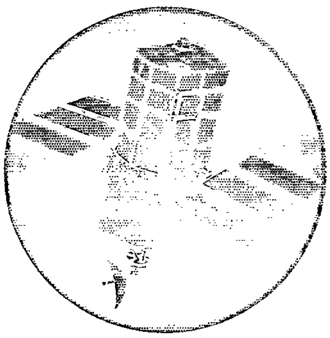
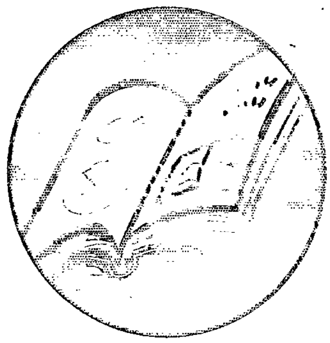
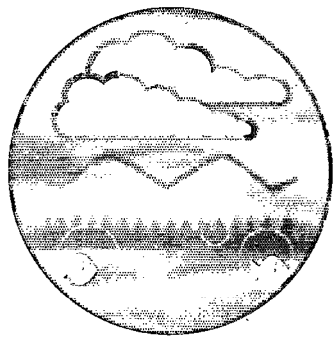
# The Impact of Grazing and Upland Management on Erosion and Runoff

**Research and Development**

Technical Report
P123

ENVIRONMENT AGENCY

# The Impact of Grazing and Upland Management on Erosion and Runoff

R&D Technical Report P123

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Research Contractor:
APEM

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**Statement of use**

This report describes work undertaken to examine the theory that the increasing impact of sheep (by grazing and trampling) in uplands is contributing to increased runoff rates and soil erosion. The report aims to awareness of this issue and will be discussed at a future meeting of the Rural Land Use Group.

**Research contractor**

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**Amendments**

Any corrections or proposed amendments to this manual should be made through the regional Agency representative on the Water Resources National Abstraction Licensing Group.

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# EXECUTIVE SUMMARY

The fundamental conclusion of this project is that the enhanced removal of vegetation, erosion of soil and rock and the consequential increased runoff of water is a widespread problem in the British uplands. Where academic study has failed to yield evidence of this, anecdotal and photographic evidence has managed to do so. The net effects of this enhanced erosion have severe impacts on the functions of the Environment Agency and the wider economy.

It would appear that the impact of intensive grazing pressure forms a large component of the cause of the problem. However, other mechanisms do cause soil erosion in the uplands. The creation of bare soil from the effects of agents such as fire, bracken control and forestry exacerbates the impacts of other erosion mechanisms. The presence of grazing animals on such areas of bare soil increases the erosion rates and retards the return of vegetation (which has the potential to reduce erosion and runoff).

In general, agriculture has become more intensive, especially in lowland areas, in that stocking densities and the numbers of sheep reared have risen in some locations. However, upland farming could also be considered as extensive, in terms of mass reductions in labour. This has direct consequences for management which has effectively decreased, resulting in a lack of shepherding (pre-war ratio's of shepherds to sheep were 1:2-300, today the ratio can be as large as 1:12-1500; Spensley, personal communication). Therefore, uncontrolled livestock cause hotspots of grazing pressure and impacts from hooves.

In the past, the management of the uplands and grazing animals was a sustainable symbiotic relationship. The numbers of sheep grazed was controlled by the amount of fodder produced by the land and the ability of the farmer to transport feed to remote moortops. Today, artificial feeds are used to sustain large flocks, and All Terrain Vehicles can transport the feeds to remote areas, promoting year round grazing. Winter grazing is particularly damaging as the vegetation is not growing during this period. In addition, stressed vegetation is more susceptible to extreme environmental conditions (e.g. drought, freezing cold) and the creation or enhancement of bare soil is more likely when such conditions occur.

The problems caused by grazing pressures and trampling may not simply be due to the higher densities of sheep on the hills, but due to a combination of high densities of sheep and the low numbers of shepherds who can reduce concentrations of livestock and spread the impact of grazing and trampling.

All agencies concerned with this issue should focus on the wider aspects of the catchment, not just discrete areas (e.g. moorlands, ESAs, SSSIs, LFAs).

Long-term data sets are required to quantify the problem; these are currently unavailable. However, the areas affected by erosion and high runoff (e.g. Swaledale) do have people living and working in them and they could be considered as "laboratories" which have had long-term experiments running in them. It is therefore worthwhile remembering these people and using their knowledge and experiences to gain a qualitative understanding of the problems. However, this type of information should not be used as a basis for remediation strategies, qualitative datasets are also required.

It is apparent from the review of literature conducted that the academic community has a full variety of conclusions on the subject of grazing, erosion and runoff which are often at odds with each other. The variety of findings from the study of the subject can be attributed to the scale at which the problem or process is viewed. Generally, experimental catchments are small and therefore tend to be non-representative. An overall model is required as different effects occur at different scales. To achieve this, long-term studies need to be initiated in a variety of different catchments.

A final consideration involves the timescale over which erosion problems are viewed. For example, there will be another glaciation in the future, the effects of which will mask the impacts of grazing induced erosion seen today. Alternatively, if a long return-period flood event occurs, such as that seen in Eastern Europe during July 1997, the impacts on the landscape will negate the physical scars of grazing induced erosion.

However, while the effects of current upland erosion may be regarded as small-scale when compared to events such as glaciations, they are obviously of great significance to current ecological and socio-economic systems. Everyone who has become involved in the uplands in any way (for example, farmers, conservationists, and walkers) has a responsibility for their physical and biological well-being. The actions of humans in the uplands will also affect other ecological and socio-economic systems in the lowlands. Instead of being fatalistic about the impact of large scale physical events, we should be positive about the natural importance of these areas and promote their longevity as part of an overall strategy of sustainable development.

## KEY WORDS

Erosion, runoff, grazing, sheep, impact, upland, management.

# 1. INTRODUCTION

This technical report explores the relationships between erosion in the uplands (defined as the Less Favoured Areas, LFAs) the amount of water running off the land and the impact that grazing animals may have on these (mainly the removal of vegetation through grazing and the effects of trampling). It is apparent that many other upland management processes have an influence or control over erosion and runoff (e.g. upland drainage or moor-gripping, burning, and forestry) both at a local scale and at the river catchment scale, and some attention is given to these and the influence grazing has when it occurs in tandem with these activities.

