Development of beef and sheep systems for improved sustainability, biodiversity and delivery of ecosystem services within hill areas of Northern Ireland (Project 12/4/08)

Final report

Report prepared by

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DISCLAIMER

The data collected as part of this project were obtained on farms across Northern Ireland where in most cases livestock were grazing areas that have been under restricted winter grazing management for more than ten years in order to comply with agri-environment schemes. Any results in relation to vegetation structure and composition presented in this report should therefore be treated with this in mind, and do not necessarily reflect all grazing systems found within hill areas of Northern Ireland.

Contents

EXECUTIVE SUMMARY

This project was commissioned by DARD in 2012, as part of the Evidence and Innovation work programme, with co-funding from AgriSearch.

There were four main components to the project. A sheep component investigated the longevity, ease of lambing and production performance of a range of composite hill ewe genotypes. A beef component examined the performance of native and continental suckler cow genotypes on commercial hill farms. A biodiversity component investigated the roles of cattle and sheep grazing for managing biodiversity. A fourth component developed tools using Geographical Information Systems (GIS) to identify the optimum grazing capacity for the maintenance and provision of ecosystem services in upland regions of NI. The project was undertaken on twelve hill farms across Northern Ireland on heather and rush-dominated habitats grazed by either sheep or cattle.

Data from 2,850 composite ewes, born between 2007 and 2012 were obtained from 6 hill farms. Replacement ewes were obtained following two contrasting strategies applied at all study farms: a criss-cross (CC) between Blackface and Swaledale rams or a three-breed (3B) rotation combining Lleyn or Belclare, Highlander and Texel rams. Mature 3B ewes were heavier than CC ewes (61.5 kg vs 57 kg), but had lower BCS (3.6 vs 3.8). Conception rate was high, with an average of 0.95 across all ewe types, regardless of breed or age. Weaning rates were similar regardless of breeding strategy (1.36 lambs weaned per ewe lambed at 4.5 years old), despite highest weaning rates for Highlander x ewes (+0.25 lambs). Overall ewe efficiency (kg lamb/kg ewe) was similar regardless of breeding strategy (benefit of slightly heavier lambs from 3B cancelled out by higher ewe live weight).

A total of six suckler producers were recruited via AgriSearch to be involved with this study located within counties Tyrone, Fermanagh and Antrim. Cows were identified as either continental or native according to their registered breed type and phenotype. Continental genotypes were significantly heavier than native genotypes, however limited differences in body condition scores were observed between the two genotypes. Native genotypes had more cows classified as “very quiet” at calving and in year 1 had more cows calving “unassisted” relative to continental genotypes. However, calving difficulty was similar across genotypes during year 2.

To identify the impact of environment on suckler herd fertility, data was extracted from a Suckler Herd Fertility Survey undertaken by AFBI on 105 farms in conjunction with CAFRE during autumn 2012 and spring 2013. Fertility of suckler cows in hill environments was lower than lowland environments, regardless of genotype.

A total of eight farms were used for the vegetation study, four sheep and four beef farms. Five of the sites were managed under DARD Countryside Management Scheme agreements. Within each of the sites (i.e. management units or fields), a maximum of four grazing exclosures were put up in pre-selected areas. Detailed habitat/vegetation maps of the study sites were produced by a field mapping survey in conjunction with use of recent orthographic images. Vegetation height, plant species composition and biomass were recorded during the periods July-October 2013 and May-October 2014.

Over the short-time period of this study, there was little evidence that livestock (sheep or cattle) had grazed late building or mature heather during the summer sampling periods. Sheep and cattle were shown to have a strong preference for newly burnt heather over older age classes. There was no evidence of sheep or cattle grazing soft rush where it was present. With the exception of purple moor-grass in some circumstances, there was little evidence that sheep (or cattle) were grazing on other dominant moorland graminoid species, i.e. cotton grasses or deer grass. As study farms generally had drier semi-improved or acid grassland areas available, these were preferentially grazed by sheep. This meant that heather or rush-dominated areas were only occasionally utilised.

A GIS methodology was successfully developed and applied to Northern Irish uplands to explore the relationship between grazing capacity and a range of ecosystem services (biodiversity, soil and water quality). To illustrate this, new maps were produced to estimate the potential risk posed to water quality due to grazing. This methodology is now available to better inform land use management.

In light of the main findings of this study and recent discussions with DARD advisors, policy and industry stakeholders, several important implications were identified for policy and industry. In particular, only limited pressure was found of grazing livestock on vegetation structure, which suggests that stocking rates and/or grazing periods may not be appropriate. Grazing prescriptions may have in some cases contributed to the presence of stands of tall heather, potentially becoming ineligible for SFP. Site-specific prescriptions may be necessary to ensure that heather or rush dominated areas are more utilised by sheep and cattle.

During the preparation and implementation of this work, and subsequent analyses of the animal and vegetation data, a number of evidence gaps were identified and summarised in this report. Further research programmes should address these knowledge gaps in order to make further progress towards improved sustainability of hill grazing systems.

INTRODUCTION

Almost 50% of the suckler cow herd in Northern Ireland (NI) and 60% of breeding ewes are found in hill and upland areas. Within these areas, cattle and sheep grazing also plays an important role in managing upland habitats to maximize biodiversity, prevent encroachment by unwanted species, and maintain the aesthetic value of the countryside. Ensuring a vibrant and profitable hill livestock sector is therefore crucial for a strong rural economy and food security. However the key challenge for sustainability of hill areas is to maximize production of both economic goods (food, tourism) and environmental goods (biodiversity, ecosystem services).

AFBI have been working with hill farmers in Northern Ireland for almost 20 years, seeking to develop more efficient breeding and management strategies. This previous research work and comprehensive reviews by the Northern Ireland Red Meat Industry Task Force (McCann and Colhoun 2007) identified poor fertility and growth performance as major constraints on profitability of hill livestock system. For the hill sheep and beef sectors to remain competitive, there is a need not only to improve animal performance, but also to better understand the impacts of grazing on those habitats, in order to maximise the sustainable utilisation of resources and inform agri-environment schemes.

The impact of grazing on upland vegetation has been well researched in the UK, particularly since the 1980’s when concern over heavy grazing and the poor condition of these habitats was raised. This was largely a result of farmers responding to policy initiatives leading to intensification by increasing stock numbers. Overgrazing of upland habitats particularly by sheep has been considered a major issue and there have been a number of studies looking at the maintenance and restoration of upland heathland and blanket bog. Addressing this became a priority for agri-environment schemes in the UK, with the introduction of grazing management prescriptions aimed at maintaining or enhancing moorland. However, more recently there has been concern about undergrazing of the uplands due to a combination of the introduction of area-based payments, reduced stocking rates under agri-environment schemes and the decline in profitability of hill farming. Grazing livestock systems, mainly with sheep, are the main land use on upland habitats in NI. The issue of undergrazing of upland vegetation has become pertinent here due to the eligibility of heather and rushes for Single Farm Payment (SFP). Thus there is a need to better understand the value of upland vegetation in relation to the utilisation of heather (*Calluna vulgaris*) and rush (*Juncus* species) by cattle and sheep, and to investigate appropriate grazing and management strategies for these habitats more fully.

Much of the research on grazing management in the uplands has been undertaken under environmental conditions which are different from those in NI so the key findings may not be directly applicable to the local environment. Cattle and sheep have different body sizes, diet selection and foraging strategies and therefore grazing by cattle has a different impact upon vegetation compared with sheep. However there has been very little research done to compare grazing behaviour, diet selection, herbage intake and impact on vegetation within and between these species. There appears to be a good understanding about the grazing preferences of sheep and, to a lesser extent, of cattle on moorland vegetation. A reasonable amount of research into the effects of sheep grazing at various stocking rates on moorland has been carried out, although the outcomes tend to be site dependant. Knowledge gaps identified were the effects of cattle or mixed cattle/sheep grazing on heathland and moorland species (Adamson & Critchley, 2007). Better understanding of the role of grazers in maintaining habitats in favourable condition was also seen to be required.

Upland regions deliver a wide range of ecosystem services in Northern Ireland including agricultural produce, carbon sequestration, provision of potable water and biodiversity. Changes in stocking rates in these areas can have a significant impact on inter alia soil erosion, soil hydrology, nutrient cycling and soil carbon, all of which have consequences for the delivery of terrestrial and aquatic ecosystem services. Historically, estimates of the grazing capacity (GC) of agricultural soils have been based on maximising agricultural productivity with limited consideration given to potential adverse impacts on other ecosystem services. One of the objectives of this project was therefore to develop tools to identify the optimum grazing capacity for the maintenance and provision of ecosystem services in upland regions using a geographical information system (GIS) framework to develop maps for across NI.

The overarching aims of the project were i) to identify breeding strategies to improve the economic sustainability of hill livestock systems, and ii) to better understand the role of livestock grazing for maintaining biodiversity and delivering ecosystem services. There were four main components to the project, reflecting the following four specific objectives:

1) Investigate the longevity, ease of lambing and production performance of a range of composite hill ewe genotypes
2) Identify suitable genotypes for efficient suckler cow production in the hills
3) Investigate the roles of cattle and sheep grazing for managing biodiversity
4) Develop tools to identify the optimum grazing capacity for the maintenance and provision of ecosystem services in upland regions of NI.

The project was undertaken on twelve study hill farms, with heather and rush-dominated habitats grazed by either sheep or cattle (see Figure 1).

