification in 2000.

When comparing these trends in historical records with stakeholder perceptions revealed through workshop activities, we found that some stakeholder perceptions accorded well with the available historical evidence, such as the major intensification of sheep farming. However, other stakeholder perceptions' were at odds with the historical records, for example those concerning the dynamic nature of vegetation changes and the patterns in agricultural labour. In discussing the relevance of this disconnect between stakeholder perceptions and available historical evidence, we noted that if policies do not address those drivers that stakeholders see as important for underpinning trends in land-use, land cover or rural jobs and incomes, then it will be harder to achieve a high level of acceptability for particular policies. This can lead to low levels of uptake and higher implementation costs (e.g. legal fees and monitoring).

Objective 7

To quantify the extent to which environmental factors constrain present-day farm production decisions and profitability and determine the relationship between current production, profitability and habitat quality.

We have not prepared manuscripts specifically addressing the role of environmental constraints on production choices, but rather have woven this regional, environmental perspective throughout the analyses detailed above.

For example, among the different types of farm production model that we have developed , we have specifically developed a family of models that examines regional variation in farm profitability across different regions within the National Park. These regions were identified a priori based on their ecological and physical characteristics (particularly wetness and elevation gradients) and the different models are then developed by grouping the economic survey results to these regions when deriving parameter estimates. There are clear shifts in profitability and enterprise mix across the different regions. This methodology is particularly important when seeking to integrate the farm production model with the ecological models (Objective 1), because the ecological models themselves are strongly influenced by the response of birds to these broad-scale environmental patterns. We have shown in our policy evaluations (discrete policy change scenarios) using these models how predictions about policy impact on land management choices, farm incomes, or biodiversity demonstrate heterogeneity across these regional gradients. In our examinations of cost effective agrienvironment scheme design, we have quantified the cost incurred if policies fail to account for this regional, environmental variation.

While this objective explicitly focuses on present day environmental variation, the data collated for the historical analyses of agricultural and habitat change allow consideration of spatio-temporal environmental variation (e.g., Fig. 1 in **Dallimer et al. 2009b**), something we have begun to explore but that could be developed further.

INTERDISCIPLINARITY

A description of how the interdisciplinary aspect of the project was designed and managed, and the contributions made to interdisciplinary research.

As is apparent from the project design, activities and results, this is a fundamentally interdisciplinary project, which has had a particular emphasis on the integration of ecology and economics. The design, collection and analysis of all datasets involved active input from both ecological and economic staff as did the design and analysis of the modelling that was undertaken. Research products (including publications and research presentations) have been coauthored by staff coming from ecological and economic backgrounds and have been published in interdisciplinary outlets.

Management of interdisciplinarity was made easier by the relatively compact nature of the project team and the prior experience of all PIs and Co-Is in past interdisciplinary work. The new interdisciplinary collaborations forged in this project are continuing now it has been completed and various combinations of the investigator team have submitted three joint grant applications within the past year (at least one of which has been funded – see below.)

Contract research staff participated in interdisciplinary training days early in the project and have gone on to secure positions in interdisciplinary science on completion of their contracts (e.g., M. Dallimer is now employed as part of an interdisciplinary EPSRC SUE 2 consortium where he is examining well-being benefits provided by biodiversity in urban river corridors).

Despite the past experience of project staff in interdisciplinary working, new lessons had to be learned by all staff about interdisciplinarity. We recognise the intellectual value in that learning process itself and have endeavoured to share those lessons with the wider research community. For example, in April 2009, we published a commentary in the *Journal of Applied Ecology* that discusses different emphases given by ecologists and economists to the assumptions that underpin statistical regression techniques (**Armsworth et al. 2009**). In a second example, we organised two technical workshops examining farm production modelling techniques to which we invited staff involved in modelling from other RELU projects.