The uplands include habitats such as open moors, grasslands, peat bogs, relict oak-wood and Caledonian pine forest and rocky terrain. As well as their obvious economic importance for farming, forestry, water gathering and game management, the uplands are important for a wide variety of other reasons including:

- *Landscape* (designated as Areas of Outstanding Natural Beauty (England, Wales and Northern Ireland), National Scenic Areas (Scotland) and National Parks);
- *Amenity and Recreation* (National Parks, and also important as a source of income and employment);
- *Biodiversity* (identified under national legislation as Special Sites of Scientific Interest, Areas of Special Scientific Interest; identified under European Community legislation as Special Areas of Conservation and Special Protected Areas; and identified under International Treatise such as RAMSAR and World Heritage Sites) and National Parks; and
- *Archaeology* (National Parks, and sites and landscapes of all periods).

If erosion and runoff are occurring in the uplands at a rate that is not sustainable, the resultant impacts will not only be of significance to locations identified under legislation. Rather, the uplands should be viewed as a whole (e.g as a series of adjacent river catchments) and any impacts arising from erosion and runoff and upland management practices that may contribute to these impacts should be assessed in the same way.

The study draws upon published academic and anecdotal evidence. Rather than initiate new research, the scoping study has identified evidence that supports the relationships between upland erosion and runoff regimes and landuse. The study also aims to determine the needs of future studies and to precipitate discussion on the subject.

## 1.1 The Role of the Environment Agency

The Environment Agency was formed in April 1996. It brought together the expertise of the National Rivers Authority, Her Majesty's Inspectorate of Pollution and the Waste Regulation Authorities. The Agency has the following vision statement: "A better environment in England and Wales for present and future generations". Although primarily a regulatory body, the Agency must take into account the Government's commitments to the UK's Biodiversity Action Plan and Sustainable Development. This requires a holistic approach to catchment wide issues including the importance of land use and soil issues and how they affect water quality, water resources, ecology and the countryside as a whole.

It is with these aspects in mind that this project was initiated. The Environment Agency is concerned about the impacts of grazing animals, both in terms of their impacts on the uplands in general and damage to rivers and riverbanks throughout England and Wales. These impacts are explored in more detail later in this report.

*See Figure 1*

The Environment Agency is acutely aware of the vital role that farmers play in maintaining the landscape, habitats and species within upland areas. Support for this role must continue in some form and it is the Environment Agency's intention to work in partnership with the farmers, landowners and all the other organisations concerned with this issue at a practical and policy level.

## 1.2 The Grazing Issue

The grazing issue is a particularly sensitive one, both politically and amongst the agricultural and environmental communities. Suffice to say that there is a considerable difference in opinion and perception on what constitutes land that is suffering from intensive grazing pressure (often termed 'overgrazing').

Intensive grazing pressure from livestock results in the removal of vegetation and trampling of soil. This occurs for a number of reasons including; too many animals in too small an area, congregation of animals around a "honey-pot" such as feeding or watering areas and along tracks.

Erosion can occur wherever the numbers of livestock exceed a stocking density suitable for a particular environment (e.g lowland pasture, scree slopes and moors), otherwise known as the carrying capacity of the land. Carrying capacities can be defined according to the desired land use/issue. They depend on a number of factors including; vegetation type, breed of sheep/cattle, angle of slope, soil type, soil moisture content, and local climate conditions.

Three definitions of carrying capacity can be used;

- livestock carrying capacity,
- ecological carrying capacity,
- erosion carrying capacity

### 1.2.1 Livestock Carrying Capacity

If the livestock carrying capacity is exceeded (i.e by stocking too many animals in a particular area of land) then the level of grazing and trampling will soon deplete the sward with the result that the livestock will require supplementary feeds to maintain productivity.

### 1.2.2 Ecological Carrying Capacity

If a stocking density is below the ecological carrying capacity of the land then in effect the number of grazing animals present can maintain the existing vegetation type without succession or degeneration. Stocking densities as low as 4 ha per sheep can retard the flowering and fruiting of plants.

### 1.2.3 Erosion Carrying Capacity

The erosion carrying capacity of the land is the maximum stocking density of sheep above which the protective sward is removed and erosion of soil and rock material ensues, and due to other factors (e.g. rain, frost), becomes self-reinforcing. Sheep stocking densities of 2 ha per sheep have been recorded as initiating erosion by the formation of sheep scars.

*See Figure 2.*

### 1.2.4 The Grazing Spectrum

In reality, there is not a fine line dividing stocking densities on land which is grazed at a sustainable level, and land with intensive grazing pressure, but a gradual progression between the two. Such a continuum is indifferent to the bias towards the agricultural argument or the environmental one. For example, in agriculture, some swards are better for certain crops (hay or silage) or stock (sheep or cattle), and a variety of sward or heather heights provide a diversity of habitats for a wide range of species. The type of management and the time of year this is undertaken will also make a considerable difference to the end result at both ends of the grazing spectrum.

### 1.2.5 Agricultural Overgrazing.

MAFFs Code of Good Agricultural Practice for the Protection of Soil (1993), which is currently being updated, has the following recommendations:

> Paragraph 59 on Soil Erosion says
>
> "Soils in upland areas with high rainfall are frequently shallow, often with a peaty topsoil that is not very fertile. When the plant cover is broken (by livestock, unsealed tracks , drainage ditches or recreational ditches or recreational activities) they are particularly prone to water erosion. When overgrazing has or is likely to cause a problem, you should reduce your stocking rates. Take care to limit the other activities mentioned in vulnerable areas. Protect eroding areas by encouraging the regeneration of plants to cover the soil.

> Paragraph 180 on Grazing Management says:
>
> "To reduce compaction and poaching, only graze with sheep and young cattle. It is preferable to cut the grass for hay or silage but only when the topsoil conditions are suitable. Graze the aftermath carefully to avoid damaging the soil. Remove livestock from the land over winter and in wet conditions".