Figure 1. Map with the location of the study sheep (blue) and beef (red) farms, with a subset of 8 farms (triangles) where vegetation was monitored as part of the biodiversity component of the project.

SHEEP COMPONENT: Investigation of the longevity, ease of lambing and production performance of a range of composite hill ewe genotypes

In the past 20 years, DARD and AgriSearch-funded research programmes undertaken by AFBI on commercial hill sheep flocks found that lamb output could be increased by at least 10% through crossbreeding (Annett *et al*, 2011); however there is further evidence from this work suggesting that crossbreeding strategies based on lowland-breed types could impinge on the role of sheep grazing for heather management (McCloskey, 2010; McCloskey and McAdam 2010). Further work is needed to help identify sheep breed types that can deliver economic as well as environmental benefits for hill areas.

Materials and methods

This study was undertaken on six hill farms across NI (Figure 1). Typically at those farms, ewes grazed improved pastures during the mating period, returned to the hill during pregnancy, were housed 2-6 weeks before lambing in Spring, and returned to the hills after lambing. Since 2006, Scottish Blackface (BF) ewes and their crosses (Swaledale × BF, Cheviot × BF, Lleyn × BF and Texel × BF) were mated with one of five ram breeds following two strategies: a criss-cross (CC) between BF and Swaledale (SW) rams or a three-breed (3B) rotation combining 1) Lleyn (LL) or Belclare (Bel) to improve fertility, 2) Highlander (H) to improve lambing ease and 3) Texel (T) rams. Ewe replacements from these crosses were retained and mated first at 18 months old using another breed than its sire breed in order to continue the replacement strategies. Specifically from the start of this project, in October 2012, 2013 and 2014, 150 composite ewes on the six study farms were weighed, condition scored and allocated to four ram breeds. Those ewes were weighed and body condition scored (BCS) again six weeks pre-lambing (Jan 2013, 2014 and 2015), six weeks post-lambing (May-June) and at weaning (August-September). Lambing data (litter size, date of birth, sex and birth weight) and lamb growth to weaning (125 ± 13 days) were also determined at each farm. Lambing difficulty was scored for each lamb on a four point scale (1 = unassisted, 2 = minor assistance, 3 = major assistance and 4 = veterinary intervention).

Overall since starting to implement these breeding strategies, a larger dataset was available and included in the analyses, with data available from 2,850 composite ewes, born between 2007 and 2012, mated between 2008 and 2013 and aged between 1.5 and 4.5 years old. All data were analysed using REML in GenStat. Models for ewe traits had repeated measures with mating year, farm, age × sire breed as fixed factors and ewe as a random term. Models for lamb traits had mating year, farm, age × sire breed (of dam), ram breed as fixed factors and ewe as a random term, with additional fixed effect days to weaning for the variable kg lamb/kg ewe, and additional fixed effects litter size, sex and number of lambs reared for lamb weight and growth data. Lambing difficulty data were log transformed and analysed using a GLM assuming a multinomial distribution with a logit-link function.

Results

Ewe body size. Breed effects on ewe and lamb traits are given in Table 1 (for each genotype) and Table 2 (overall for each of the two strategies). The 3B ewes were heavier than the CC ewes, with mature Bel × and T × ewes being 5-6 kg heavier at mating than the BF × or SW × ewes ($P < 0.001$, Table 1). Overall, mature average body weight of 3B ewes was heavier than CC ewes by 4.5 kg at mating ($P < 0.001$, Table 2) and 3.0 kg at weaning (data not presented).

Ewe body condition. The 3B ewes had a 0.10 to 0.12 unit lower BCS than the CC ewes, with the H × ewes having the lowest BCS. Differences in BCS were small, yet significant ($P < 0.001$). Further details are presented in Figure 2, indicating that the same trends were observed pre lambing and at weaning. The data also indicates that BCS at mating and weaning were similar for most ewes, except for LL × ewes who were slower to gain their conditions back after lambing, to levels similar to those observed at mating.

Ewe fertility, lamb output and lambing difficulty. Conception rate (proportion of ewes pregnant) was high, with an average of 0.95 across all ewe types, regardless of breed or age (no significant differences). Most variations were due to mating year, with lowest rates of 0.91 in 2008 and highest of 0.98 in 2010, most likely in response to weather conditions. Lamb output for 3B ewes was greater than CC ewes at birth (by 0.11 lambs on average, $P = 0.019$) but not at weaning, despite the highest weaning rates obtained with the H × ewes (+0.25 lambs compared to T × and BF × ewes). A greater proportion of CC ewes did not require assistance at lambing (90%) compared to the 3B composites (76%).

Lamb performance. Lambs born to T ×, BF x and LL x ewes were 0.21-0.24 kg heavier at birth compared with those born to SW × ewes ($P = 0.048$), leading to no overall difference between the two strategies. Lamb live weight at weaning was also not significantly different between the two strategies, despite small, yet significant differences in live weight gain up to weaning (+ 12g/day on average for lambs from 3B ewes than CC ewes, $P = 0.024$).

Ewe efficiency. Ewe efficiency was calculated as the total kg of lamb weaned per kg of ewe lambed, thus reflecting the combined effects of ewe fertility, lamb growth and lamb survival to weaning. Low weaning rates for T × and BF × ewes led to low efficiencies, whereas high weaning rates for H × ewes led to higher efficiency of 0.76. The efficiency of SW × ewes were similar to H × and LL × ewes due to their lower body weight, compensating for a lower weaning rate. Overall, due to their greater body weight, 3B ewes had similar efficiency to CC ewes.

Table 1 Effects of ewe genotype on ewe and lamb performance

	Ewe breed						s.e.d	P
	Three-breed strategy				Criss-cross strategy			
	Bel ×	H ×	LL ×	T ×	BF ×	SW ×		
Ewe mating weight (kg) [1]	62.0^{a}	60.5^{ab}	59.5^{bc}	62.5^{a}	56.5^{d}	57.5^{cd}	0.62	***
BCS at mating	3.63^{b}	3.56^{a}	3.68^{bc}	3.70^{c}	3.77^{d}	3.75^{d}	0.019	***
Litter size/ewe lambed	1.61^{cd}	1.69^{d}	1.53^{bc}	1.41^{ab}	1.32^{a}	1.52^{bc}	0.078	***
Lambed unaided (%)	68^{a}	81^{b}	88^{c}	72^{d}	90^{e}	90^{e}	0.76	0.011
Lamb birth weight (kg)	3.90^{ab}	3.95^{abc}	4.05^{cd}	4.08^{d}	4.05^{bcd}	3.82^{a}	0.078	0.048
Lamb weaning weight (kg)	31.8	30.9	31.4	31.6	29.8	30.2	0.61	NS
Lamb live weight gain (g/d)	226	218	222	224	208	214	4.9	NS
No. weaned/ewe lambed	1.30^{ac}	1.40^{c}	1.33^{ac}	1.15^{ab}	1.14^{a}	1.27^{abc}	0.082	***
Efficiency[2]	0.69^{ac}	0.76^{d}	0.73^{acd}	0.64^{ab}	0.64^{a}	0.72^{abcd}	0.045	***

[1]4.5 year old ewes only, [2]weight (kg) of lamb weaned/ewe body weight (kg)

Table 2 Effects of ewe genotype on ewe and lamb performance, when combining ewes within the 3B or CC strategy

	Three-breed strategy	Criss-cross strategy	P
Ewe mating weight (kg) [1]	61.5	57.0	***
BCS at mating	3.65	3.77	***
Litter size/ewe lambed	1.51	1.40	0.019
Lambed unaided (%)	76	90	0.085
Lamb birth weight (kg)	3.99	3.92	NS
Lamb weaning weight (kg)	31.4	30.0	NS
Lamb live weight gain (g/d)	223	211	0.024
No. weaned/ewe lambed	1.23	1.17	NS
Efficiency[2]	0.67	0.66	NS

[1]4.5 year old ewes only, [2]weight (kg) of lamb weaned/ewe body weight (kg)

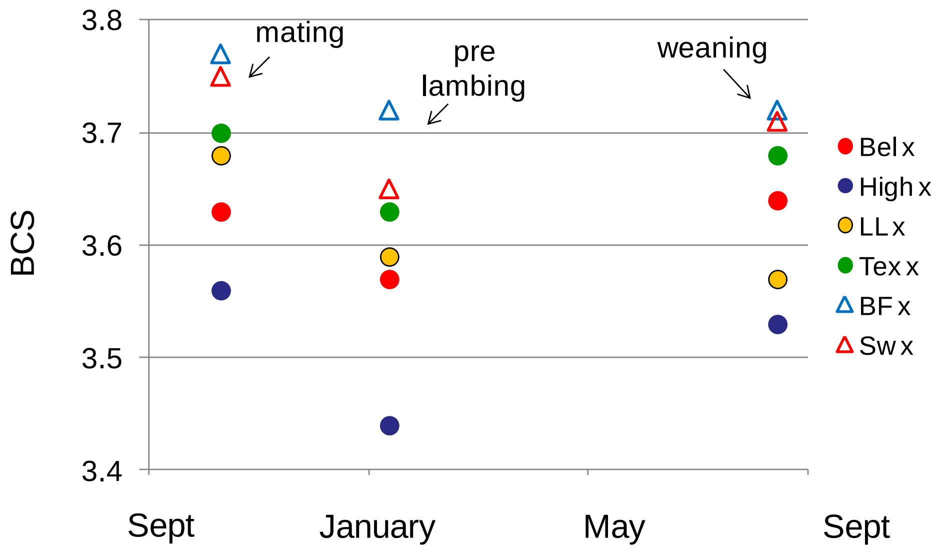


Figure 2. Ewe body condition scores at mating, pre lambing and weaning.

