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# Impact of Livestock on Hill Environment

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# SUMMARY

The hill and mountain landscape of western Ireland is an area of high scenic value as well as contributing to the livelihood of local farmers mainly through extensive grazing. Measures that were intended to support lamb prices led to increased ewe numbers. Public concern attributed this increase to an apparent deterioration in the status of the semi-natural vegetation and to an increase in the rate of soil erosion.

In the absence of an existing databank, Teagasc undertook a research programme to quantify the impact of hill sheep on the semi-natural vegetation, the progress of soil erosion and changes in certain weather elements e.g. 'driving rain'.

A detailed database of the physical background (physiography and soils) of the Teagasc hill sheep farm, Leenaun, was compiled on the basis of a grid, 100 m x 100 m. Changes in the frequency of vegetation on the unimproved hill were monitored, 1995-2002, by point quadrat. Ten permanent exclosures representing the main vegetation types and a controlled grazing experiment on the upper steep slope were established. Sequential aerial photography (1973/7-1996/8) for selected sites in western counties and wind and rain data (1957-2000) for five western synoptic stations were obtained. The classification of the peatland and heathland habitats was considered.

Analysis of data highlighted a range of issues among which were the physical complexity and fragility of the landscape, the sustainability of the hill sheep system on the Teagasc hill sheep farm, the beneficial effects of controlled grazing, the progressive erosion of hill soils and an increase in high intensity levels of 'driving rain'. The classification of the habitats, peatland and heathland, should encompass other forms of biodiversity as well as flora.

The sustainable use of this landscape requires a deep knowledge of the of the grazing management system, which increasingly involves part-time farming, and its impact on the soils and semi-natural vegetation.

# INTRODUCTION

There has been a widespread perception of increased soil erosion and damage to vegetative cover in the hill environment due to agricultural land use, mainly increased sheep population (Bleasdale and Sheehy-Skeffington, 1992).

The soils of the hill landscape are generally organo-mineral soils or peats. They are much less stable than their mineral counterparts either on the hill or on the lowland and especially where such soils are on steep gradients.

Land use, in whatever form, exerts its own influence on the environment. Changes that result from such influences need to be quantified so as to provide realistic and serious input to the formulation of land use policies. Thus, a detailed and continuous assessment of the effect of a particular hill sheep system on the physiography, soil and vegetation of an unimproved hill farm was undertaken. The details of the hill sheep system, its management and flock performance, are outlined in *Hill Sheep Production System* (Hanrahan and O'Malley, 1999).

The extensive dataset that was compiled from 1995 to 2002, on the physiography, soil and vegetation of the Teagasc Hill Sheep Farm, Leenaun, was assessed in relation to the objectives. Initial results and conclusions are outlined in *Evaluation of the Impact of Livestock on the Hill Environment – Sheep Series No. 10,* (Walsh *et al*., 2000). Results of other studies using sequential aerial photography and Met Éireann data on 'driving rain' and the concept underlying habitat classification were evaluated.

# OBJECTIVES

The overall objective of this study was to:

Evaluate the research activities on the physical environment of the farm in relation to the objectives of the sub-programme – Grassland and grazing management (Teagasc 2000, 1999). The relevant objective in the sub-programme was to:

"Develop hill sheep production systems that ensure the continued viability of producers while reducing environmental impacts."

The initiatives that were outlined in response to this objective were:

- Define the interactions between hill sheep and the different types of hill vegetation so that basic principles can be used to develop management strategies that protect the sensitive hill environment while enabling the hill sheep sector to make an integrated and sustainable contribution to national sheep production.
- Evaluate and monitor the status of hill areas with particular reference to national programmes on environmental protection and identify suitable indicators that can be widely used to describe the status of the hill environment.
- Develop animal performance guidelines for hill flocks with reference to the range of land resources available in hill areas and maintain detailed monitoring programme of all environmental aspects of hill sheep production using the Teagasc hill sheep farm, Leenaun, as a base.

# MATERIALS AND METHODS

Several discrete activities were established in an effort to provide information that would enable the development of hill sheep production systems that are compatible with the environment and ensure the viability of producers.

## Teagasc hill sheep farm

*Physiography, soils and vegetation:* A farm grid, 100 m x 100 m, was established (Walsh *et al*, 2000) to provide 226 intersection points on the unimproved part of the hill. These provided the basis for describing and monitoring physiography, soils and vegetation. The physiography was quantified by slope gradient measurement over a 10 m distance at each grid intersection. Terracettes ('sheep tracks'), which are a dominant feature of the micro-topography, were examined and quantified using a transect method (Clavin, 2000). Soils were described using a gouge auger, 1 m long, with 1 m extensions. One probe was made at each intersection except where boulder/rock prevented the full use of the auger for soil classification. In the latter case, the soil was described based on the results of four probes at 1 m radius from the grid intersection. The vegetation was monitored by point quadrat inventory (Walsh *et al*, 2000) at all grid intersections from 1995 to 2002.