In 1996, MAFF produced a leaflet "Your Livestock and Landscape" which is a guide to the environmental conditions attached to livestock subsidy schemes. The leaflet gives advice to farmers on how to identify and avoid overgrazing in areas important to wildlife and suggests that MAFF will reduce or withhold livestock subsidies if:

- "Land is grazed with too many livestock so that the growth, quality or diversity of the vegetation is adversely affected" **or**

- "Supplementary feed is provided in such a way that the vegetation is trampled or poached by animals, or rutted by vehicles used to transport the feed."

*See Figure 3.*

"Your Livestock and Landscape" gives details on how to recognize overgrazing and suggests that: "Many farmers will think of overgrazing in terms of reduced animal performance such as lower lamb weaning rates, smaller ewe size and an increased need for supplementary feeding. Even in the absence of these signs, there may be considerable damage to the vegetation."

The following lists are copied from the leaflet.

**For unimproved grassland signs of overgrazing may include:**

- a short sward (less than 2cm) with pulled vegetation lying on the surface.
- a reduction in the palatable grasses
- reduced flowering of herbs.
- an increase in coarse grasses.
- an increase in moss cover.
- excessive bare ground in conjunction with other indicators of overgrazing.
- an increase in species which are more resistant to trampling such as daisies.

**For heather moorland signs of overgrazing may include:**

- a gradual retreat of heather and dwarf shrubs from the edge of the moor together with an increase in coarse grasses and heath rush.
- a break-up of the heather or dwarf shrub cover leading to isolated heather patches or bushes.
- typical growth forms of the heather including trampled stems and pulled heather stems lying on the surface.
- a lack of regeneration of the heather and dwarf shrubs in newly burnt or cut areas.

### 1.2.6 Environmental Overgrazing

It is generally understood, amongst environmentalists and some agriculturists, that there is a problem caused by grazing and trampling (be it from sheep, cattle, deer or rabbits) and it is not the purpose of this report to prove that this is so. In the foreword of the booklet 'Managing the English Uplands', by English Nature (1997) (the Governments statutory advisers on conservation issues) Dr Derek Langslow, the Chief Executive, says "Despite the progress being made, overgrazing remains the most significant issue that adversely affects the quality and extent of upland habitats. Reduced grazing levels would enhance the biodiversity". A great deal of work has already been carried out on this subject and certainly from an environmentalist's view, problems caused by intensive grazing pressure in Britain's uplands are regarded as very serious, with the biodiversity of these areas declining as a result.

The Wildlife and Countryside Link (WCL) in their 1997 report "Farming the Uplands in the Next Millennium" (written on behalf of members including the Council for National Parks, National Trust, The Wildlife Trusts, Wildfowl and Wetlands Trust, WWF-UK, RSPB, and CPRE) clearly state that recent agricultural changes (e.g elevated grazing pressures) have affected the natural environment in numerous ways including the loss of habitats such as heather moorlands, associated flora and fauna, the creation of bare soil and its subsequent erosion. ***See Figure 4.***

Environmental overgrazing may also be summed up as "the decline in the growth, quality or diversity of heather moorland and unimproved grassland areas". This refers not just to the vegetation, but to the whole ecosystem and food chain associated with it. Any decline in the growth, quality or diversity of the vegetation is likely to have a negative effect on the species that rely on it. Small declines will have small effects, the larger the scale of damage the larger the detrimental impact is likely to be.

### 1.2.7 Differing Perceptions of the Problem

Differences in opinion regarding grazing, trampling and erosion are not associated with identifying the problem, but in the perception of the scale of the problem. The environmentalists (with exceptions) see the problem as serious and widespread with many associated knock-on effects. The agriculturists (with exceptions) see the problem as less serious, more locally based, and may fail to see the impacts on other parts of the environment.

This perception is further complicated by the complexity of the problem. What does healthy growth, quality and diversity mean? Signs of decline can be difficult to see and monitor, they are often insidious and occur over a long period of time, possibly several generations. These characteristics mean that many of the symptoms are difficult to identify except to the trained eye. Hence the grazing problem has taken a long time to become a prominent issue and it is usually the serious cases that may highlight the scale of the problem. As mentioned at the beginning of this section, there is no fine line between healthy, quality and diverse vegetation and intensely grazed, eroding land, it is a progression from one to the other. Remove the grazing pressure and in most circumstances, the transition from one to the other can be reversed.

The Royal Commission on Environmental Pollution's Report (1996) lists a figure of 35% of soil degradation due to overgrazing throughout the world and 23% in Europe. More than half of the worlds pasture land is affected by overgrazing. Overgrazing is more common than is generally recognized.

Examples of overgrazing and soil degradation through this last century have been identified. Over 100 people were forced to leave the Monach Islands in the Outer Hebrides in the early 1800s after overgrazing weakened the grassland and a storm blew the topsoil away. In the nineteenth century in the Tatra National Park in Poland, changes in management and numbers of stock severely damaged alpine meadows and the wildlife and game associated with them. In 1960 the land became national property and the majority of the sheep and other livestock were removed to allow nature to restore the land (Zbiorowa 1962).

In America in 1934 the Taylor Grazing Act became law to prevent the "free and unrestricted grazing of livestock on public lands". This Act aims to protect 80 million acres of public land. Today the Taylor Act remains one of the primary authorities used by the Bureau of Land Management to improve and maintain the health of public rangelands (United States Department of Agriculture). In 1987, non-point source amendments to the Clean Water Act gave American authorities the power to deal with problems originating from degraded riparian areas (Chaney *et al*, 1993). A recent survey of Iceland has shown that desertification or severe or catastrophic soil erosion is affecting some 40% of the total area of Iceland (Soil Conservation Service of Iceland).

The Independent on Sunday (5th July 1998) featured an article that highlighted the fact that a quarter of England and Wales is now at moderate, high or very high risk of erosion. It continues by stating that "overgrazing – and the merciless tramp of the boots of nature loving walkers- have eroded large parts of the Lake District, Peak District and other uplands." In 1997, East Anglia which is suffering from high levels of soil erosion was re-classified by the United Nations as one of the worlds semi-arid zones. Approximately "85% of the area's rich peat soils have been lost, and the Royal Commission on Environmental Pollution has predicted that the fenlands will be "worked out" altogether by the middle of the coming century".