Conclusions

The main conclusions are that:

- Mature 3B ewes were heavier than CC ewes (61.5 kg vs 57 kg), but had lower BCS (3.6 vs 3.8)
- Conception rate was high, with an average of 0.95 across all ewe types, regardless of breed or age
- Similar weaning rates regardless of breeding strategy (1.36 lambs weaned per ewe lambed at 4.5 years old), despite highest weaning rates for Highlander x ewes (+0.25 lambs)
- Weaning rate key driver of ewe efficiency
- Similar efficiency of ewes (kg lamb/kg ewe) regardless of breeding strategy (benefit of slightly heavier lambs from 3B cancelled out by higher ewe LW)

The main implications of these findings are that the strategy with CC ewes appears most suitable for hard hill conditions, since they had a similar efficiency compared to 3B ewes, were able to maintain a slightly higher body condition than 3B ewes on hill habitats and required less assistance at lambing. In addition, previous work (McCloskey 2010) and ongoing studies using remote sensing techniques (GPS collars) to monitor grazing behaviour in these habitats (A Aubry, unpublished data) found that horned ewes tend to use hill habitats more efficiently by spending more time on heather dominated areas and by having a greater foraging area compared to 3B composites. Ongoing research on the performance of lambs during the finishing period will determine whether the 3B strategy is suitable for 'greener' hill areas.

BEEF COMPONENT: Investigation of suitable genotypes for efficient suckler cow production in the hills

Introduction

There is a diverse range of suckler cow genotypes within NI. Native breeds have been gradually replaced by larger continental breed types over time such that a recent survey of BovIS data comprising 229 NI suckler herds shows that less than 10% of suckler genotypes are native breeds. The ability of these contrasting genotypes to utilise upland vegetation is largely unknown. Furthermore, fertility amongst suckler herds in NI has not improved in the last two decades and continues to be a problem for the industry. The aim of this component of the project was to evaluate the performance of native and continental suckler cow genotypes on commercial hill farms over a three year period.

Materials and methods

A total of six suckler producers were recruited via AgriSearch to be involved with this study located within counties Tyrone (n=3), Fermanagh (n=2) and Antrim (n=1) (see Figure 1). These farms were selected from a total of 16 farms who had expressed an interest in the project. The selection was based on land suitability (Severely Disadvantaged and unimproved pasture) and cattle only grazing. Cows were weighed and condition scored where possible prior to turn-out to the upland area and again after removal from the upland pasture. Cows were identified as either Continental or Native according to their registered breed type and phenotype. At calving the farmers assessed their cows for calving behaviour. Calving difficulty was assessed on a 1-5 scale, with 1 being unassisted and 5 being a caesarean section. Calving temperament was assessed in a 1-5 scale, with 1 being very quiet at calving and 5 being very wild and aggressive. Calf vitality was assessed on a 1-3 scale, with 1 being up and suck without intervention, 2 being slow to suck and 3 being helped to suck. Mothering ability was assessed on a 1-4 scale, with 1 being accepts calves readily, 2 being accepts calf after encouragement, 3 being rejects calf and 4 being aggressive towards the calf.

To identify the impact of environment on suckler herd fertility, data was extracted from a Suckler Herd Fertility Survey undertaken by AFBI and in conjunction with CAFRE during autumn 2012 and spring 2013 (Titterington, unpublished data). Within this survey farms were categorised into severely disadvantaged (SDA), disadvantaged (DA) and lowland. Fertility was measured as the average calving interval and the age at 1st calving. The data was subdivided into native and continental according to the breed type of the cow registered on APHIS.

Results and discussion

The live weights and condition scores of the native and continental cows at turnout and at removal from upland pasture are presented in Table 3. The native genotype cows were always significantly ($P<0.001$) lighter than the continental cows although differences in condition score were much less defined. This data also suggest that both the continental and native genotypes were in "fit" body condition score indicating that the hill could sustain either native or continental cows.

Table 3. Live weight and condition score of the continental and native suckler cows at turnout and removal from SDA pasture during 2013 and 214

Period	Continental	Native	sed	Significance
		Live weight (kg)		
Turnout 2013	552.4	469.3	21.52	***
Removal 2013	583.6	496.0	17.63	***
Turnout 2014	569.3	496.1	13.97	***
Removal 2014	640.0	505.2	20.29	***
		Condition score		
Turnout 2013	2.97	2.79	0.078	*
Removal 2013	3.16	3.04	0.080	NS
Turnout 2014	3.19	3.15	0.054	NS
Removal 2014	2.80	2.99	0.101	P=0.054

The data collected as part of this work enabled a comparison of native and continental genetics in terms of their easy care characteristics (Table 4), but was not appropriate to run the statistical models required to identify the most appropriate strategy. To do so, longer term data and from a greater number of animals are required. In both year 1 and year 2, cows of native genotypes had a better calving temperament relative to continental cows. In year 1 native cows had less calving difficulties that continental cows, however calving difficulty was similar across both genotypes during year 2. There were no genotype differences for mothering ability or calf vitality.

Table 4. A comparison of suckler cow genotypes for calving performance

	Year 1		Year 2	
	Native	Continental	Native	Continental
Calving temperament	<		<	
Calving difficulty	<		=	
Calf vitality	=		=	
Mothering ability	=		=	

Results from the suckler fertility survey which was undertaken on 105 farms spread across NI indicated that the age of 1st calving was older and calving interval lower on SDA and DA relative to lowland farms. These results indicate that herd fertility was poorer on upland farms than on lowland farms. When the data was subsequently separated into native and continental cows no significant differences were apparent.

Conclusions

The hill environments on the six farms evaluated within this study were able to sustain both native and continental suckler cow genotypes. The continental genotypes were significantly heavier than the native genotypes, however limited differences in body condition scores were observed between the two genotypes. Native genotypes had more cows classified as “very quiet” at calving and in year 1 had more cows calving “unassisted” relative to continental genotypes. However, calving difficulty was similar across genotypes during year 2. Fertility of suckler cows in hill environments was lower than lowland environments, regardless of genotype.

BIODIVERSITY COMPONENT: The impact of cattle and sheep grazing on vegetation on hill farms

The biodiversity component of the project aimed to provide data on vegetation types, plant species composition, vegetation biomass and height, in order to assess the impacts of livestock grazing by cattle or sheep on hill farm habitats. Biodiversity is a concept, not a simple variable, and monitoring requires appropriate biodiversity indicators that are easily measured. Due to the short-term nature of the current project, vegetation structure was seen as the most suitable variable to give an indication of longer term impacts of livestock grazing on species diversity.

Materials and methods

Site selection and sampling

A total of eight farms were used for the vegetation study (Table 5), four sheep and four beef farms (see Figure 1). The study area used on most of the farms was a management unit usually grazed as a single area, although in some farms this consisted of a number of fields. Two of the beef farms (B2 and B4) had more than one study area. Five of the sites were managed under DARD Countryside Management Scheme (CMS) agreements and as such had set maximum stocking densities and grazing periods permitted for specific habitats.

Table 5. Details of the sheep (S) and beef (B) hill farms used in the study

Farm ID	Location	Altitude (m)	Study area (ha)	Main habitat types	Land under CMS	Approx. grazing period
S1	Co.Antrim	150-200	106	WH (50%)	Yes	May – Sept
S2	Co.Londonderry	250-400	151	BB (80%)	Yes	May – Sept
S3	Co.Antrim	280-340	35	DWH (40%) BB (18%)	Yes	April – Oct
S4	Co.Antrim	300-370	103	BB (68%) DBB (20%)	No	May – Oct
B1	Co.Antrim	260-280	17	WG (88%)	Yes	April –Sept
B2	Co. Fermanagh	160-180	60; 15	LRB (45%); WG (25%)	No	All year
B3	Co.Tyrone	200-220	27	WH (60%)	No	July – Oct
B4	Co. Tyrone	250-350	20; 4; 5	DWH/BB (47%;67%) WH (67%)	Yes	May – Sept

(BB=blanket bog, DBB = degraded blanket bog, WH= wet heath, DWH= degraded wet heath, WG=wet grassland, LRB =lowland raised bog)

Within each of the sites (i.e. management units or fields), a maximum of four grazing exclosures were put up in pre-selected areas. For those sites characterised by the presence of heather, exclosures were set up on heather of different heights/ages* where possible. On sites grazed by sheep, 8m x 8m exclosures were used, constructed of post and wire. For the beef farms, 6m x 6m exclosures were set up using electric fencing. The position of all exclosures was marked using a hand-held GPS.

***** Heather growth is characterized by changes that have been classified into pioneer, building, mature and degenerate phases, each larger and with a larger proportion of wood content than the previous phase. Each phase lasts about 5–10 years but heather grows most rapidly in the building phase and reaches its maximum cover and density during this phase.

Habitat mapping

Detailed habitat/vegetation maps of the study sites were produced by a field mapping survey in conjunction with use of recent orthographic images. These were used to create a GIS map and database for each of the sites. This enabled the area of each vegetation type within individual management units to be calculated. Subsequently maps were used to provide information on grazing behaviour on selected farms through the overlaying of point data from GPS collars.