*Terrain roughness:* The concept of terrain roughness (TR) and its contribution to physiographic classification and erosion risk assessment was considered based on measurements of slope gradient at 216 points. The physiographic element was taken as the primary unit and the degree of roughness was expressed as the proportion (%) of slope gradient records that were outside the range of ± 20% of the mean value. TR was not calculated where the mean gradient value was < 5°. The scale ranges from 0 (smooth) to 100 (very rough)

*Terracettes* ('sheep tracks')*:* Characteristics of over 400 terracettes of which more than 100 were on the farm, were examined and quantified using a transect method (Clavin, 2000).

*Controlled grazing experiment:* Replicated exclosure plots, 6 m x 15 m, were established on the eastern part of the farm, 150 m above sea level and on steep (20 to 28º) slopes with shallow peat soils. The status of the vegetation was monitored twice yearly. The treatments and stocking rates are outlined in Table 1. Observations (vegetation, bare soil and rock) were made at 10 cm intervals using a pointer along both diagonals of each exclosure**.**

*Permanent exclosures:* Three main habitat types – low level atlantic bog, wet heath and upland grassland were monitored at 11 exclosures (6 m x 15 m) from which sheep were permanently excluded. These were compared with surrounding areas that were grazed at 0.9 ewes /ha.

**Table 1. Experimental design of controlled grazing treatment, 1995-1999**

| **Treatment** | **Stocking rate (ewes/ha)** |
|---|---|
| Total exclosure (no grazing) | 0.0 |
| Winter exclosure (Summer grazing - May to October) | 1.05 |
| Summer exclosure (Winter grazing – November to April) | 0.77 |
| Freely grazed control (unfenced) | 0.9 |

## Other resources

Sequential (1973/7–1996/8) aerial photography and digital photogrammetry with field validation were used to quantify changes in eroding, western hill and mountain landscape.

The frequency and intensity of ‘driving rain’ from 1957 to 2000 at five western synoptic stations were analysed.

The concept of the habitat and its contribution to landscape description and management was considered.

The extent to which these activities achieved the objective of the programme were evaluated and aspects that require immediate attention are outlined.

# RESULTS

*Physiography and soils:* Six main physiographic units, based on the surface morphology model of Dalrymple *et al.,* (1968), were quantified and mapped (Table 2). Two of the units, transportational mid-slope and the lower colluvial slope occupied about 70% of the hill. Slope aspect, being south-south-easterly to southerly facilitates near maximum use of solar radiation throughout the year. Elevation amplitude within the larger units (colluvial slope and transportational mid-slope) was relatively large, i.e. 100 and 200 m respectively.

**Table 2. Physiography and soils**

| **Physiographic. element** | **Lithosol** | **Peat** | **Mineral soil distribution %** |
|---|---|---|---|
| | **distribution % & depth** | | |
| Colluvial slope | 36.6 (19)* | 57 (103)* | 5.4 |
| Transportational mid-slope | 51.6 (14) | 24.2 (44) | 24.2 |
| Moraine-backed hollow | 0 | 100 (189) | 0 |
| Alluvial toe-slope | 0 | 100 (203) | 0 |
| Truncated moraine | 22.7 (17) | 59.1 (154) | 18.2 |
| Crest | 25 (10) | 75 (53) | 0 |

* depth (cm)

The proportion of fine particles (silt and clay) is comparatively low in the mineral soils of this environment (Walsh *et al* 1969; Egan, 1995, Clavin, 2000). However, the soils in the upper steep transportational mid-slope have almost twice the proportion of fine particles than in the lower, less steep, colluvial slope (Egan, 1995). This difference may have resulted from differing weathering regimes associated with the most recent glaciation and it contributes to the diversity in vegetation in these areas. Finer textured soils also have a higher moisture retention capacity resulting in more pronounced shrink-swell properties. This results in greater cracking of the soil during periods of drought thus increasing the risk of erosion on the steep slopes.

*Terrain roughness:* Hoffman and Krotkov (1989) defined terrain roughness (TR) using the range of heights and slopes and the repetitiveness of prominent micro-relief features. Sakude *et al* (1998) claimed that a better roughness classification is achieved by removing the variation due to slope gradient. However, due of the lack of detailed information on altitude and the repetitiveness of prominent micro-relief features, the definition of TR was confined to data on slope gradient.