### 1.2.8 Collaboration

It is hoped that this document will encourage the agricultural and environmental communities to discuss this important issue and work together to improve the quality and diversity of our landscape. Farmers need support to achieve these aims. Both communities acknowledge that it is the farmers that (to use MAFFs words, 1996)

*"Through countless generations.....created much of our most precious landscape and many important wildlife habitats. The nation looks to the livestock farmers to maintain and safeguard them for the future".*

# 2. BACKGROUND

## 2.1 The Role of Vegetation

Vegetation has a significant role in determining the occurrence and extent of upland erosion and runoff.

### 2.1.1 The Influence Vegetation has on Erosion and Runoff

A cover of dense, robust vegetation will protect soil material from erosion by binding the soil with its roots/rhizomes and its foliage will bear the brunt of much of the impact caused by the passage and trampling of animals.

In addition, vegetation acts as a good insulator protecting the soil from the effects of the sun, frost, wind and rain. The foliage will intercept rain, prolonging the time taken to reach the soil and therefore reducing the risk of the soil becoming saturated and runoff occurring. Bare soil also suffers from the impact of rain or hail detaching and transporting soil particles. Good root systems also improve the drainage of the soil, and surface litter and dense foliage increase the rate of evapotranspiration.

Most kinds of vegetation have the capacity to impede the surface flow of water and therefore reduce its erosive efficiency. For example, Evans (1990) describes a slope in the Peak District where, due to grazing pressure for more than 30 years, the vegetation cover diminished to leave a bare slope. The rate of erosion from this area was calculated to be 17.5 $m^3$ per year, between 3.5 and 7 times faster than the highest mean rates of erosion recorded on arable land. The rate of increase in the expanse of bare soil stopped when the number of sheep grazing the slope was reduced. Evans found this rate of erosion to be similar for other parts of the Peak District.

### 2.1.2 Environmental Stress

Vegetation in the uplands is subject to more environmental stress than its lowland counterpart, having to overcome: greater extremes of temperature; higher quantities of rain and snow; drought; poor, thin soils; inadequate drainage; steeper slopes; fire; air pollution; and recreational pressures. Although often adapted to these conditions, upland vegetation is very vulnerable to damage and any additional stress exerted by grazing and trampling may be too great for the vegetation to sustain.

### 2.1.3 The Changing Stability of Landscapes

Britain's uplands have been described as a "uniquely open and predominantly anthropogenic landscape" (Ratcliffe and Thompson, 1988), and Thompson and Horsfield (1988) describe an absence in Britain of the natural altitudinal zonation of vegetation; walking up the side of a hill, this would have been a transition from woodlands to scrub, shrubs, and grasses. Instead, the uplands in much of Britain are characterised by short vegetation, with shallow roots and little foliage.

During the Wildwood Era (7000-8000 years ago) the vegetation would have been highly resistant to erosion and would have intercepted much of the rainfall. Today, only about 10% of Britain is covered with trees. Evans (1993) ranks sensitive landscapes from "wildwood" (least sensitive) to arable (most sensitive) and states that more of Britain is sensitive to erosion than it has been at any time since woodland clearance began.

The transition through the grazing spectrum from stable woodland to scrub, shrubs, short grazed grasses to bare eroding rock and soil are illustrated by the following photographs:

*See Figures 5 to 9.*

The progression through the grazing spectrum can be reversed, but only if it has not progressed too far. Intensive grazing pressure will shift the continuum towards instability. If the grazing pressure is reduced enough then the continuum will shift towards progressively more vegetation and stability. Vegetation, especially when allowed to develop into a complex community (herbs, shrubs and trees) offers the best level of stability to a landscape promoting greater biodiversity. There are many cases where the exclusion of stock from eroding areas (e.g through the use of fencing) has resulted in the restoration of vegetation and reduction of erosion (e.g Chaney *et al*, 1993).

## 2.2 The Impacts of Grazing Animals From an Environment Agency Perspective

This section illustrates some of the impacts of upland erosion and increased runoff rates.

### 2.2.1 Fine Sediments

One effect of erosion is the increase in material readily available for removal. Fine sediments transported in streams and rivers can be damaging to plants and animals. Habitats are often be smothered by silt which can; strip oxygen from the water as organic matter decays; block fish spawning gravels, preventing the flow of oxygen and water to fish eggs; block sunlight from oxygen producing plants; and nutrients associated with the silt can contribute to eutrophication and promote the growth of algae.

Eroded soil material and excess runoff can cause the siltation of reservoirs, reducing their storage capacity. Fine silts, metals and pesticides associated with the silt, colour (from peat for example), excess nutrients and pathogens such as Cryptosporidium may be transported with the silt. In addition to the pollution and ecological implications of this, if the water is to be used for potable supply the impurities will have to be removed adding additional expense to the cost of treating water.

During floods, excessive silt and sand in the river can act as a scourer damaging plants and animals, especially affecting fish by abrading scales and exposing areas of tissue which are then vulnerable to infection (Newcombe and Jenson, 1996).

### 2.2.2 Coarse Sediments

Accelerated erosion, including riverbank erosion, can cause an increase in the quantity of coarse debris being carried downstream. Boulders and cobbles may be deposited at points where the water velocity is slower, reducing the storage capacity of a river channel and increasing the pressure on the banks. Some upland tributaries have been completely blocked to fish passage by coarse deposits from eroded sources higher up (e.g Joshua's Beck, a salmonid spawning tributary of the River Wyre in Lancashire, 1997). Riverbanks and beds will be eroded more effectively when this sort of material is being transported.

Damage can occur when coarse material is transported by rivers in flood. Trees growing along riverbanks can have their bark abraded or stripped, bankside vegetation can be crushed or ripped up, flood defence structures including floodbanks, walls, and bridge supports can all suffer severe impacts.

*See Figure 10.*

Accelerated erosion and rates of run-off are likely to create a hostile environment for many species of plant, animal and fish living in the channel or on the banks.