Vegetation height

The height of plant species was recorded at 4-5 week intervals between July-October 2013 and May-October 2014. Forty measurements of sward height were taken both from within and outside each grazing exclosure during a W-walk through the vegetation. Heather, rush and graminoid (i.e. grass and sedge) species were recorded separately. For the grazed area, measurements were taken between 2m and 5m distance from the exclosure. In 2014 a minimum of 20 heights of heather (or rush where applicable) and 20 graminoid heights were taken.

Plant species composition

The estimated percentage cover of all vascular plant species was recorded within $1m^2$ quadrats located within and outside each exclosure in July 2013 and July 2014. In addition plant species within a further four quadrats was recorded along a marked 100m transect, in order to give a wider assessment of the vegetation for each site. Canes were used to mark corners of quadrats and GPS positions taken, in order to allow accurate relocation.

Biomass

Clips of vegetation to ground level were taken from inside and outside exclosures within a $50cm^2$ quadrat. This was carried out in July 2013, May 2014 and late September/early October in both years. Samples were separated into main plant components in the laboratory and then oven dried at 80^oC overnight before weighing. Data on dry weights were then calculated as gDM/m^2 (excluding moss and burnt heather material if present).

Data analysis
Vegetation heights and dry weights were analysed using t-tests and ANOVA with grazing as a treatment.

Results

Habitat maps

Habitat maps of the study sites were produced for all farms (see Appendix 1 and example in Figure 3). From these maps, the area of each habitat/vegetation type for each site was calculated. The proportion of the main habitat types found at each site is given in Table 5.

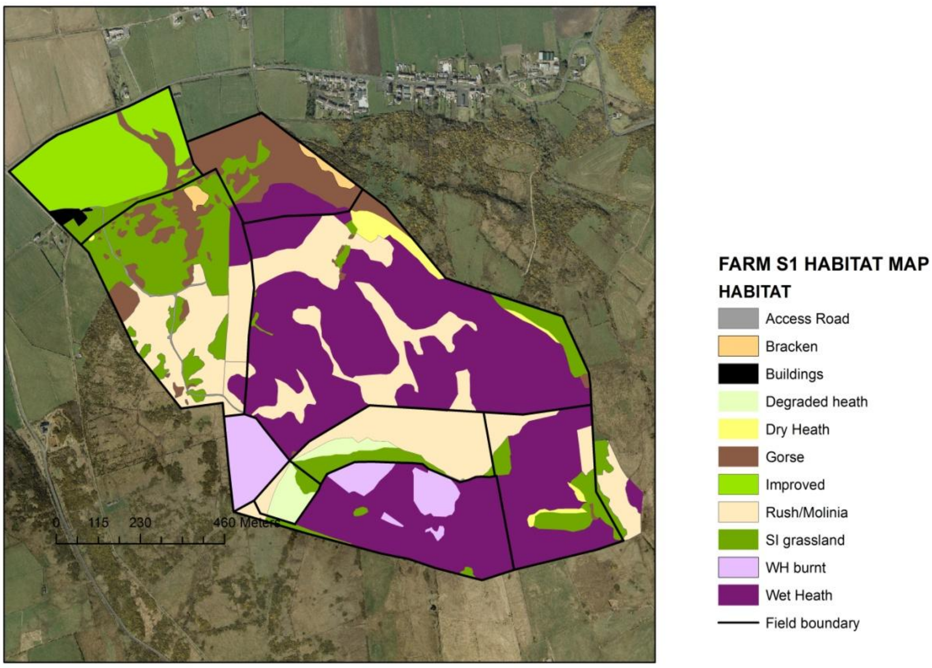


Figure 3. Example of a habitat map produced for this project

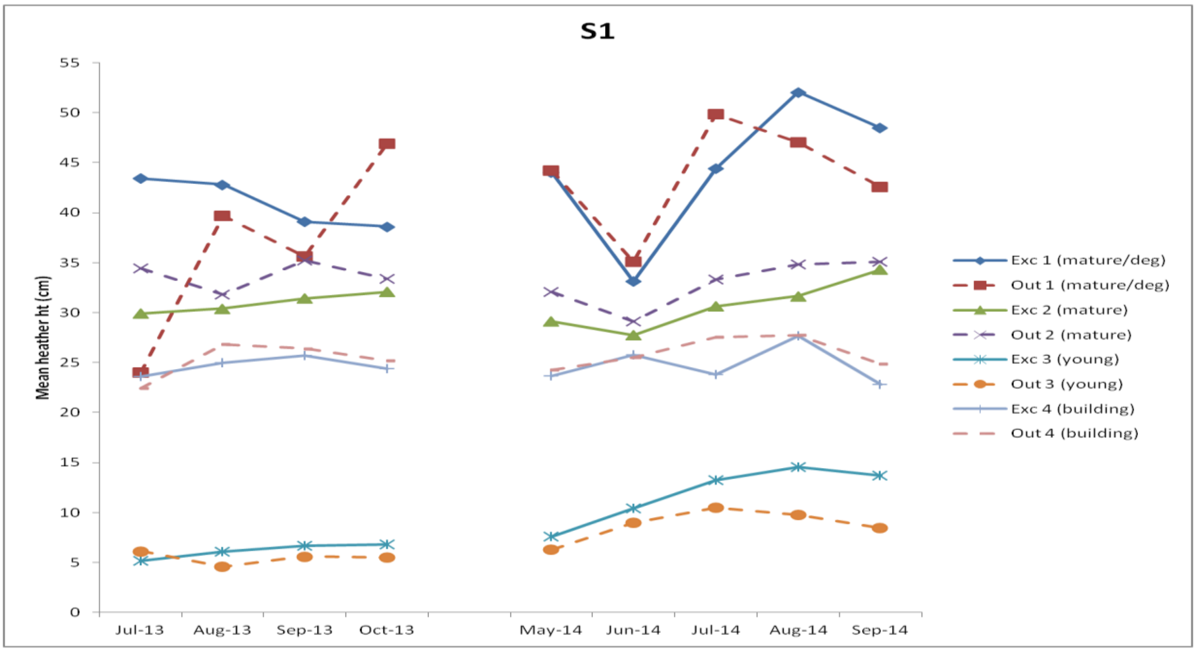
Vegetation height

Farm S1
There was no significant difference in mean height of building or mature heather (*Calluna vulgaris*) between ungrazed exclosures and grazed wet heath vegetation at the end of the second grazing season (Figure 4). The height of young pioneer heather (burnt site 3) was significantly higher within the exclosure in 2014 from July onwards (p<0.001). There were large fluctuations in the mean height of mature/degenerate heather (site 1) recorded during the season over both years. This

was mainly due to recorder differences where large heather bushes were scattered within grass. There was little growth in heather between October and May. Annual growth rate of young, pioneer heather within exclosure at site 3 was 7cm, compared to 2cm when vegetation was subject to grazing. There was no significant growth of the building/early mature heather (sites 2 and 4) when either grazed or ungrazed. This was possibly due to suppression by wind-clipping, as heathland was on an exposed coastal site.

Those sites nearer to the lane and/or a gate had a lower mean graminoid height. The exclosure on recently burnt vegetation also had a significantly taller graminoid height than outside in 2014 ($p<0.05$). Where fine grasses, e.g. bent grass (*Agrostis* sp.) or young purple moor-grass (*Molinia caerulea*) were present, these species were grazed by sheep, whereas on areas of wet heath with mixture of common cotton-grass (*Eriophorum angustifolium)* and tall *Molinia* there was no evidence of grazing of these species.

Figure 4. Mean heather height over grazing season in 2013 and 2014 for farm S1



Farm S2

Data from blanket bog vegetation showed no significant difference in mean height of building or mature heather between grazed vegetation and ungrazed exclosures by the end of the second grazing season. On the area which was burnt in April 2014 (site 1), there was a significant difference in mean heather height from July onwards ($p<0.001$). Heather growth within this exclosure between May and September 2014 was 11cm, compared to 5cm outside, indicating sheep were grazing the new young growth. Growth of building heather (sites 2 and 4) was around 5-8cm per year.

Mean graminoid height was not significantly different in exclosure to outside at burnt site 1 in 2014 There was no obvious grazing of *Eriophorum* species. Graminoid height was greater within the exclosure at site 4 over most of the season, this was a lower altitude site adjacent to grassy area. Graminoid height was much greater within mature heather, indicating lack of grazing of these species due to inaccessibility to sheep.

Farm S3

For one of the sites with building heather (site 3), there was a significantly greater mean heather height in September 2014 within the exclosure ($p<0.001$), suggesting that sheep had grazed some heather. However there was no difference between grazed and ungrazed vegetation for the two other sites (1 and 2) with short heather. The management unit as a whole was degraded heathland, where heather was short (10-15cm) although in building stage, suggesting heavy grazing in past years and/or 'wind-clipping'. Heather growth was slow, generally 2 to 5cm per year.

Graminoid species both within and outside exclosures showed an increase in growth between May and July. There was no obvious grazing of *Eriophorum* spp or deer grass (*Scirpus cespitosus)*. However there was evidence of light grazing of some species later in the season, mainly *Molinia* and fine grass species.

On site 4 dominated by sharp-flowered rush (*Juncus acutiflorus),* there was some evidence to suggest that sheep were grazing this rush species early in the season. Mean graminoid height was significantly shorter outside the exclosure throughout the summer, indicating grazing of the fine grass and sedge (*Carex* spp.) species present.

