# PLANT-SOIL RELATIONS IN ACID GRASSLAND ON LUNDY

By

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## ABSTRACT

Three grasslands belonging to the community U4 (*Festuca ovina-Agrostis capillaris-Galium saxatile* grassland) under the National Vegetation Classification were examined. Vegetation was surveyed and soil samples were taken. These were analysed for carbon, nitrogen and sulphur content as well as soil pH. The results showed that species richness was highest at the site located towards the north of the island. Statistical analysis of the vegetation composition indicated that the species on this site are more indicative of a damper soil than the other two areas investigated. Although the other two sites had similar species richness their composition differed, possibly influenced by grazing.
Keywords: *U4 grassland, Galium saxatile, correspondence analysis, nitrogen, soil moisture.*

## INTRODUCTION

This study formed part of a larger study looking at the influences of atmospheric nitrogen deposition on UK acid grasslands (Stevens *et al.*, 2004). Sixty-eight acid grasslands were visited across the UK along a gradient of nitrogen deposition ranging from 6 to 36 kg N $ha^{-1}$ $yr^{-1}$. Lundy has the lowest deposition in England and Wales at 7 kg N $ha^{-1}$ $yr^{-1}$.

The aim of this paper is to investigate the plant-soil relations on Lundy by examining differences in the species composition of three U4 grasslands on Lundy in relation to soil pH and nutrient content. The grasslands studied belonged to the acid grassland community U4 *Festuca ovina-Agrostis capillaris-Galium saxatile* grassland under the National Vegetation Classification (NVC) (Rodwell, 1992). This community is widespread throughout western, northern and central England, Wales and Scotland on acid substrata. The grassland is common on well-drained soils making up the bulk of rough grazing in some parts of the UK, particularly upland fringes. U4 is commonly found as part of a patchwork with other grasslands, heathlands and mires. Climate and grazing are very important in determining the species composition of these grasslands (Rodwell, 1992).

On Lundy U4 grassland is found predominantly on the western side of the island mixed with different grasslands and heathland, commonly in areas where the grass has not been fertilised but the grazing intensity of sheep and horses is high.

Soils can also have an important influence over the vegetation composition in an area. Soil pH, nutrient concentration, organic matter content, soil structure and texture, and hence drainage all have an important influence on the composition of the vegetation.

## METHODS

### Field Methods

Three sites of acid grassland (U4 *Festuca ovina-Agrostis capillaris-Galium saxatile* grassland - sheep's fescue, common bent grass and heath bedstraw) (Rodwell, 1992) were selected for study on Lundy. Figure 1 shows the locations of the sites. Site 1 was located just north of the Threequarter wall, to the west of the track. Site 2 was located north of the halfway wall, also to the west of the track. Site 3 was located to the south of the Old Light. These grasslands are dominated by acid loving plants and are common throughout the UK. All three of the sites are actively managed. At the time of survey site 1 had a moderate grazing intensity with an average vegetation height of 4cm. Grazing was by sheep, goats, horses and rabbits. The altitude of site 1 was 99m. Site 2 was more intensively grazed with an average vegetation height at the time of survey of 2cm. Grazing was by horses, sheep and rabbits. The altitude of this site was 127m. Site 3 showed a similar intensity of grazing to site 2 (vegetation height 2cm) with grazing by sheep and rabbits. The altitude of site 3 was 120m.

At each site the vegetation was surveyed in 5 randomly located 2 x 2 metre quadrats within a 100 x 100 metre area. All of the species present were identified and their percentage cover estimated. Topsoil (approximately 5cm depth) and subsoil samples (30-40cm depth) were collected from each quadrat. A full description of the field methods used is given in Stevens *et al.*, 2004.

Two concepts were used to estimate the variety of species present. Species richness is the average number of species per given area, in this case 2 x 2m. Diversity was also estimated from the species data collected. Diversity was calculated using the Shannon diversity index (*H'*) (Kent & Coker, 1992) which accounts for both abundance and evenness (a comparison between the actual diversity and maximum possible diversity) of the species present. A higher value denotes a higher diversity.

### Soil Analysis

Analysis was carried out using air-dried soil. The soil pH was determined following the method described in Thomas (1996) using an Acumet AR20 pH meter. Soil carbon, nitrogen and sulphur content of the soils were determined using a LECO CNS-2000 elemental analyser.

**Data Analysis**

Differences in the number of species present and the soils of the three sites were analysed using analysis of variance (ANOVA). In an ANOVA analysis the mean and random error of each group is used to determine if the difference between the sites is statistically significant. This was followed with Tukey's test which provides an additional comparison of the data means to see which of the sites are statistically different.