### 2.2.3 Grazing on River Banks

Where grazing occurs right up to the river or stream edge, there is likely to be a reduction of bankside vegetation. In extreme cases this reduces the height of the vegetation and the root depth to a few centimetres and leaves the bank more prone to damage and erosion. Vegetation, when robust and dense, protects the surface of the bank with vegetative cover and the bank itself is bound together with strong root systems.

*See Figure 11.*

The removal of vegetation will potentially reduce the size of a flood required to initiate erosion. Therefore, banks may become undercut, and slump into the channel more often.

The presence of riparian vegetation not only provides protection against erosion, but also may intercept runoff and sediments (and possibly contaminants) from adjacent land.

Trampling pressure and poaching of river banks from grazing animals can also cause serious erosion.

### 2.2.4 Mass Movements

The movement of bare soil and rock on slopes can have serious impacts on roads and footpaths, if a rockfall, landslide or slump occurs. In some locations, houses and people may also be at risk.

In February 1997, material in Dry Gill (on the slopes of Helvellyn, Lake District) and more from the surrounding scree slopes was mobilised downslope during a heavy storm. The coarse debris was carried through a forestry plantation and blocked the main arterial road from Ambleside to Keswick in three places for the best part of a week, subsequently roadside highway repairs were required during April and May 1997.

This road blockage has occurred before, in Jan, 1995 (Loxham, personal communication, 1997). The cost to the Highway Authorities, local economy, owners of the plantation and reservoirs below the gill is not insignificant. The pattern of events has become established and is threatening to repeat itself again.

### 2.2.5 Water Resources

If run-off rates increase, it follows that aquifer recharge is also likely to be reduced. Baseline flows may be affected particularly during periods of drought and this could affect the availability of water for abstraction.

### 2.2.6 Biodiversity

Biodiversity in the uplands is likely to continue to decline if grazing pressure is not reduced. The continued reduction in the biomass of vegetation means that there are fewer niches for wildlife to occupy. In addition, actively eroding hotspots may expand and smother previously stable vegetated areas, killing plants and creating new zones of bare ground. The total area of bare ground and scree appears to be increasing in many upland areas of Britain (e.g Evans, 1996).

*See Figure 13.*

### 2.2.7 Cost Implications

It is very difficult to pin a cost to such diverse impacts. Their implications are not just financial, but include visual and wildlife considerations. The costs could be described as being a) direct (e.g. impact on flood defences); b) indirect (e.g. the cost of agri-environmental grants), and c) non-quantifiable (e.g. the loss of wildlife, visual appeal).

Evans (1996) gives an estimate for the cost of water related pollution incidents in the uplands of £2 million per year and an estimated total cost of the impacts of erosion in the uplands and lowlands as £23 million to £50 million per year. Evans (1996) also makes an estimate of the cost involved in fencing off stock from actively eroding moorlands to allow vegetation to colonise exposed peat and mineral soils. It is likely that hundreds of kilometres of fencing would be needed to reduce the risk of erosion. However, by excluding stock from these areas, they may become concentrated elsewhere and initiate erosion there.

White *et al* (1996) have compiled and analysed a database of sedimentation information for 77 reservoirs in Yorkshire. The data indicate that sediment has reduced the original total capacity of these reservoirs by nearly 9000 million litres, (or 7.5%) since impoundment (a few are over 150 years old). To place this in context, the most recently constructed reservoir, Scammonden, has an original capacity of nearly 8000 million litres. Yorkshire Water Services have calculated that this loss has a value of approximately £74,000 000, £650,000/annum, or 25 days supply.

The paper summarises that catchment management is the only permanent solution to excessive reservoir sedimentation, and land use policies that encourage healthy, well managed vegetation of all types are likely to improve the water quality and the water holding capacity of the reservoir's catchment. The report concludes "The management of catchments to reduce erosion has a symbiotic and beneficial effect in reducing colour and *vice versa*. An holistic approach to the management of catchments will lead to cost savings and a combined management policy should therefore be achievable and beneficial.

### 2.2.8 Implications of Upland Erosion and Runoff to the Environment Agency

The effects of loss of biodiversity, erosion, increased runoff and low flows in relation to the Functions of the Environment Agency can be summarised as follows:

**Water Quality** - eutrophication of flowing and standing waters, siltation, turbidity and possible diffuse pollution with soil erosion, poor dilution due to low flows.

**Water Resources** - low flows, loss of reservoir capacity due to infilling with sediments, increased costs to treat potable water supplies (rising nitrate and pesticide levels, algae, Cryptosporidium, silt and colour).

**Flood Defence** - increased flood risk due to accelerated run-off. Increased capital and maintenance costs due to flood damage, repairs to riverbanks, floodbanks and flood defences, gravel extraction from the channel, flooding, excessive weed growth in lowland streams due to eutrophication.

**Waste Management** - increased fly-tipping, use of inappropriate material (rubble, hard-core, concrete etc) to stabilise banks.

**Fisheries** - loss of good bankside and in-channel habitat, problems with high and low flows, siltation of spawning gravels, poor recruitment, increases in water temperature and light, reduced food supplies, restricted fish passage, eutrophication.

**Conservation and Recreation -** loss of biodiversity, ponds and lakes filling with sediments, eutrophication, loss of landscape quality.

**Navigation -** increased sedimentation of navigable waters and the associated costs of removal.

**Others Organizations -** the National Parks (footpath, dry stone walls and river bank repairs), Highways Authorities (road and bridge repairs), and local and county councils (footpath, road and bridge repairs), landslides and mud deluges and their clean-up. Changes in the visual quality and amenity aspects of the countryside.

**Landowners -** loss of soils, land and crops, fences, walls, deposition of sediments (including toxic materials eg lead).

# 3. AGRICULTURAL POLICIES AFFECTING UPLAND FARMING

The National Sheep Association (1995) in their report "Sheep UK, our Natural Hidden Asset" documents a 40% increase in sheep numbers between 1980 to 1993 in the UK to a total of 44 million sheep. The number of sheep has not subsequently increased above this threshold level. The same report states that many of the LFAs (upland and hill areas) account for almost 70% of the total flock numbers in the UK. This proportion rises to 85% in Scotland and 88% in Wales, indicating the extent to which sheep are mainly found in areas difficult to farm. Of the total agricultural land use in the UK it is estimated that as much as 27%, being rough grazing is only suitable for dedicated sheep production.