**Table 3. Physiography, altitude, slope gradient and terrain roughness**

| Physiographic element (No. of obs.) | Altitude range (m) amsl[1] | Slope gradient (°) | | Terrain roughness (%) |
|---|---|---|---|---|
| | | mean | range | |
| Colluvial slope (92) | 27-122 | 8 | 0-20 | 72 |
| Transportational mid-slope (64) | 73-274 | 23 | 11-42 | 36 |
| Moraine-backed hollow (21) | 55-67 | 2 | 0-10 | ND |
| Alluvial toe-slope (13) | 27-30 | 2 | 0-6 | ND |
| Truncated moraine (22) | 27-64 | 8 | 1-19 | 82 |
| Crest (4) | 183-280 | 6 | 5-7 | 0 |

[1] above mean sea level

The transportational mid-slope (TR36) is twice as smooth and three times as steep as the colluvial slope. The soils on the transportational mid-slope crack more easily under prolonged dry spells and having lower TR values are more susceptible to mass movement than their deeper more organic counterparts on the rougher, colluvial slope.

*Terracette study sites* Terracettes are features that represent the process of slope stabilisation in the hill and mountain landscape worldwide. They have been exploited by man for cultivation since ancient times and have the same descriptive terminology as a stairway – the flat and vertical parts known as treads and risers, respectively. Twenty three transects, c. 25 m long and representing over 400 terracettes were studied in four sites from Donegal to Galway (Clavin, 2000). They were often a distinctive feature of both the lower colluvial slopes and the upper transportational mid-slopes and the treads were often locally referred to as 'sheep tracks'. They contained a number of quantifiable elements that were indicative of the intensity of land use. Examination of the depth of the surface soil horizon indicated a displacement from the inner (*riser foot*) to the outer (*tread toe*) part. Localised attenuation of the depth of soil horizons, which is normal in areas of terracette formation, becomes emphasised particularly in the surface horizon by animal treading. Thus, the ratio of depth of surface soil horizon, *tread toe* to *riser foot,* may be used as an indicator of the relative intensity of animal treading. A comparison of the four sites (Table 4) indicates that the relative intensity of animal treading in Leenaun is intermediate. The transects in Leenaun were located in what was later identified as preferred grazing areas (Walsh and Feinstein, 2003).

**Table 4. Mean depth (cm) of surface soil horizon at *tread toe* and *riser foot* and their ratio**.

| Site | No. of terracettes | Tread toe mean (s.e.) | Riser foot mean (s.e.) | Ratio* |
|---|---|---|---|---|
| Malin Head (Donegal) | 59 | 26 (1.1) | 19 (1.1) | 0.7 |
| Leenaun (Mayo) | 148 | 20 (0.8) | 12 (0.9) | 0.6 |
| Griggins (Galway) | 76 | 17 (1.0) | 9 (0.7) | 0.5 |
| Griggins (Galway) | 124 | 40 (1.7) | 28 (1.5) | 0.7 |

*tread toe:riser foot

The widest range in ratios, 0.03 to 0.08, occurred in Leenaun. This appears to signify an uneven intensity of animal treading on the farm.

Other features that were associated with the impact of livestock on terracette treads included exposure of the sub-surface soil horizon, full tread concavites, negative angles (tread sloping into hill) and relatively sparse cover of vegetation. While these features are inevitable at virtually any stocking rate their frequency of occurrence is indicative of the intensity of use by livestock.

Negative tread angles and tread concavities, the more obvious surface signs of animal impact, occurred on 4% and 17%, respectively of all terracettes but were as high as 9% and 27% in areas of known high sheep occupancy.

*Vegetation:* The change in the general vegetative cover in the period 1995 – 2002 showed an increase of 15 percentage points which was reflected in all major groups – grasses, sedges, heathers, bryophytes and 'other plants' (Figure 1). Plant species that are indicative of heavy grazing i.e. Mat-grass and Heath rush, accounted for less than 1.5% of the total cover.