- Farm Production Modelling workshop, 1st October 2007, Sheffield. Project staff organised, ran and participated in a meeting of RELU researchers on Farm Production Modelling in Sheffield on the 1st of October. Eighteen researchers met to discuss approaches being taken to farm production modelling in six different RELU projects (The Sustainability of Hill Farming, Modelling the Impacts of the Water Framework Directive, Sustainable Uplands: Frameworks for Adaptive Management, Integrated Management of Floodplains, Management Options for Biodiverse Farming, Implications of a Nutrition Driven Food Policy for the Countryside). Funding for the meeting was provided through the Programme Directorate. The meeting also gave new RELU International Exchange Fellow Professor Shortle an opportunity to meet with each project. During his stay, Professor Shortle also visited field sites in the Peak District and explored more focused opportunities for collaboration with our project staff.

- Farm Production Modelling Workshop 2, 30/06/08, Technical workshop on how farm production modelling techniques can be integrated with other activities within the programme including Exchange Fellow Jim Shortle plus representatives from two other RELU teams (Sutherland and Hubacek)

KNOWLEDGE TRANSFER, USER ENGAGEMENT AND IMPACTS

We have undertaken 6-8 outreach activities per year for / with different stakeholder audiences and organisations through the life of the project. These include formal presentations, running workshops face-to-face meetings / visits by the project team, production of bespoke reports and written materials, etc. We highlight some examples only below.

1. Rural Economy and Land Use Programme Project Launch. 27/02/06. Castleton. Joint project launch run in collaboration with the Hubacek-led RELU project and Moors for the Future. As well as featuring a presentation from both project teams, the event also featured presentations from the Chief Executive of the Peak District National Park Authority, the RELU Programme Director and the head of Moors for the Future and a discussion panel. 80 delegates registered for the meeting representing 25 stakeholder organisations and 10 research institutions.

2. Historical Drivers of Change Workshop at the Moors for the Future: Upland Ecosystem Services Conference. 10/11/06. Castleton. In collaboration with the Hubacek-led RELU team, we organised parallel RELU workshop sessions at this conference. Paul Rose from JNCC and the RELU Strategic Advisory Committee opened the session. Paulette Posen from the Bateman-led RELU project also participated. The session included a short overview of the project and discussion with the full conference. Then, our project team members ran a workshop session for half of the delegates in which stakeholders and scientists were working together to build historical time-lines of land use and agricultural change in the Peak District. 110 delegates were registered for the conference representing 28 different stakeholder organisations and 14 different research institutions.

3. Earlier in the project, participating farm businesses received bespoke reports regarding the ecological and economic condition of the farm. These have subsequently been used by farmers to inform HLS applications. In July 2009, we ran an evening meeting with local farm businesses in Hathersage where we presented results from the farm models and the ecological and economic surveys and elicited feedback from the farm businesses on the accuracy of model predictions, on the usefulness of the project and on how the science agenda was administered. This feedback was collected in person and using questionnaires and choice experiments.

4. A RELU Policy and Practice Note about the project is currently with the publishers and will see wide circulation. Because this format must address a general audience, we are also producing bespoke summary reports in response to questions asked by particular local stakeholder groups as part of an initiative supported by the ESRC Follow-on Fund.

In addition, we have presented project results in evidence to the Campaign for Rural England, in an education session run for the Board of Natural England, to a visiting MEP, etc. and have visited and held meetings with the NFU, RSPB, PDNPA, NE, etc. throughout the work.

CAPACITY BUILDING AND TRAINING

In the course of the project, we have trained two interdisciplinary post-docs and a PhD student and have contributed to the training of other interdisciplinary post-docs, PhDs and a research fellow funded through other RELU projects and sources. The project has also established a new interdisciplinary collaboration among the investigator team and between the investigator team and a network of stakeholder organisations that continue to support new research activities and grant applications.