## 3.1 Subsidies in the Uplands

Farmers began to benefit from the introduction of subsidies in the 1930s. In 1940 a subsidy was given for every hill ewe; this was extended in 1943 to each hill cow. After the end of World War Two, the 1946 Hill Farming Act introduced headage payments. Guaranteed prices were established and in 1967 the range of financial aids for improvements was extended (Grigg, 1989).

It may be true to say that, without public subsidy, hill farming in its current form would not be viable. In 1995, British Farmers received £655 million in special allowances. These were composed of the Sheep Annual Premium Scheme (SAPS) and the Hill Livestock Compensatory Allowance (HLCA). Together these amounted to approximately £30 per breeding ewe (Wildlife Trusts, 1996). Farmers wishing to claim under the SAPS must own or lease an appropriate number of stock which is subject to the quota. The stock can be bought on a permanent basis or leased on an annual basis. Quotas are not tied to the land and may be transferred within an LFA. This trade in quotas has had the result of concentrating sheep stock, which has led to overgrazing in some areas (Wildlife Trusts, 1996). Headage payments for sheep and beef cattle encourage maximising of stock numbers, within limits of quota restrictions.

In 1993, Member States acquired new optional powers to impose environmental conditions upon headage payments. MAFF has introduced such conditions to control overgrazing. MAFF have also introduced the Moorland Scheme that pays farmers to remove stock from hilltops. However, this scheme has not been widely taken up by farmers mainly because headage payments such as Hill Livestock Compensatory Allowance (HLCA) and the Sheep Annual Premium Scheme (SAPS) are more lucrative.

Currently, options for CAP reform are under discussion following the recent publication of the European Commission's AGENDA 2000 proposals.

# 4. A REVIEW OF RELEVANT RESEARCH

The information used to form the basis of this section of the report has been collated from a wide variety of sources including literature searches, a questionnaire, and a workshop on upland erosion attended by key persons from a variety of organisations and backgrounds.

## 4.1 The Impact of Livestock on Upland Erosion

Many authors have described potential links between intensive grazing by sheep and erosion (Evans, 1977, 1996, 1997a; Sansom, 1996; McVean and Lockie, 1969; Birnie and Hulme, 1990; Tivy, 1957; Thomas, 1965; Baker *et al.*. 1979) in locations ranging from the highlands and islands of Scotland, to the Southern Uplands, Central and North Wales, the Peak District and the Lake District.

The Wildlife Trusts have produced a report entitled "Crisis in the Hills" which focuses upon issues associated with high grazing pressures. In 1996, Friends of the Earth released a report which assessed "Soil Erosion and its Impacts in England and Wales" (Evans, 1996). This report discussed the impacts of grazing animals as well as a wide range of other issues. Evans (1997a) focused specifically on "Soil Erosion in the UK Initiated by Grazing Animals" and highlighted the need for a national survey.

Much attention has been given recently to the impact of grazing animals on the uplands. This section will review this information and assess whether there is evidence of grazing animals, (in particular sheep) causing large scale erosion in the uplands and increasing runoff rates.

### 4.1.1 The Extent of the Upland Erosion Problem

There are a limited number of studies into the direct effects of grazing animals on erosion in British uplands (e.g. Evans, 1977; Birnie and Hulme, 1990, Tivy, 1957; Thomas, 1965) and, although much work has been undertaken in America on the impact of grazing on forests and riverbank stability, (e.g. Marlow *et al.*, 1987; Renard, 1988) there is a lack of research into the effects of grazing animals on soil erosion and loss (e.g. Owens, Edwards & Van Keuren, 1997).

In 1981, the Peak District Moorland Erosion Study, Phase 1 Report (Phillips, Yalden and Tallis, 1981) was published. It explored the nature and extent of the erosion problem in the Peak District. The report covered a wide range of topics and identified a range of factors (such as grazing animals) as being responsible for the degradation of 33 $km^2$ of upland within the National Park. The study also reviewed the range of options available for attempting to restore eroded areas and put forward suggestions for a number of field trials.

Evans (1992) states that erosion initiated and continued by animals grazing upland grassy swards occurs in soils covering 2.7 % of England and Wales and 16.4 % of Scotland. As long ago as 1965, Thomas surveyed the slopes of Plynlimon (Wales) and found that 5% were affected by "upland sheet erosion" induced by sheep.

Scottish Natural Heritage (SNH) has recently undertaken a survey to quantify the extent and spatial distribution of soil erosion in the Scottish uplands. This was originally accomplished by the use of aerial photographs (Grieve *et al.*, 1994) and was extended by the use of questionnaires sent to people who had detailed local knowledge of the erosion. A range of erosional processes were considered and SNH concluded from this survey that a widespread and obvious erosion of mineral soil is occurring in the Scottish uplands. The questionnaires sent out by SNH indicated "that 40% of reported instances of gullying were associated with land management, mainly heavy grazing by sheep and deer, or drainage work". SNH also concluded that a major factor that is contributing to an increase in soil erodibility is the loss of protective vegetation cover on slopes.

Loxham (1997) feels that the problems of upland erosion found in Scotland "is a situation mirrored in the Lake District and in other upland areas to a greater or lesser degree, where sheep rearing is the main agricultural enterprise".

Loxham also describes some of the particular aspects of upland farming that promote sheep originated erosion. These include the "changing husbandry, shepherding, supplementary feeding, year round grazing, ratios of cattle to sheep, an increase in the density of grazing animals beyond the carrying capacity of the farm unit, over-wintering in woodland and on the fell, and off wintering of first year lambs to lowland farms". Tallis (1985) relates the current erosion of southern Pennine moorlands (initiated 200-300 years ago) to intensified grazing and trampling of the moorlands, compared to past erosion events which predate major forest clearance (1000-1200 years ago), which may have been generated by naturally occurring movements of soil and rock.