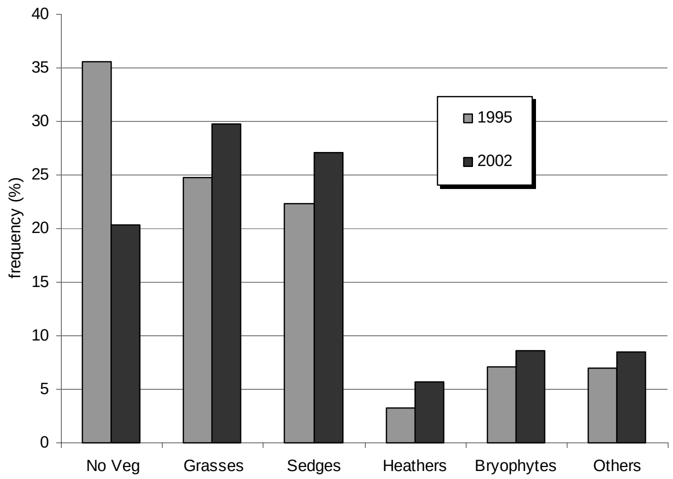


*Figure 1: General vegetation cover , 1995 and 2002, Teagasc Hill Sheep Farm, Leenaun*

The increase in vegetative cover and the low occurrence of species that are indicative of heavy grazing, allied to the substantial increase in flock performance parameters compared with those for S. Blackface hill systems in general (National Farm Survey) indicate that the hill system at Leenaun represents a sustainable use of the hill resource.

*Controlled grazing experiment:* In general there was a significant increase in vegetation height and an increased frequency of tussocks when vegetation was released from grazing (Guinan, 2005).

**Table 5. Mean sward height (cm) of *Molinia caerulea* and *Calluna vulgaris* and the number of tussocks for controlled grazing plots at Teagasc Hill Sheep Farm**

| Grazing treatment | Year | *Molinia caerulea* | *Calluna vulgaris* | Tussocks (No. in 2001) |
|---|---|---|---|---|
| None | 1995 | 17 | 3 | 89 |
| | 1999 | 23 | 18 | |
| Summer | 1995 | 12 | 1 | 75 |
| | 1999 | 18 | 13 | |
| Winter | 1995 | 15 | 3 | 56 |
| | 1999 | 18 | 9 | |
| Year-round | 1995 | 10 | 2 | 66 |
| | 1999 | 16 | 12 | |

Dwarf shrubs, mainly heathers and bog myrtle, increased on the Summer grazing as well as on the No grazing treatment. The exclusion of grazing resulted in vegetation colonising former sheep tracks (terracette treads) after a brief number of years. There was a clear lack of vegetation cover in tracks where there was year-round grazing.

Controlled grazing had a positive effect on species composition and vegetation structure.

*Permanent exclosures:* Dwarf shrub cover increased significantly *($P$ < 0.001)* in the lowland blanket bog while low-growing plants such as *Carex, Pinguicula* and *Juncus* spp. declined. Similar patterns were observed in all exclosures. The presence of heathers and bracken in the acid grassland exclosures and not in their environs indicated that a succession towards a heath community was occurring.

Species richness was lower in the permanent exclosures and in the No-grazing treatment (controlled grazing experiment) than in the surrounding grazed areas. The evidence from the exclosure experiment indicates that grazing increased species diversity (Guinan *et al.,* 2002).

*Sequential aerial photography:* The change in the frequency of eroding features in four study sites from Co. Donegal to Co. Kerry (Table 6) indicates a substantial increase over a relatively brief period (Guinan, 2005).

**Table 6. Frequency (%) and change (percentage points) of terrain features classified as eroding (1973/7-1996/8)**

| Site | Area ($km^2$) | 1973/7 frequency | 1996/8 change |
|---|---|---|---|
| Malin Head | 8.14 | 43.6 | +16.6 |
| Belmullet | 2.54 | 33.1 | +10.4 |
| Tully Mountain | 4.5 | 18.3 | +13.8 |
| Brandon Mountain | 4.5 | 52.2 | +6.3 |

A micro-level study comprising 23 plots ranging from 1 to 10 ha indicated increases in the area occupied by rock/vegetation mosaic and residual peat. Cumulative gully length increased substantially particularly in the higher altitude plots.

Erosion of blanket peat and peaty soils in the western hill and mountain landscape is well documented (Bradshaw and McGee, 1988). The accumulation of blanket peat is dependent on ≥ 1250 mm annual rainfall (Hammond, 1981) and its erosion is accelerated by high-intensity storms (Tallis, 1981). Thus, the stability of the blanket peat cover is at least partly dependent on changes in the frequency and intensity of the phenomenon – driving rain (the product of wind and rain)

*Driving rain:* The phenomenon was studied based on hours of ≥ 2 mm rainfall with accompanying wind speed, pluvio-aeolian (P-Æ) index, in the western seaboard over the period 1957 to 2000 (Guinan, 2005). It was expressed in $mm^2s^{-1}h^{-1}$ and four categories, **0** to **III**, representing increasing intensity were recognised. The values for the individual categories were;

**0 –** 0

**I -** >0 to 12

**II -** >12 to 24

**III** - >24

The frequency of category **0,** which was windless, decreased significantly (*P<0.05*) over the 44-year period and that of categories **I** to **III,** with the exception of period 1968 to 1978, increased relative to 1957 to 1967 (Figure 2).