Some specific examples of training activities

- Outreach activities were designed in a way that would provide all project staff, and particularly the PDRAs and PhD student, with important practise in meeting with and engaging stakeholders. Specifically, these activities have included joint presentations made by junior and senior project staff to stakeholders about the project, having younger research staff lead workshop activities, having natural scientists shadow experienced farm surveyors conducting the socio-economic survey, etc.
- We employed a local farmer as a consultant at the start of the project to run an 3-hour education session for new project staff on site on a local farm.
- The PDRAs on the project participated in interdisciplinary training events offered by RELU (e.g.,the BAAS-RELU RA Training Event at the BA Festival of Science 11-13th Sept 2007 in York).
- Project staff organised, ran and participated in two meetings of RELU researchers on Farm Production Modelling, one in Sheffield on 1/10/07 and one in Stirling on 30/06/08. These training and ideas workshops are described in more detail above. The goal of the meetings was to bring together researchers drawn from across projects working on farm production modelling. The invitations to participating project specifically invited one investigator and one PDRA. Six RELU PDRAs participated in this event in the 2007 meeting and 4 participated in the 2008 meeting.
- To develop the project's collaboration with RELU Exchange Fellow (Shortle) the project helped support a visit by Shortle's PhD student, Simanti Bannerjee, to the UK (including field visits to the Peak District as well as meetings and seminars in both Sheffield and Stirling), and supported a return visit by project PDRA, Szvetlana Acs, to Shortle's group in Penn State in 2008. During this visit, Acs received instruction in a range of new modelling techniques including non-linear programming.
- Acs also undertook a training course in mathematical modelling using Matlab in order to support the development of this work in 2008
- Dugald Tinch received training in relevant econometric techniques from a range of external visitors to and workshops held in the University of Stirling in 2008. Tinch also participated in activities organised through the Scottish Graduate

Programme in Economics, including giving a presentation about his work on the project to SGPE in January.

- In 2008, Tinch received training in the use of relevant programmes and statistical analysis has been sought and gained from Sergio Colombo (IFAPA Granada), Mikołaj Czajkowski (Warsaw Ecological Economics Center, University of Warsaw). A workshop on the use of multinomial logit models by Danny Campbell (Queens Belfast) held at the University of Stirling was both organised and attended by Dugald.
- Martin Dallimer was the first member of the project staff to come out of contract in 2009. Dallimer received career development support through University of Sheffield's formal Staff Review and Development Scheme, which helped him secure a new contract from the University of Sheffield when his tenure on the RELU project expired. This new follow-on position is again on an interdisciplinary project (funded through EPSRC's SUE 2 programme) that brings together natural and social sciences.
- Szvetlana Acs came to the end of her RELU contract more recently and was subsequently employed as a consultant on a DEFRA contract on Future Farming run by Cranfield University in collaboration with NDH that built on the RELU modelling work.
- The project continues to support independent fellow, Althea Davies. Davies has participated in project meetings and discussions throughout the year. Davies also gained experience of choice experiment methodologies when participating in a valuation workshop run in February. The project has also provided detailed historical data on land cover change in the Peak District to support her fieldwork.

CONFERENCES / NETWORKS

A detailed list of over 30 conference and seminar presentations by project staff is provided above, as is a description of our outreach activities with a network of stakeholder and practitioner groups.

FUTURE RESEARCH PRIORITIES

Are there lines of research arising from this project which might profitably be pursued (not necessarily with ESRC funding)?

Analyses of models and data produced in the project are ongoing and future manuscripts are planned and in preparation.

Hanley has been awarded a grant through ESRC's Follow-on Fund to extend the project's Knowledge Exchange activities in ways described above as well as participated in the DEFRA contract mentioned above.

Future grant applications that build on different elements of the work (e.g., the trade-off in policy design between requiring spatial cooperation among farms to produce ecological benefits but competition among farms to achieve cost efficiency and overcome problems of adverse selection) are currently in development.

Ethics

All project activities with human participants (e.g., surveys with farmers, choice experiments) were subject to review according to the University of Sheffield's Ethics Policy through Sheffield's Ethics Review System (http://www.shef.ac.uk/ris/gov_ethics_grp/ethics/system.html). On each occasion, Ethics approval was granted before research activities began. Measures to anonymise project data to protect human participants before data archiving were agreed with RELU Data Support Services and discussed with RELU DSS as the project developed and agreed standards have been maintained in the archived version of the data.

1.8 Confidentiality

If the report needs to refer to material which may be sensitive, this should be put in an annex clearly marked as confidential. A covering letter should be added to the report emphasising this.

Not applicable.

REFERENCES

Alvarez-Farizo, Begonˇ a, and Nick Hanley. 2006. ''Improving the Process of Valuing Non-Market Benefits: Combining Citizens' Juries with Choice Modeling.'' Land Economics 82 (3): 465–78.