Evans (1990) describes an increase in area of bare soil on an exposed slope in the Peak District (Derwent Edge). This was about 4% per year between 1975 and 1986. The slope was covered in vegetation in 1948 but by 1986 there was about 1670$m^2$ of bare soil, the vegetation having been lost as a result of grazing. He describes this area as having a rate of erosion of about 17.5 $m^3$ a year, which is 3.5-7.0 times faster than the highest mean rates of erosion recorded on arable land. The rate of increase in the expanse of bare soil stopped when the number of sheep grazing the slope was reduced. Evans found this rate of erosion to be similar for other parts of the Peak District (e.g. Kinder Scout).

Anderson and Radford (1994) produced some of the most scientifically sound data to show the how effective recolonisation of eroded slopes by vegetation could be following a reduction in grazing pressure.

Greene *et al* (1998) investigated the effects of high and low grazing regimes on the surface soil properties of a dunefield land system in E. Australia. They concluded that at low sheep grazing densities (0.2-0.3 animals per hectare) the soil remained in excellent condition. However, at high intensity grazing (4 animals per hectare) there was a rapid depletion of perennial grasses, removal of most of the shrubs and a conversion of the soil structure to one that was either easily erodable or, formed a strong, physical crust. They conclude that this crust may cause a change in the hydrology of the land system and limit recovery of palatable sward, thereby propagating grazing pressure elsewhere.

Bare peat soils are highly vulnerable to disturbance by the hooves of sheep. In addition, lambs disturb the soil surface and stop vegetation growing back in the summer (Evans, 1996). Wilson (1993) describes how the bare soil at Kinder Scout became revegetated once the sheep were removed from the area.

Van der Post *et al* (1997) constructed a record of accelerated erosion in the recent sediments of Blelham tarn in the English Lake District. Two frozen cores from the tarn were subsampled and measured. A detailed chronology was established using sedimentological data, radionucleides and algae. This has resulted in an accurately dated reconstruction of sedimentation evidence over the past 40 years. Despite a large increase in lake productivity, the evidence Van der Post *et al* collected suggests that the increase in sedimentation rates can be attributed to erosion within the catchment (largely eroded soil). Citing from Van der Post *et al* (1997), "a comparison between the trend of accelerated sedimentation and the record of increased sheep stocking density for the area...as well as observations of contemporary surface processes within the catchment, both suggest that much of the recent erosion is a direct response to increased pressure from sheep grazing".

O'Sullivan (1994) undertook assessment of sediment cores taken from Slapton Ley National Nature Reserve. He identified that an increase in sedimentation of the Ley since 1950 is associated with the post-war intensification of agriculture and the resultant loss of top-soil.

A survey of erosion features in Scotland (Grieve *et al.* 1995) describes how as much as 6% of upland areas are covered by eroding peat, a sizeable area of land in which erosion was either initiated by or has been maintained by grazing animals. Tallis and Yalden (1983) agree with this view, stating that active erosion at peat margins is clearly increased, if not caused by, intensive sheep grazing.

A questionnaire survey of 9 National Park Authorities undertaken for this R&D Project showed that 18.4% of erosion occurring in the parks is perceived to be caused by trampling pressures; 16.3 % of erosion was perceived to be caused by grazing and 16.3% by recreation. Other agents of erosion included climate, fire, increased runoff and loss of vegetation.

There is enough scientific, anecdotal and photographic evidence collated, and currently eroding sites observed for this R&D study for the extent of the erosion problem in Britain's uplands to cause serious concern.

### 4.1.2 The Mechanics of Grazing Induced Erosion

Evans (1997a) gives a full account of the formation of sheep induced erosion and the effect of the formation of sheep scars. He describes how sheep most commonly form crescent-shaped scars at breaks in slope where they rub against vegetation. "The scars are not only used as scratching posts but also for shelter. The scars can be small (having a height to width ration of less than 1:5) or large. The larger scars have an 'apron' of bare soil below the back wall of the scar and can be complex in shape when they coalesce with adjacent scars." Evans continues by saying how the 'apron' cannot become re-vegetated because the surface is constantly disturbed by the hooves of sheep, the impact of frost and other natural agents of erosion.

*See Figure 14.*

In the 1980s Carr (1990) assessed the summer stocking densities of sheep in Coledale (the Lake District) where sheep scars were extensive. Stocking densities were 0.2 - 0.4 ha per sheep. Evans (1977) found that bare soil was created in Hey Clough (Peak District) during the 1960s with year round stocking densities as low as 0.5-0.6 ha per sheep. On the Armbroth Fells (Lake District) scar initiation probably took place at summer grazing densities of 2.0 ha per sheep. The occurrence of such scars is widespread throughout upland Britain. Loxham (1997) says "sheep have always created these scrapings to protect themselves, (the problem is) there are just so many more of them today. The incidence and evidence of these scrapings are available in every major valley throughout the region" (The Lake District).

The formation of gullies has been attributed to the damage of blanket bog vegetation by sheep. If the gullies retreat and drain pool and hollow complexes on peat, then wind, frost and sheep can all play potent parts in further eroding peat into hags (Shimwell, 1974). Innes (1983) dated debris-flows in the Scottish Highlands by lichenometry and considers sheep grazing to have played a major role in creating instability of slopes and the occurrence of screes. This opinion is also echoed by Evans (1990) and Loxham (1997).

In addition to forming scars, sheep accentuate them. Evans (1990) describes how scar margins are broken down more quickly by sheep than by the natural agents of erosion alone. In this situation, it is normal for weathering (e.g by rain, frost, wind) of the back wall of the scar to undercut a turf mat which will consequently slump down and afford some measure of protection to the exposed soil. However, sheep rubbing or treading these turf mats prevent this situation being achieved. Therefore sheep scars can rapidly expand, joining up with others to create large areas of bare soil, especially at high altitudes and steep slopes where the natural retreat of the back scar is more rapid, especially where the turf is already stressed by trampling and grazing pressures.

It is not just the impact of sheep that contributes towards the accelerated erosion of the uplands. Other animals do play a major role (e.g rabbits and deer). Rabbit populations have increased in many locations as survival rates have increased due to recent mild winters (Long, 1990) and short, closely grazed turf, especially when it is found in conjunction with dry sandy soils, is highly favoured by rabbits. Evans (1997a) describes how rabbits favour short grass for grazing. Where rabbits and sheep are found on the same slope, the sheep can create scars and the rabbits can then burrow into the weakened turf as well as the scars.