Farm S4

There was no significant difference in building or mature heather height between exclosures and grazed blanket bog vegetation. Growth of heather between May and September 2014 was around 5cm. The lower site near to access gate (site 1) was heavily grazed with suppressed heather (5-10cm) and showed very little growth in the exclosure throughout the summer. However there was a significant height difference between this and grazed heather shown in October ($p<0.05$).

Graminoid growth (mainly *Eriophorum* spp) showed a large increase between May and July then levelled off. There was no difference in mean height between exclosures and grazed vegetation on three higher altitude sites, indicating low grazing levels and/or avoidance of these species. On the lower site there was a slightly higher graminoid height in the exclosure by September.

Farm B1
On two exclosures in this wet grassland field with dominant *Juncus acutiflorus* (sites 1 and 2), this species was significantly shorter outside the exclosures in 2013 when there had been continuous light grazing from late spring. In 2014, when cattle were not put on until July, there was less difference in rush height. On the site dominated by soft rush (*Juncus effusus)* (site 3*),* there were no indications that this had been eaten by cattle. Mean graminoid height (fine grasses and sedges) was significantly greater in exclosures ($p<0.05$).

Farm B2
On the recently burnt drier site towards the edge of the bog (site 2), mean heather height was significantly greater in the exclosure in 2014 ($p<0.001$). There was no difference in height of heather or *Eriophorum* in exclosure further onto the bog (site 3), indicating that cattle were rarely grazing this extensive area. At sites 1 and 2 where *Molinia* was abundant, it was significantly taller in the exclosures (40-50cm) compared to grazed vegetation (10-20cm).

On the rushy wet grassland site in a separate field (site 4), there were indications that cattle had eaten some rushes (mainly *Juncus acutiflorus*) early in the season, but there was no significant difference in mean height recorded outside the exclosure in October.

Farm B3
There was no difference in height of mean mature heather (site 1) between exclosure and grazed wet heath vegetation. On the recently burnt area (site 2), there was very little difference in mean height of young heather in exclosure, although there were signs that growth rate was slightly greater over the season. The other site (site 3) showed significantly lower heather height ($p<0.001$) outside the exclosure in 2014 particularly later in the season. Heather was patchy (10% cover) and was being grazed by cattle as mixed with *Molinia*, which also showed a significant height decrease from July onwards.

Farm B4
Site 2 on degraded heathland was subject to very light cattle grazing. There was little heather (10%) and no height differences between exclosure and outside. Sites 3 and 4 were on a 5ha wet heath area that was fenced off in 2014 for the purposes of this study. There were no differences between mature heather height in exclosures and outside. However there was some trampling and breaking of stems of mature heather bushes. There was evidence that cattle were grazing *Molinia* but not eating the other main graminoid species, hare’s tail cotton-grass (*Eriophorum vaginatum*).

Biomass

There was a large variation in plant biomass within and between sites. Due to the heterogeneity of the vegetation on most sites, there was generally a greater variation in dry weight of heather or grasses between each clip than between the grazed and ungrazed plots.

There was a significant difference in the mean total plant biomass between grazed and ungrazed vegetation recorded on beef farms ($p<0.05$) in September/October 2014 (Table 6). Mean plant biomass was also greater within the ungrazed exclosures on sheep farms, although not significantly. There was no significant difference in the mean dry weight of heather between grazed and ungrazed sites at the end of the grazing season in 2014, for either sheep and beef farms.

For sheep farms, there was no overall difference in the mean dry weight of heather for the two years combined (i.e. from 4 clips) between grazed and ungrazed vegetation. However on two sites that had been most recently burnt on the sheep farms there was an indication that sheep grazing had decreased the biomass of heather. For example, data from the site burnt in spring 2014, indicated that 67% of the biomass of young heather had been removed by sheep grazing compared to the exclosure. For recently burnt plots on beef farms, there was less heather biomass within one of the exclosures, possibly due to competition from *Molinia*.

Table 6. Mean biomass of vegetation and heather (where present) from ungrazed and grazed plots in September/October 2014

	Mean heather biomass (gDM/m^2)		**Mean plant biomass (gDM/m^2)**	
	Sheep sites (n=15)	Beef sites (n=7)	Sheep sites (n=16)	Beef sites (n=14)
Ungrazed	537 (±134)	281 (±104)	793 (±117)	533 (±64)
Grazed	500 (±142)	281 (±93)	628 (±131)	338 (±64)

Vegetation composition

There were limited changes in plant species composition and abundance recorded in quadrats between 2013 and 2014. The exceptions were sites where vegetation had been recently burnt and was recovering. For example, heather cover increased by up to 15% within these quadrats. The short term data collected as part of this project can be used within future long term studies to investigate potential spatial and temporal differences in vegetation composition.

Conclusions

The biodiversity component of the project concentrated on the impacts of livestock grazing on heather. There was only one sample farm which was rush-dominated, although most sites did have patches of rushes (generally *Juncus acutiflorus*). There were considerable differences between the study sites, e.g. size of management unit, vegetation type, abundance and age of heather. Sheep study farms had larger extensive areas of blanket bog or wet heath, whereas beef farms generally had smaller management units often with less heather. Management varied both within and between sites. Therefore only a limited comparison can be made between all sites, particularly in terms of comparing the relative impacts of cattle and sheep grazing. As this was not an experimental trial, there were no changes to usual stocking rates on the farms (either CMS or non-CMS). Stocking rates and grazing periods were therefore variable between sites. Burning of heather was an additional complicating factor, interacting with grazing. This had occurred on a number of the study sites in recent years, both through accidental and managed burning.

Although vegetation measurements were taken over two grazing seasons only, this study has demonstrated potential impacts of grazing by sheep and cattle on moorland vegetation. These results, together with the available scientific evidence highlighted, can provide implications for livestock grazing on biodiversity of upland habitats. The main conclusions can be summarised as follows:

- Over the short-time period of this study, there was little evidence that livestock (sheep or cattle) had grazed late building or mature heather during the summer sampling period. Utilisation of heather and dwarf-shrubs by sheep is lower in summer and greater in autumn/winter as sheep will only begin eating heather in the winter when there is reduced digestibility and biomass of grasses (Armstrong, 1996). Only heather shoots produced in the most recent growing season are eaten. The management prescription under agri-environment schemes in Northern Ireland for no winter livestock grazing on blanket bog and heathland has been considered by some as leading to undergrazing of heather. The limited evidence from this study suggests this grazing prescription may have contributed to presence of stands of tall heather, potentially becoming ineligible for SFP.

- There were significant differences in mean heather height and biomass between exclosures and grazed areas demonstrated where young heather was present following recent burning. Sheep show a strong preference for newly burnt heather over older age classes. Heather shoots have an increased nitrogen content for about two years following burning. However burning of heather on blanket bog is not recommended, or permitted under AE schemes.

- There was no evidence of sheep or cattle grazing soft rush (*Juncus effusus*) where it was present. Therefore livestock grazing is not likely to impact on this species and control by herbicide may be needed in addition where it is abundant. Cattle were shown to eat sharp-flowered rush (*Juncus acutiflorus*) and sheep also, where young growth was eaten occasionally. This rush species is an integral component of unimproved wet grassland communities and dies back each year. As such it is not generally a problem in terms of ineligibility for SFP.

- Grazing levels on the large sheep-grazed moorland areas were generally low, due to low stocking rates allowed under CMS. With the exception of purple moor-grass (*Molinia caerulea)* in some circumstances, there was little evidence that sheep (or cattle) were grazing on other dominant moorland graminoid species, i.e. cotton grasses (*Eriophorum* spp.) or deer grass (*Scirpus cespitosus)*. All these species are more palatable to sheep in spring but then have low digestibility.

- There was very little change in vegetation cover and composition between 2013 and 2014, except on recently burnt heather plots. Vegetation can take several years to show a substantial response to grazing. The exceptions were sites where vegetation had been recently burnt and was recovering.

- As study farms generally had drier semi-improved or acid grassland areas available, these were preferentially grazed by sheep. This meant that heather or rush-dominated areas were only occasionally utilised. As a result low density, summer-only sheep stocking rates permitted on blanket bog or heathland habitats under AE schemes, could potentially result in undergrazing of these areas. There was little evidence of grazing of heather or other moorland species, except in patches e.g. near gates, in proximity to grassy patches or when recently burnt.

- Lack of grazing of *Molinia* has shown that this will soon result in dominance by tall tussocks, thus outcompeting heather and low-growing plant species. The build-up of dead grass material (particularly *Molinia*) when grazing was excluded or at very low levels, could result in the loss of species diversity. Periods of grazing by cattle can be beneficial in terms of controlling invasive hill species such as *Molinia* and *Nardus stricta* (Fraser *et al* 2011). Results of the current study indicated that cattle consumed *Molinia* in preference to other heath/bog species.

- Cattle grazing may need careful management on some habitats. Where cattle were put onto a small area of mature heather, trampling, dunging and damage to the woody stems of heather occurred. Generally cattle should not be grazed on intact blanket bog or lowland raised bog where *Calluna* is dominant, due to potential damage caused to sensitive vegetation. However cattle may have a role where *Molinia* is dominant in heathland or mixed vegetation, or to control scrub invasion on drier fringes of raised bog.

- Cattle often created a mosaic of short and tall vegetation which may be beneficial for biodiversity. Cattle grazing can increase sward heterogeneity with potential to influence abundance and diversity of different taxa, e.g. birds (Evans *et al*, 2006) and invertebrates (Dennis, 2003).