Differences in the species present at the three sites were assessed using two methods, detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA). DCA is a statistical technique that uses multiple variables to arrange or ordinate the sites in relation to each other. CCA examines the sites in relation to each other and environmental variables on a diagram. Using this diagram it is possible to view large amounts of information regarding the variables measured and their relations to sites and species. The association of different environmental variables can be estimated by the angle of incidence of the lines describing the variables, with narrow angles describing environmental variables that are highly positively related. CCA distributes individual species in this ordination diagram in a position that reflects their net tolerance all of the environmental factors. The importance of any environmental variable in discriminating among different species is represented on the diagram by the length of the arrow (Leps & Smilauer, 2003). CCA was carried out using the statistical package CANOCO 4.5 (ter Braak & Smilauer, 2002).

## RESULTS

Site 1 belonged to the acid grassland sub-community U4a (typical sub-community). It was characterised by *Agrostis capillaris*, *Anthoxanthum odoratum*, *Potentilla erecta*, *Festuca ovina* and *Galium saxatile*. It had a mean species richness of 19.8 (variance 5.2). Using the Shannon diversity index diversity at the site is 1.00. Site 2 also belonged to the sub-community U4a. It had a mean species richness of 15.6 (variance 6.3). Diversity at the site is 0.78. Site 3 belonged to the acid sub-community U4b (*Holcus lanatus-Trifolium repens* subcommunity). It was characterised by *Agrostis capillaris*, *Anthoxanthum odoratum*, *Holcus lanatus*, *Achillia millefolium*, *Trifolium repens* and *Cerastium fontanum*. It had a mean species richness of 15 (variance 1.5). Diversity at the site is 0.74.

Using analysis of variance followed by Tukey's test it was possible to show that species richness at site 1 was significantly higher than sites 2 and 3 which were not significantly different from each other. Figure 2 shows the means and variability of the species richness at each site. Diversity was also highest at this site.

There was no significant difference between the topsoil and subsoil pH, carbon or nitrogen contents of the soils between the three sites. There was a significant difference between the soil sulphur content at the sites. Site 3 had significantly lower sulphur content than the other two sites.

DCA showed there was a clear separation between the species composition of the three sites (Figure 3) however there were also differences between quadrats within the sites. Examination of the species biplot shows that *Carex* sp., *Juncus effusus, Ranunculus repens, Molinia caerulea* and *Nardus stricta* are species clustered to the left of the ordination diagram indicating that they are typical of site 1. Species clustered to the right of the diagram are indicative of site 3. These include *Viola riviniana, Plantago lanceolata, Stachys betonica* and *Leontodon autumnalis.* Site 2 is located towards the top of the ordination diagram with species including *Prunella vulgaris, Erica cinerea, Danthonia deucumbens* and *Rumex acetosella* associated.

Using canonical correspondence analysis (CCA) made it possible to link environmental variables to both the sites and species. High soil pH was most closely associated with site 3 and low pH with site 1 (Figure 4). The reverse was true of soil C, N and S content. The species above, correlated with these sites, are also correlated with these variables.

## DISCUSSION

Species richness was significantly higher in site 1 than sites 2 or 3 ($p<0.05$). Examination of the soils data is inconclusive as there is no significant difference between the sites for pH, carbon or nitrogen (Table 1). Sulphur is significantly lower in site 3 ($p<0.05$), however, species richness in this site is not significantly different from site 2. This would suggest that the difference in species richness is not related to the soil variables measured.

Species composition is dependant on numerous abiotic and biotic factors but in the present paper I have only considered the likely effects of pH, carbon, nitrogen and sulphur content. Using the CCA we can see that although there is not a significant difference between the nutrient content of the soils at the sites there is a tendency for the soils at site 1 to have higher soil carbon, nitrogen and significantly higher sulphur than the other two sites. It is at slightly higher altitude and also tends to have a lower pH. This is surprising as high diversity is usually associated with a higher (less acidic) pH (Partel, 2002) although there is not a great difference between the soil pH of the sites. The higher sulphur may be of little importance for the distribution because although it is a nutrient essential for plant growth the majority of semi-natural grasslands are limited in their growth by the nutrients nitrogen or phosphorus, key nutrients in determining species diversity (Janssens *et al.*, 1998). There are many other variables that could potentially be influencing the species richness, diversity and species composition of the sites; examination of the DCA can be used to shed light on this.

By examining the characteristics of the species in the DCA we can determine what may be affecting their distribution. The species characteristic of site 1 are those of moist soils. This ties in well with the higher carbon and nitrogen content, which could be as a result of an accumulation of organic matter in the damper soil. Soils with a higher organic matter content also tend to be more acidic. Although there was no measurement of soil moisture content the preferences of the species found at this site indicate that this is the most likely explanation for the differences.