Anderson, P. (1983) The Semi-Natural Vegetation of The Peak District National Park. Peak Park Joint Planning Board, Bakewell, Derbyshire, UK.

Anderson, P., Yalden, D.W., 1981. Long-term changes in the extent of heather moorland in upland Britain and Ireland: palaeoecological evidence for the importance of grazing. Biological Conservation 20, 195–213.

Barr, C.J., Bunce, R.G.H., Clarke, R.T., Fuller, R.M., Furse, M.T., Gillespie, M.K., Groom, G.B., Hallam, C.J., Hornung, M., Howard, D.C. & Ness, M.J. (1993) Countryside Survey 1990: Main Report, vol. 2. Department of the Environment, London.

BTO 2005. http://www.bto.org/birdtrends2005

Defra (2005). Farm Incomes in the United Kingdom. Department of Environment, Food and Rural Affairs, London.

Haines-Young, R., Barr, C.J., Firbank, L.G., Furse, M., Howard, D.C., McGowan, G., Petit, S., Smart, S.M. & Watkins, J.W. (2003). Changing landscapes, habitats and vegetation diversity across Great Britain. Journal of Environmental Management, 67, 267–281.

Haines-Young, R., Barr, C.J., Black, H.I.J., Briggs, D.J., Bunce, R.G.H., Clarke, R.T., Cooper, A., Dawson, F.H., Firbank, L.G., Fuller, R.M., Furse, M.T., Gillespie, M.K., Hill, R., Hornung, M., Howard, D.C., McCann, T., Morecroft, M.D., Petit, S., Sier, A.R.J., Smart, S.M., Smith, G.M., Stott, A.P., Stuart, R.C. & Watkins, J.W. (2000) Accounting for Nature: Assessing Habitats in the UK Countryside, Department of Environment, Transport and the Regions, London.

Moss, C.E. (1913) The Vegetation of the Peak District. Cambridge University Press, Cambridge, UK.

Ordnance Survey. (1952) Vegetation: Grasslands of England & Wales: Sheet 2 England and Wales – south of Kendal. Director General of the Ordnance Survey Office, Chessington, Surrey, UK.

Peak District Rural Deprivation Forum. 2004. Hard Times: A Research Report into Hill Farming and Farm Families in the Peak District. Peak District Rural Deprivation Forum, Hope, Derbyshire, UK.

Sim, I.M.W., Gregory, R.D., Hancock, M.H. & Brown, A.F. (2005) Recent changes in the abundance of British upland breeding birds. Bird Study, 52, 261–275.

Thompson, D.B.A., MacDonald, A.J., Marsden, J.H., Galbraith, C.A. (1995). Upland heather moorland in Great Britain : a review of international importance, vegetation change and some objectives for nature conservation. Biological Conservation 71, 163-178.

Tudor, G., Mackey, E.C., 1995. In: Thompson, D.B.A., Hester, A.J., Usher, M.B. (Eds.), Upland Land Cover Change in Post-war Scotland Heaths and Moorlands: Cultural Landscapes. HMSO, Edinburgh.

relu
Rural Economy and
Land Use Programme

Rural Economy and Land Use Programme
Centre for Rural Economy
School of Agriculture, Food and Rural Development
Newcastle University
Newcastle upon Tyne NE1 7RU

Telephone: 0191 222 6903
Fax: 0191 222 5411
Email: relu@ncl.ac.uk

www.relu.ac.uk

The Sustainability of Hill Farming

A Rural Economy and Land Use Programme research project to examine the impacts of agricultural policy reform on hill farm economics, biodiversity and upland landscapes.

Policy and Practice Notes

Note No. 13
December 2009

The Rural Economy and Land Use Programme is a UK-wide research programme carrying out interdisciplinary research on the multiple challenges facing rural areas. It is funded by the Economic and Social Research Council, the Biotechnology and Biological Sciences Research Council and the Natural Environment Research Council, with additional funding from the Scottish Government and the Department for Environment, Food and Rural Affairs.