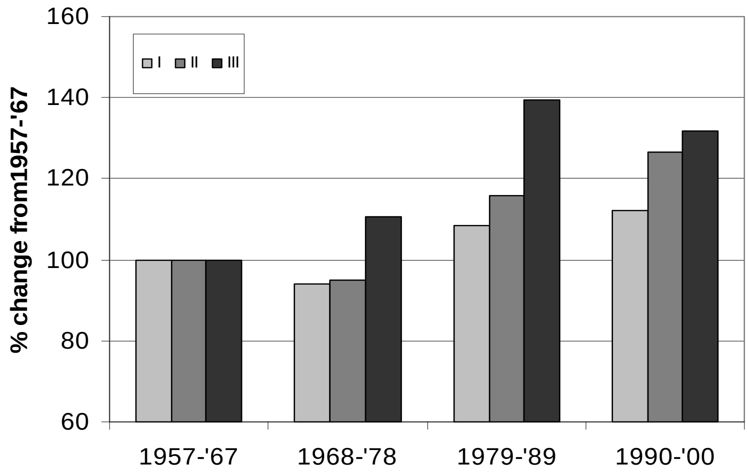


*Figure 2: Percent change in frequency of categories I-III for all stations by 11-year period. Data Met É.*

The frequency of category **III**, the most severe, peaked in 1979 to 1989 which coincided with the increase in hill sheep numbers associated with the introduction of the ewe premium scheme in 1980 (DAFF, 1995).
The combination of increased frequency of 'driving rain' and erosion-sensitive soils indicates that the interactions between land use and landscape require continuous monitoring.

*Habitats:* Many of the habitats in this environment are considered as rare and priority for conservation. The EU Habitats Directive aims "*to promote the maintenance of bio-diversity,* and acknowledges that this *"may require the maintenance or indeed encouragement of human activities"*.
The essence/concept underlying the identification, description and classification of most terrestrial habitats is that of wildlife environment (The Heritage Council, 2000). Heathland and Peatland habitats are defined in terms of vegetation composition with aspects of human impact and management being confined to peat cutting, overgrazing and erosion. Research has shown that controlled hill sheep grazing increases the species richness of these habitats and has minimal adverse impact on the vegetation and soil cover. Fauna, including the badger, hare, small mammals (wood mouse and pygmy shrew) and a variety of bird-life also share these habitats. The classification of heathland and peatland habitats should encompass the biodiversity of the fauna as well as flora and, in addition, recognise the beneficial effects of appropriate and controlled land use systems.

# DISCUSSION and CONCLUSIONS

The studies of the physiography, soil, vegetation, erosion and micro-topography (terracettes) revealed a complex and fragile landscape. A balance between natural and anthropogenic activities is crucial to conservation.

Terracettes, which are a common micro-topographic feature of this environment, contain some physical features that are clearly associated with livestock and can be readily monitored using geo-referenced transects.

Changes in the overall hill vegetation suggest that the present hill sheep system in the Teagasc farm, Leenaun, represents a sustainable use of this resource.

Controlled grazing increases the biodiversity of unimproved hill vegetation and benefits its structure and species composition.

Erosion of mineral and organic soils is a common and progressive feature of the hill and mountain landscape particularly at higher altitudes. Digital photogrammetry, using sequential aerial photography, was adapted to quantify this natural process.

The frequency of the higher intensities of 'driving rain' increased during recent decades. This phenomenon, in an erosion-sensitive environment, has implications for the management of land use systems and the stability of the soil and vegetation cover.

Continuity of controlled monitoring on a detailed and regional basis using geo-referenced transects, digital photogrammetry and weather data would provide an early warning system on the risk of erosion in this environment.

Future research activities must also focus on changes to hill sheep production systems arising from current and projected socio-economic circumstances e.g., the volatile market situation for sheep products.

The concept of 'distance shepherding' through the development of electronic sounding devices that are programmed to minimise habituation and promote more even grazing activity, should be considered. Such devices would avoid the introduction of extra minerals to the environment, e.g. through mineral blocks.

Habitat classification has the potential to present a comprehensive and integrated description of the biodiversity of a landscape. Aspects of biodiversity in addition to flora should be included in some of the more extensive habitats in this environment e.g. peatlands and heathlands.

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