Site 2 is in the middle of the range however and the ordination tells us something further about it. Three of the quadrats in this site are located towards the top of the ordination diagram. The species characteristic of this area are all species tolerant of grazing. This area is one of the most heavily grazed semi-natural areas of the island, commonly grazed by the ponies. The final site, site 3, is characterised by a number of very generalist species with a wide range of soil pH and nutrient tolerances. The clustering of the sites on the DCA ordination (Figure 3) reflects the grassland sub-communities very well with the two U4a communities close together but the third site belonging to the sub-community U4b separated. These results potentially have some implications for grazing management, reductions in grazing intensity (although not complete removal of grazers) could lead to increased species diversity.

Considering the Lundy sites as part of a wider survey (Stevens *et al.*, 2004) shows that not only is nitrogen deposition low but the species richness is high in comparison to other grasslands in England of this type.

## CONCLUSIONS

Of the three U4 grasslands examined species richness and diversity is highest in the moist U4a grassland at site 1. The distribution of the species between the sites confirms the findings of Rodwell (1992) that the composition of species is determined by grazing however this is not as important for the number of species found there. It additionally highlights the potential importance of soil moisture in determining species distribution in U4 grasslands although soil moisture was not measured in this investigation. The soil chemical properties measured in this study were not found to be very important in determining species distribution.

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Table 1. Soil chemistry results (average of 5 samples per site)

| Site | Soil pH | Carbon % | Nitrogen % | Sulphur % |
|---|---|---|---|---|
| 1 | 4.5 | 16.05 | 0.86 | 0.86 |
| 2 | 4.5 | 17.78 | 0.85 | 0.85 |
| 3 | 4.8 | 9.74 | 0.57 | 0.57 |


**Figure 1.** Map of Lundy with site positions marked.

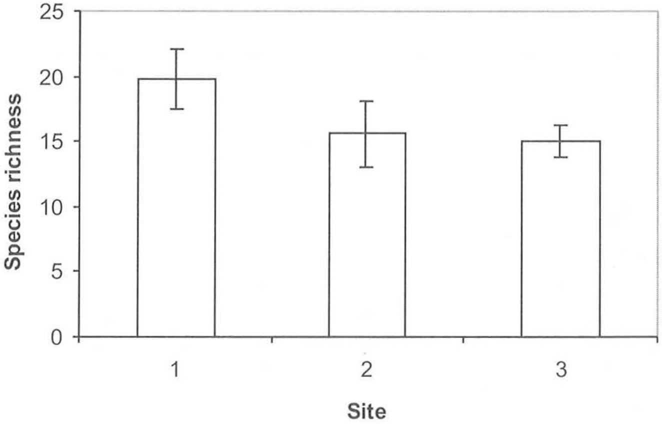


**Figure 2.** Mean species richness of the three grasslands. Error bars show the standard deviation.

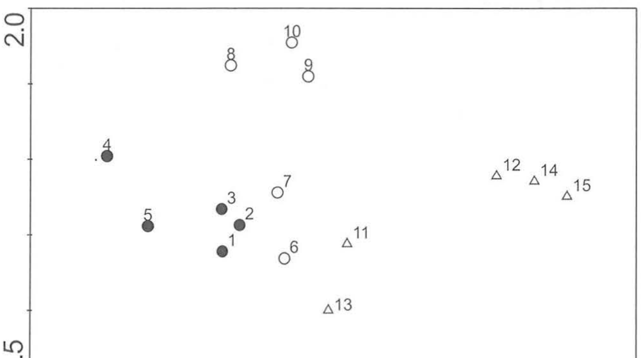


**Figure 3.** DCA ordination of sites. Quadrats are numbered. Closed circles = site 1; open circles = site 2; triangles = site 3.

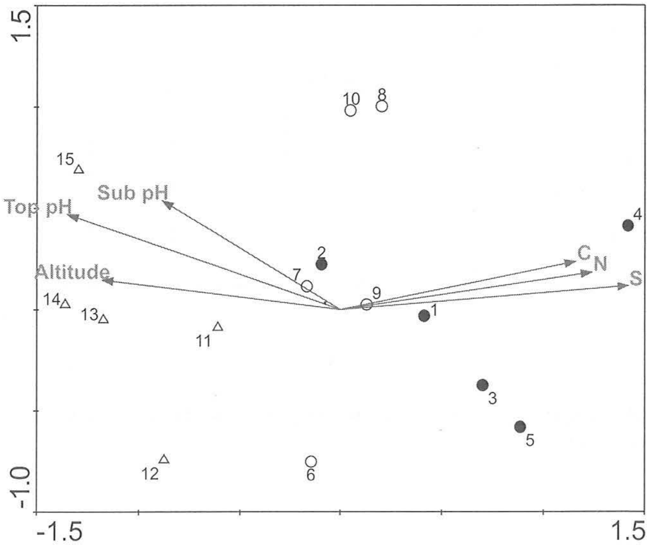


**Figure 4.** CCA ordination of sites showing environmental variables – Topsoil and subsoil pH, soil carbon (C), nitrogen (N), and sulphur (S) and altitude above sea level. Symbols as Figure 3.