Upland ecosystems support traditional rural industries like hill farming, are home to species and habitats of conservation concern, and provide a wealth of ecosystem goods and services. The landscapes that we see today have been shaped over many years by the management practices of farmers and others, partly influenced by government policies on agricultural support. However, these policies are in a state of flux. Policy-makers need information regarding how ongoing policy changes are likely to affect farming communities and upland ecosystems and whether these policies will deliver what the public wants from the hills.

What happened to the hills?

Upland ecosystems have been shaped by centuries of human exploitation. Indeed, many emblematic upland habitats, such as heather moorlands, depend on ongoing land management through grazing and burning. For many people, upland landscapes provide an important "sense of place". However, the uplands are very dynamic environments and are undergoing significant upheavals.

This project examined hill farming in the Peak District National Park as a case study. An examination of historical records for the Peak District reveals that since 1900:

- Sheep numbers maintained by farms in the hill parishes increased five-fold.
- Medium-sized farms decreased in numbers as large farm businesses and hobby farmers emerged.
- Farming simplified as traditional mixed enterprises disappeared, resulting in increased specialisation in livestocking.
- Upland ecosystems demonstrate considerable turnover among habitat types.

What do people want from the hills and who is going to pay for it?

Currently, agricultural subsidies provide the primary means by which the public "contract" with farmers to supply the types of benefits from the hills that people want to see. However, the long-term future of subsidy payments is uncertain and depends on public support. The project therefore assessed what people wanted from upland landscapes and whether they would be willing to pay to achieve that vision and found that:

- Visitors to the Peak District National Park would be willing to pay an additional parking fee to support greater conservation of key habitats, especially for moorland, where people would be willing to pay an average of £4 per visit.
- Residents of towns surrounding the National Park are willing to pay to maintain current levels of conservation.
- Estimates of people's willingness to pay can be affected when respondents are given time to reflect on their choices, taken to visit exemplar sites, or provided with expert witness testimony regarding the National Park.

View of the Peak District landscape from Stanage Edge Copyright M Dallimer

What has been the effect of agricultural supports?

Delivering rural policy in the hills today depends on agricultural subsidies, and socioeconomic surveys of hill farm businesses showed that farms rely on this support to be viable. However, subsidies for hill farms have been undergoing major changes. Previously farmers were given a subsidy payment for each animal they produced (a "headage payment"), but now they are paid a Single Farm Payment on an area basis, decoupled from production – ie the payment is not related to how many livestock they keep. This policy encourages:

- a reduction in stocking densities with a shift away from beef cattle.
- a reduction in the application of chemical fertilisers to inbye land.
- a reduction in the amount of labour employed on the farm.
- further specialisation by farms in what they produce.
- little abandonment of land, with farming likely to continue in a way that keeps the land in "good agricultural condition".

But the strength and direction of these incentives varies for farms in different regions and producing different combinations of produce (ie only sheep, sheep and beef, or sheep and dairy). The switch to the Single Farm Payment results in minor changes to average farm incomes with some farms seeing slight increases and others losses.

What part do agri-environment schemes play?

Agri-environment schemes, such as existing Environmentally Sensitive Area contracts, provide additional support, upon which many farmers have come to depend. These payments are designed to encourage farmers to provide "public goods", such as improved habitat for particular species or public access for recreation. However, agri-environment policies are also undergoing major changes.

Currently, they play a role in moderating the likely effects of the change to the Single Farm Payment by:

- reducing the impact on farm incomes of decoupling.
- encouraging further reductions in upland beef cattle, although they have a variable impact on sheep numbers.

The evidence from ecological surveys that agri-environment schemes improve the state of upland birds as an indicator of biodiversity is mixed:

- The types of land management actions specified in agri-environment agreements explain little of the variation in patterns of bird species richness.
- Farms inside agri-environment agreements, if anything, have fewer not more species.

However, the influence of agri-environment schemes becomes clearer when looking at individual species of conservation concern. Greater densities of key species were found on fields where more of the farm and the surrounding area is included in agri-environment agreements.

How could we design agri-environment policies better?

Further work is being undertaken in the project to examine how agricultural subsidy schemes can be designed more effectively to provide benefits for biodiversity.