Variation among sites in the response to grazing means that blanket stocking rates are often inappropriate for maintaining the condition of heather or overall biodiversity. Undergrazing, as well as overgrazing, can cause environmental damage. Simply reducing sheep numbers is often not sufficient to effect an improvement in the habitat and might be detrimental to other taxa (e.g. Gordon *et al*. 2004). There does not appear to be any scientific evidence as yet that undergrazing is currently causing a negative impact on heather-dominated habitats in the UK or Northern Ireland. An analysis of the impact on the natural heritage of the decline in hill farming in Scotland has been carried out (Holland *et al*., 2011). This concluded that the recent reduction in livestock numbers is likely to have benefited some upland habitats, such as dwarf-shrub heath and blanket bog. However it was also considered that complete abandonment of the hill grasslands and dwarf-shrub heaths would be detrimental. The authors suggested that there is no such thing as an optimal grazing level for the uplands, different habitats requiring different levels of grazing to maintain their biodiversity and conservation value.

A review of scientific evidence was recently undertaken focussing on the effects of different grazing regimes and stocking rates on moorland biodiversity and ecosystem delivery (Martin *et al*, 2013). It was found that the quality of evidence was variable and that there was a lack of good quality studies on which to base management decisions. There remains concern and disagreement about the effects of grazing on the upland landscape and biodiversity, in particular stocking rates, different livestock types and timing of grazing regimes. Controlled grazing studies show that the level of utilisation and stocking rate that maintains heather cover varies depending on factors, e.g. heather/grass ratio, climatic/environmental factors. The impact of a given stocking rate will also differ between sites and years.

This short-term study together with existing scientific evidence suggests that recommending suitable grazing regimes to promote biodiversity is a complex issue. Low/moderate levels of livestock grazing are required to prevent dominance by undesirable species, keep heather at a lower height and maintain biodiversity of hill and upland habitats. Outcomes depend on management and vegetation characteristics, so site-specific regimes are necessary to meet particular objectives. Cattle can have a role in moorland grazing management and can reduce competitive grasses but may damage sensitive habitats such as blanket bog. More flexibility in grazing regimes for moorland should be considered for future agri-environment schemes, depending on site-specific objectives and targets (Flexen & McAdam, 2011). However there are considerable knowledge gaps, indicating that further research and monitoring is required.

ECOSYSTEM SERVICES COMPONENT: Linking grazing capacity to the delivery of freshwater ecosystem services in Northern Ireland Uplands

In Northern Ireland the area described as the 'Upland Vegetation Zone' is often given an altitude limit of ≥300m. However, Kirkpatrick (1988) recorded upland heathland at altitudes as low as 120m. For this study the criteria used to select upland areas were; Less Favoured Areas (LFA) above 100m altitude, identified by DARD as the utilized agricultural area (UAA) and with slopes < 60% (George *et al* 2007). Figure 5 illustrates the distribution of upland in the study area, based upon implementation of these filters.

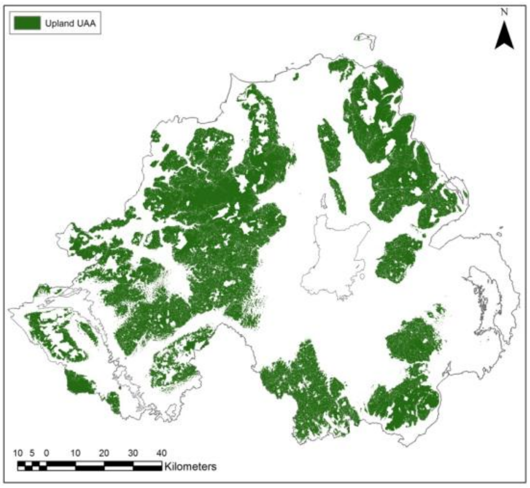


Figure 5. Upland Area within Northern Ireland delineated based on Less Favourable Areas designation, above 100m altitude and identified by DARD as the utilized agricultural area (UAA) with slope <60%

Materials and methods to determine grazing capacity

Although a number of sophisticated models exist for the prediction of dry matter yield (DMY) (e.g. Jouven *et al* 2006; Barrett *et al* 2005), they require a comprehensive array of meteorological and plant parameters as input, not readily available at regional levels. Instead, for this study an approach was developed using a multi-layered GIS model, incorporating DMY predictions developed by Han *et al* (2003). Here, dry matter production between April and July was estimated based on the number of days with daily mean temperature > 5^{o}C after 1st March and the average daily mean temperature accumulation throughout the full growing season. The daily mean temperature data was derived from the Met Office 1971-200030-year average maps for Northern Ireland.

A significant issue with the DMY predication based on the model of Han *et al* (2003) is that, due to well recognized issues in estimating DMY in grasses (e.g. Jouven *et al* 2006), it does not accurately predict production over the entire growth period (until the end of October). As no adequate DMY model was available after July, the growth predictions were based on the GrassCheck long term grass growth values for Northern Ireland (Dale *et al* 2012).

The developed model over-predicts DMY in the uplands area due to underlying general assumptions, i.e. good drainage on the site, well managed, generally high productivity grasses. In order to address this overestimation in upland areas, yield estimates were constrained based on the work of Laidlaw (2009) who found that in perennial ryegrass the optimum soil moisture level for maximum DMY was 0.75 field capacity (FC). In soils maintained at 0.5 FC, DMY was 69.75% of the average yield while in soils maintained in a waterlogged condition, 1.25 FC, DMY was reduced to 80.85% of the average yield. Initial predicted DMY yields for Northern Ireland were generated (Figure 6), based on the output from the model, incorporating adjustments due to average soil moisture conditions during the growing season and GrassCheck long term grass growth values.

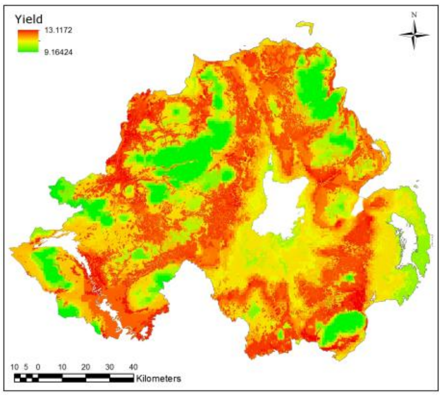


Figure 6. Predicted Dry Matter Yield March – November.

The DMY models' assumption of well managed, generally high productivity grasses is obviously not spatially valid across Northern Ireland; areas of semi natural or extensively grazed vegetation would require identification, as productivity is significantly lower. To address this, Land Cover Map 2007 (Morton *et al* 2011) broad habitat classes were imposed on the final predicted map with yield values assigned based on habitat class (Figure 7).

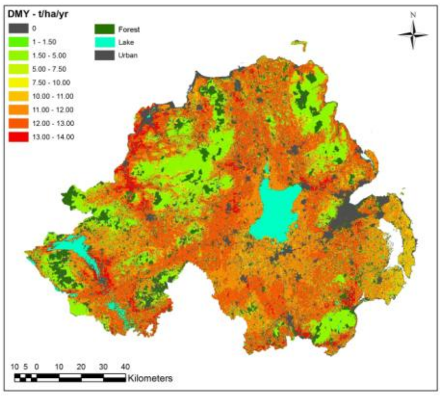


Figure 7. Estimated DMY using model prediction and Land Cover Map 2007 broad habitat class production values.

Results

Grazing capacity for upland areas

The grazing capacity of the land was calculated on the basis of the required dry matter intake per dairy cow equivalents (DCE) based on an annual requirement of 6374.7 kg for a standard 600 kg dairy cow in a lactation cycle (60 days dry) (Dillon *et al* 2003). It is assumed (Figure 8) that the animal's annual requirement for dry matter intake is met from herbage production in the period March to November. Subsequently the grazing capacity map was linked to the risk posed to water quality through determination of hydrological connectivity between the land and water-bodies.

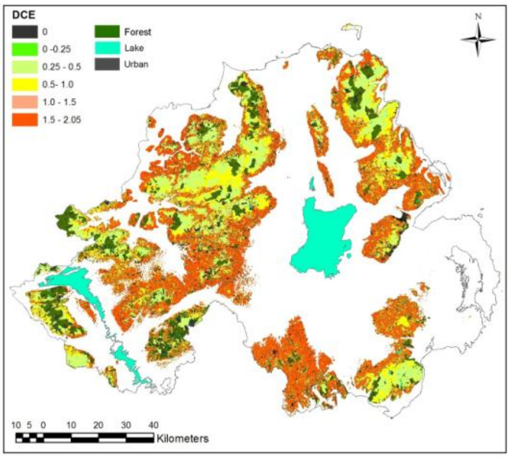


Figure 8. Estimated grazing capacity expressed in terms of Dairy Cow Equivalent (DCE) for the defined upland area.