– There might be benefits in allowing payment rates to vary across space or to vary with the amount of biodiversity benefit provided.
– The cost effectiveness of agri-environment schemes could be enhanced by recognising the different costs which farmers face in "producing" environmental benefits.
– Ecological effectiveness could be improved by designing incentives which encourage spatial coordination across several farms.

Further information

The research has been carried out at the University of Sheffield, University of Stirling and University of Nottingham, in collaboration with the Moors for the Future Partnership.

Key Contacts:
Dr Paul Armsworth, University of Tennessee, Knoxville
(formerly University of Sheffield)
Email: p.armsworth@utk.edu
Professor Nick Hanley, University of Stirling
Email: n.d.hanley@stir.ac.uk

Useful resources:

Acs, S., Hanley, N., Dallimer, M., Gaston, K.J., Robertson, P., Wilson, P. & Armsworth, P.R. 2009. The effect of decoupling on a marginal agricultural system. *Land Use Policy*, in press advanced copy available online, doi:10.1016/j.landusepol.2009.07.009

Dallimer, M., Acs, S., Hanley, N., Wilson, P., Gaston, K.J. & Armsworth, P.R. 2009. What explains property-level variation in biodiversity? Taking an inter-disciplinary approach. *Journal of Applied Ecology*, 46, 647-656.

Dallimer, M., Acs, S., Tinch, D., Hanley, N., Gaston, K.J. & Armsworth, P.R. 2009. 100 years of change: examining agriculture, habitat change and stakeholder perceptions through the 20th century. *Journal of Applied Ecology*, 46, 334-343.

Tinch, D., Hanley, N., Dallimer, M., Posen, P., Acs, S., Gaston, K.J. & Armsworth, P.R. 2009. Historical perspectives on the development of multifunctional landscapes: a case study from the UK uplands. In: *Multifunctional Rural Land Management: Economics and Policies*. Brouwer, F. & van der Heide, M. (eds.). Earthscan, London, UK, pp. 277-294.

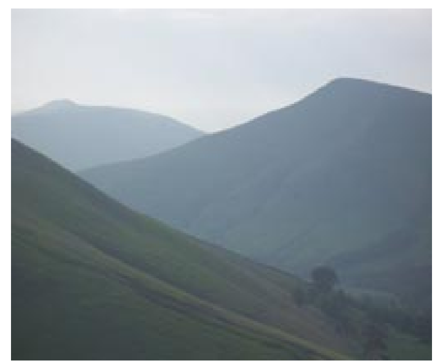
Project Website: www.biome.group.shef.ac.uk/RELU/People.htm

Hill Farm Economics, Landscapes and Biodiversity in the Peak District

An interdisciplinary research project conducted as part of the Rural Economy and Land Use Programme (RELU)

An interdisciplinary research project conducted as part of the Rural Economy and Land Use Programme

Project Outline



People

Feedback:f.eigenbrod@sheffield.ac.uk

Hill Farm Economics, Landscapes and Biodiversity in the Peak District

An interdisciplinary research project conducted as part of the Rural Economy and Land Use Programme (RELU)

Project Outline

Moorlands support traditional hill farming communities, are home to species of international conservation concern and provide emblematic landscapes with high recreational value. This collaboration launched in 2006 between researchers in the Universities of Sheffield, Stirling and Nottingham and the Moors for the Future initiative aims to discover how we can manage moorland ecosystems in a way that delivers sustainable hill farming communities while also protecting the environment. Taking the Peak District as a case study, we will examine how farmers respond to policy changes and how they can design business plans to cope with these changes most effectively. We will explore the impact that hill farming has on moorland species and predict how those impacts are likely to change over the next 20 years.

To do this, we will
· conduct questionnaire surveys with local farmers regarding the economics of hill farming and ongoing policy changes
· survey moorland birds to assess how they respond to different land management practices
· develop new modelling techniques that allow us to assess how the actions of one farmer affect those of neighbours and how upland bird species rely on a diversity of habitats across the landscape.
· conduct valuation workshops with the general public to discover what it is they most value about moorlands.

Finally, we will combine these results to evaluate how effectively different policies balance the multiple demands on moorlands.

For further details, please contact one of the researchers working on the project.