Risks posed to water quality

Hydrological connectivity was estimated based on the Network Index of Lane *et al* (2004) which used the topographic wetness index (TWI) of Beven and Kirkby (1979) to model the tendency of a point in the landscape to be saturated based on slope and upslope contributing area to each cell. The network index considers the lowest value of TWI along a flow path to a stream as the limiting point for connectivity. This driest point is assumed to require longer to become saturated, limiting overland flow and thus connectivity to the stream. All connected cells in the flow path upstream of this cell are assigned this low value of TWI until a lower value is encountered. In a probabilistic framework the hydrological connectivity of lower network index cells will be less frequent and of shorter duration than cells with a high network index value. Network Index calculations were undertaken using the SCIMAP model (Lane *et al*., 2006, Milledge *et al*., 2012, Reaney *et al*., 2011) in the Colebrooke and Upper Bann catchments due lack of higher resolution (5m) elevation data at NI scale. In estimating the potential risk posed to water quality due to grazing, high values of the Network Index generated (i.e. high connectivity areas) from the SCIMAP model and high values of DCE, should indicate areas of greatest risk. To apply equal weighting to the Network Index (NI_{norm}) and DCE (DCE_{norm}) in terms of risk, both were normalised between 0 and 1 using the 5th and 95th percentiles of each as limits, and the product ($NI_{norm.}$ DCE_{norm}) calculated, shown in Figure 9 for the Upper Bann and as risk resolved to land parcel level for a sub-area of the catchment in Figure 10. (Note: Maps for the Colebrooke catchment are not presented).

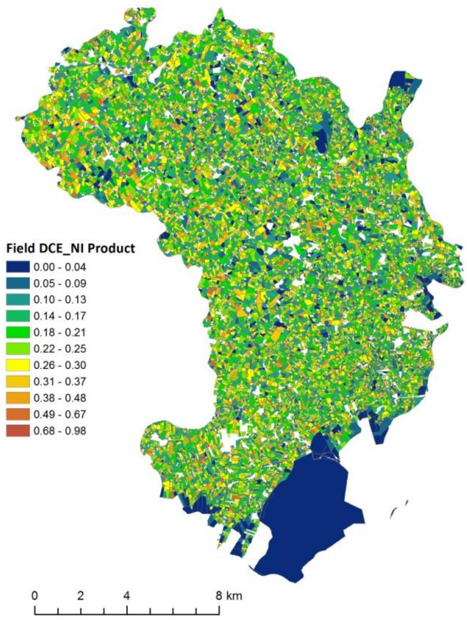


Figure 9: The potential risk posed to water quality by grazing in Upper Bann catchment (area ~213 km2) resolved to land parcel level

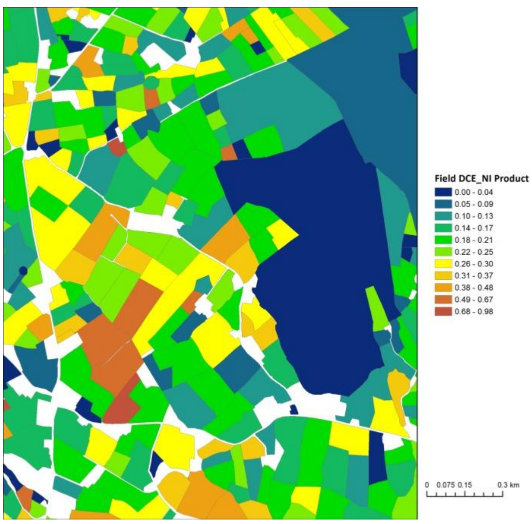


Figure 10: The potential risk posed to water quality by grazing in a sub-area of Upper Bann catchment resolved to land parcel level.

Conclusions

A GIS methodology was successfully developed and applied to Northern Ireland uplands to explore the relationship between farming practices and a range of ecosystem services (biodiversity, soil and water quality). New maps were produced to estimate the potential risk posed to water quality due to grazing. Importantly, levels of risks were resolved to catchment levels and also to land parcel level for sub-areas of catchments. This methodology is now available to better inform land use management.

IMPLICATIONS FOR POLICY AND INDUSTRY

In light of the main findings of this study and recent discussions with DARD advisors, policy and industry stakeholders, several important implications have been identified for policy and industry, and these are summarised below.

Breeds most suitable for hill conditions

Performance data collected as part of this work suggest that both beef genotypes (native and continental) are suitable for hill habitats. Horned ewes are more suitable for hard hill conditions than composite ewes obtained from breeds more typical of lowland areas, because of their similar efficiency (in terms of kg lamb weaned / kg ewe body weight), higher body condition score and lesser assistance at lambing. In addition, previous work and ongoing studies found that horned ewes are more likely to use hill habitats more efficiently by spending more time on heather based habitats and having a greater foraging area.

Grazing impacts on biodiversity

It is important to note that 7 of the 8 study farms within the biodiversity component were under restricted winter grazing management (grazing up to October at the latest), with 5 farms under CMS. The main implications of this work are that:

- Only limited pressure was found of grazing livestock on vegetation structure, which suggests that stocking rates and/or grazing periods may not be appropriate.
- The important variability between sites and years indicate that site-specific prescriptions may be necessary to ensure that heather or rush dominated areas are more utilised by sheep and cattle.
- The control of soft rush by grazing animals is unlikely to be sufficient and therefore the use of herbicide or cutting is still required.
- Mixed grazing can be beneficial because cattle are able to control invasive species and create a mosaic of vegetation heights beneficial for biodiversity. However, in some instances, the negative impacts of trampling by cattle also need to be taken into account when defining grazing strategies. Using the smaller native cattle breeds will help to minimise the risks of damaging sensitive areas through trampling.

NEW EVIDENCE GAPS

During the preparation and implementation of this work, and subsequent analyses of the animal and vegetation data, a number of evidence gaps have been identified and summarised below. Further research programmes should address these knowledge gaps in order to make further progress towards improved sustainability of hill grazing systems.

There is a need to investigate the performance of lambs during the finishing period to assess the suitability of the breeds investigated as part of this work for greener hill areas. There is also a need to investigate the performance and easy care characteristics of a larger number of native and continental suckler cows on similar land types, to further investigate the conditions required for hill habitats to support both genotypes.

Vegetation data need to continue to be collated and analysed over a longer time period, and if possible to include instances where winter grazing is possible. Only long term data will enable the detection of changes in vegetation structure and composition in response to grazing, taking into account seasonal differences.

There is a need to better define the ‘end points’ required (in particular within the Agri-environment schemes) in terms of habitat status. This could possibly be based on the definition of ‘indicators of change’ to use as monitoring tools to inform changes in grazing regimes at site specific levels.

Future work needs to investigate the impacts of other habitat management measures on biodiversity (in addition to grazing regimes) such as the addition of lime (although not appropriate on heather moorland) and measures specifically targeted at heather (burning versus cutting).

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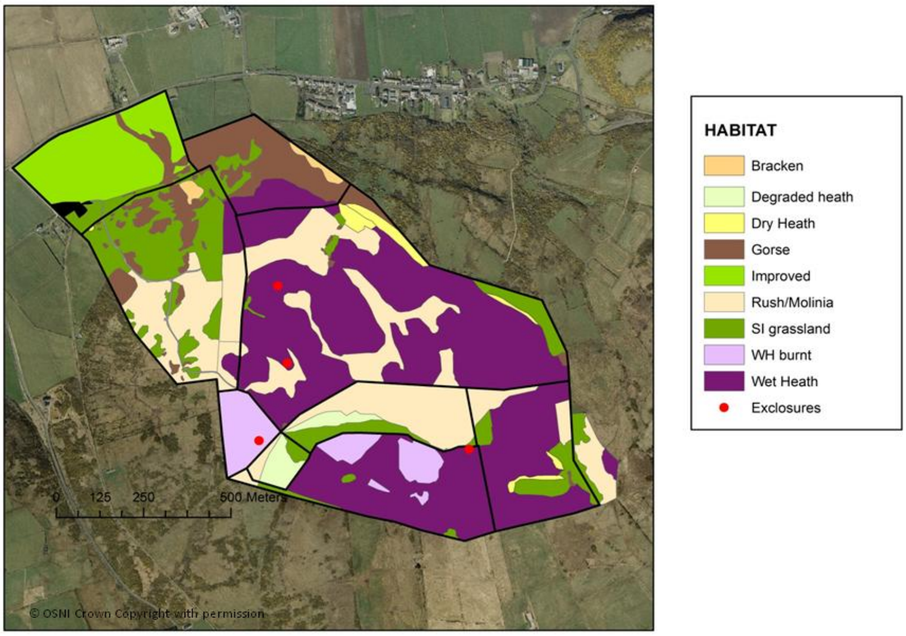
APPENDIX 1 Habitat maps of study farms used for the biodiversity component

FARM S1



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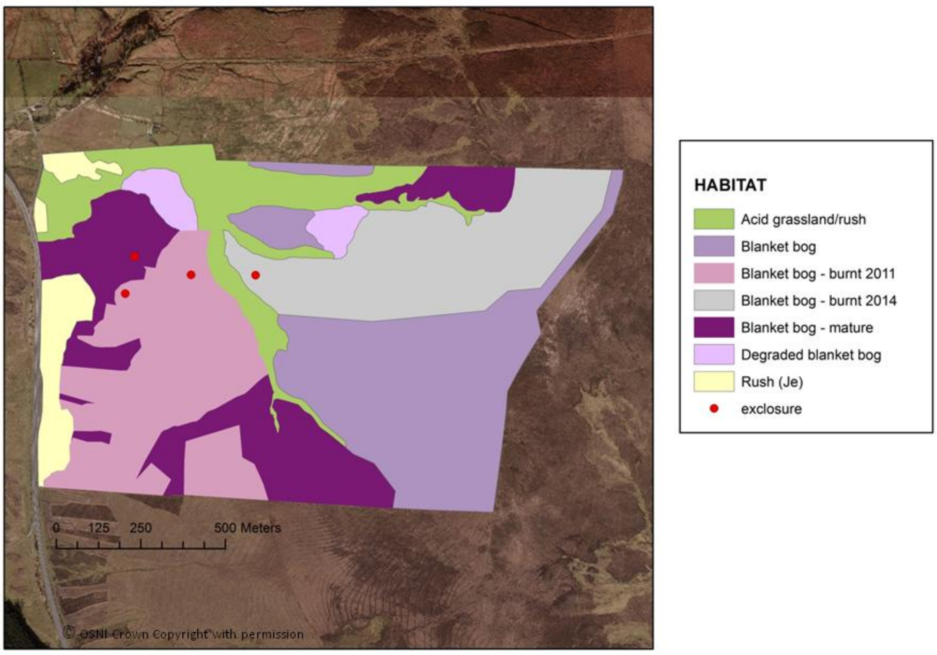

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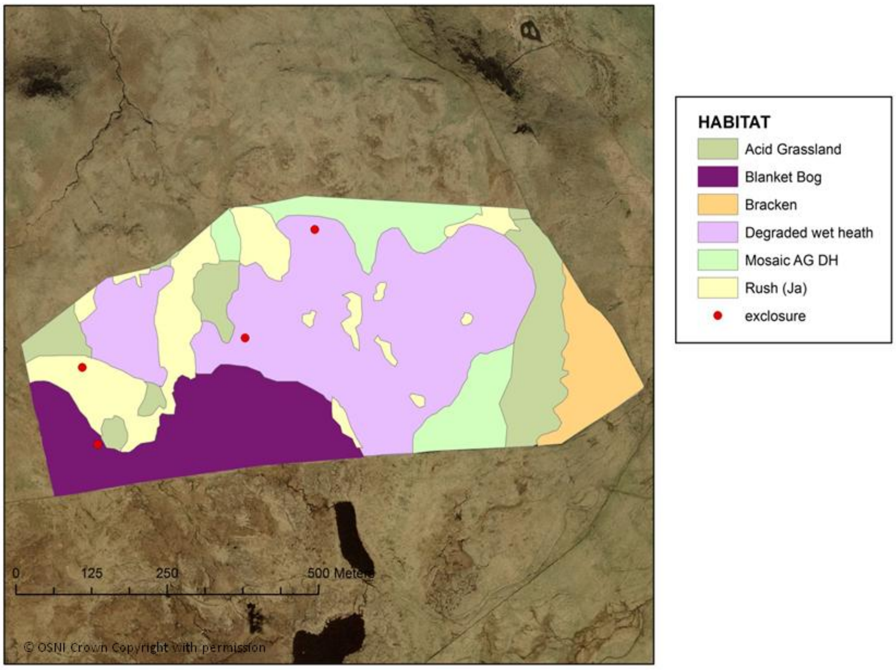

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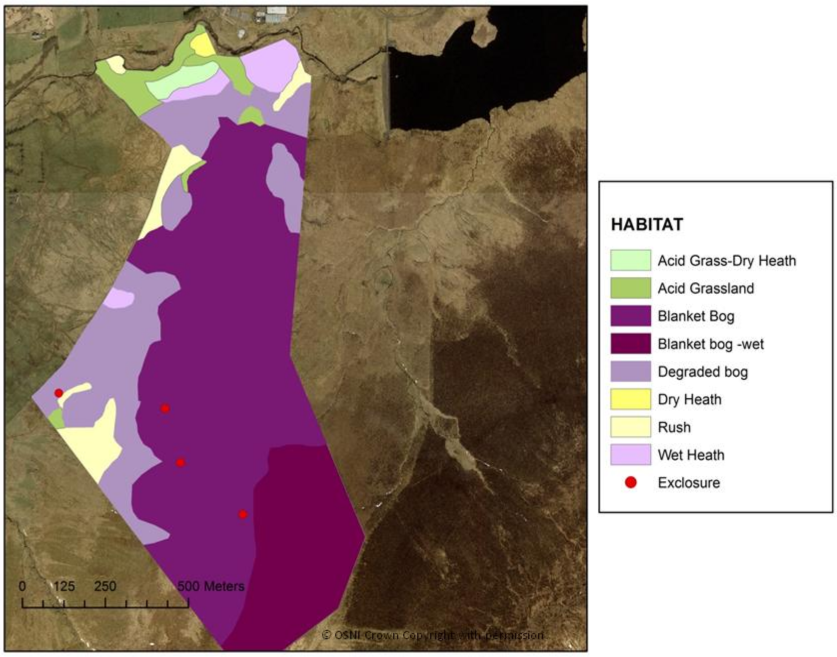

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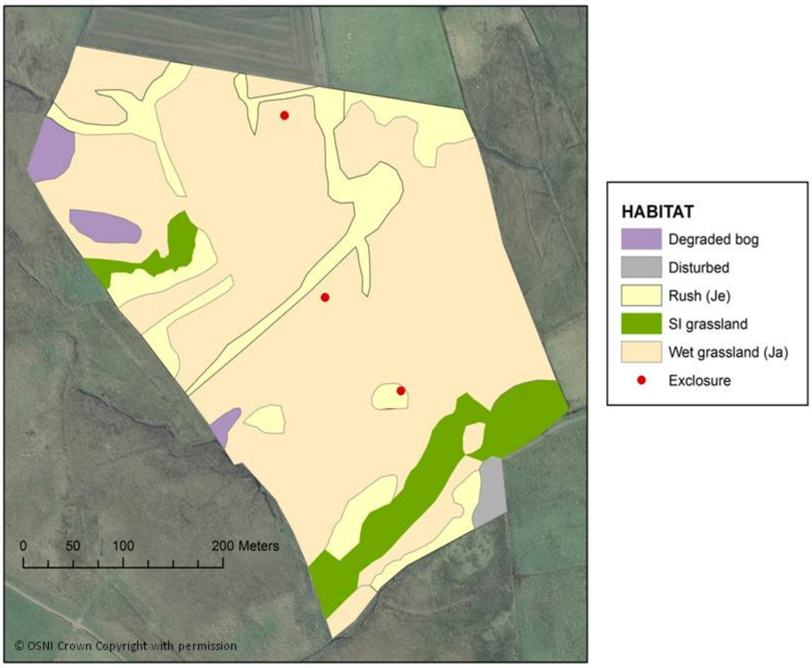

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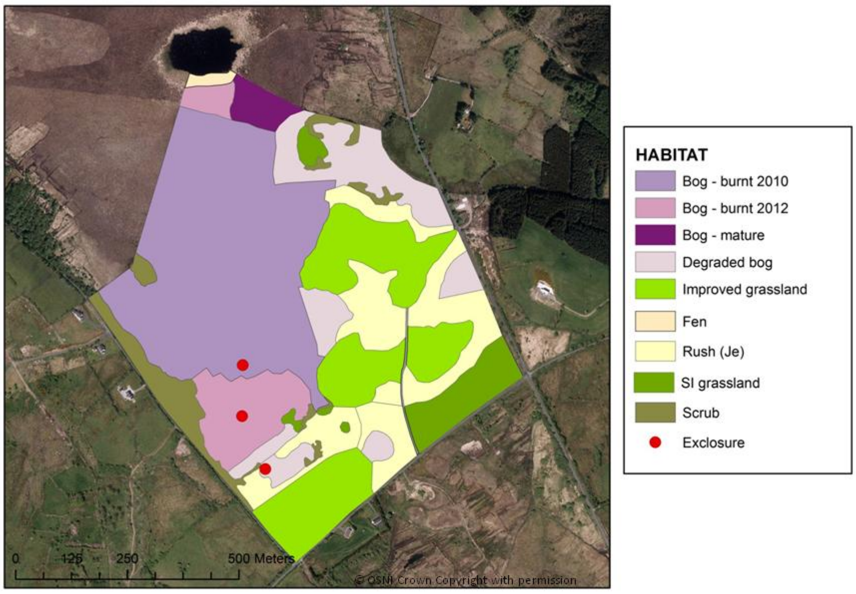

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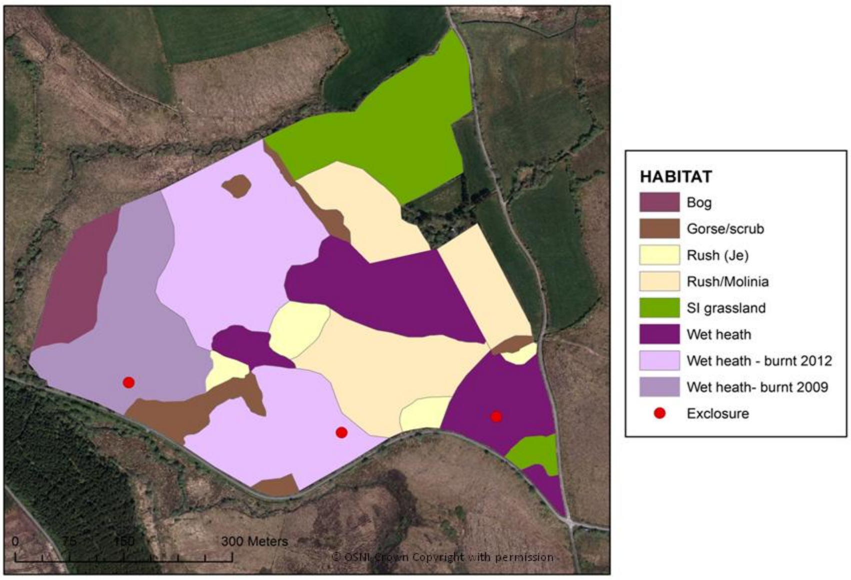

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