*See Figure 15.*

Soil spread around burrow entrances then kills underlying vegetation (in the same manner that sliding scree will). Deer can also create damage, as highlighted by Evans (1997b).

Bare soil is also commonly exposed along tracks that are used by livestock. Evans (1997a) describes bare soil initiated by trampling along fence lines, around gateways and farm buildings, anywhere where livestock can congregate.

Evans (undated) describes parallel paths that can be seen on most Lake District fells. These are unlikely to be created by walkers as the majority of walkers use paths that run directly to the point of destination. When walking in the hills, it is obvious which paths are created by walkers and which are created by sheep. In terms of overall impact, it is the sheep which track over whole hillsides, whereas people tend to confine themselves to well defined paths.

Loxham (1997) feels that it is not a question of "sheep grazing habits having changed (although actual sheep numbers in some places are leading to a breakdown of natural herding instincts). It is more a case of sheep doing what they normally do, but doing much more of it i.e. foraging, tracking back and forth, causing trampling damage." This is as a result of greater competition for food (as there are more sheep than in the past) and of there being less food available (having been grazed out, removed by accidental or deliberate fires, or smothered by bracken or old heather stands).

Drought over the past few years has also contributed to a reduction in the amount of vegetation available to grazing animals over the summer months as the vegetation, stressed by drought, stops growing. The pressure on vegetation is increased substantially over the winter months for the same reason. In both situations, the pressure from sheep is critical, resulting in the vegetation still being eaten and trampled, while not growing.

### 4.1.3 Recovery from Grazing Induced Erosion

Once bare ground has been established it is very difficult for the vegetation to recover, especially if environmental conditions are difficult (Evans 1990) and grazing animals are present. Grant *et al.* (1978) recorded the tendency for sheep to graze near bare areas and, in doing so, enlarge them. Some soils are extremely unstable (e.g. shale, scree and loose sand) and vegetation cannot easily take hold. This is made worse at high altitudes and, in some circumstances, once bare soil has been created, erosion will continue until a surface more suited to colonisation or one that is more resistant to erosion (e.g. hard rock) is exposed.

Macay and Tallis (1996) investigated the incidence of summit type mire erosion in the Forest of Bowland, Lancashire. They identified a wide range of causative agents (including climate, decline in upland management, and catastrophic fires). However, they believe that it is the current high sheep stocking levels that may prevent recolonisation of bare peat surfaces, thereby allowing peat erosion to continue.

Chaney *et al* (1993), in their report Livestock Grazing on Western Riparian Areas, which was produced for the US Environmental Protection Agency provides a comprehensive review of river bank erosion and grazing strategies employed to reduce the impact of this. It also includes 11 case studies where a wide range of "riparian area conditions, problems and opportunities" are discussed in detail. On the whole they demonstrate that "the productivity of degraded riparian areas can be restored, usually with a net gain in forage". The report also states that "a successful riparian grazing strategy must be custom designed to fit the specific circumstances" (e.g hydrology, geology, climate, soils, vegetation, plant species, and livestock breed).

*See Figure 16.*

In 1937, Fenton noted that it took longer for bare soil to be recolonised by vegetation if sheep were present than if they were excluded. Evans (1990) relates different situations where this has been found to be true. Rawes (1983) found that within exclosures of blanket bog over 15 years, bare peat began to diminish in area as it was fragmented by colonising plants while Lance (1983) observed that burned and grazed heather in western Ireland was slower to increase in standing crop and ground coverage than burned but ungrazed heather.

In the Lammermuirs, south-east of Edinburgh, a fence separating ungrazed water-gathering grounds for Whiteadder Reservoir from adjacent grazed slopes separates an eroding grassy slope on the grazed side from a non-eroding grassy slope (Evans, unpublished). In the Cardingmill valley of the Long Mynd (Shropshire), steep grassy slopes outside an exclosure are eroding and appear exceedingly vulnerable, whereas inside the exclosure there is little bare soil, and grasses come into flower and set seed (Evans unpublished). Similar patterns have been observed in exclosures in the Peak District where attempts to colonise bare soil with vegetation proved difficult, especially on peat and if sheep were not excluded.

Further to the Moorland Erosion Study (Phillips, Yalden and Tallis, 1981), Phase 2 of this project was undertaken and the report was released in 1983, under the revised title of Peak District Moorland Restoration Project, Phase 2 Report: "Re-vegetation Trials" (Tallis and Yalden, 1983). This report contains the results from a number of different experimental plots, some of which were fenced to exclude sheep and people, while some were seeded with heather and located on both peat and mineral soils. Where the plots were located on mineral soils that were protected from sheep, some success had been attained. However, where revegetation was attempted on bare peat, the trials failed completely.

The Phase 3 Report, "Restoring Moorland", Peak District Moorland Management Project (Anderson, Tallis and Yalden, 1997) relates the progress which has been made and describes attempts to restore heather cover to eroded or degraded moorlands. This report concludes that "not all damaged moorland can or should be restored. Restoration is appropriate for recently fire damaged sites, overgrazed vegetation and trampled or mechanically disturbed sites".

## 4.2 The Influence of Grazing on Runoff

Braunack and Walker (1985) considered that the natural recovery of soil physical properties after permanent pasture would depend on soil type, the severity of the grazing impact and the climate and biological agents acting afterwards. They found that after 16 years without grazing, the surface soil properties of a semi-arid woodland showed evidence of prior damage by grazing sheep. Gifford and Hawkins (1978) reported that infiltration rates might still have been increasing 13 years after grazing ceased. In some studies they reviewed, infiltration rates were actually lower for the first 8 years after protection from grazing.

Langlands and Bennet (1973) suggest that greater grazing pressure may lead to lower rates of infiltration into the soil and consequently more runoff into streams. This in turn may lead to erosion of stream banks and headward retreat of gullies into peat. It has been shown in the previous section that the activities of grazing animals can result in areas of bare soil being established, exacerbated and, in many cases, maintained. An increase in such areas of bare soil will lead to more rapid runoff according to Branson and Owen (1970), with consequent flooding and river bank erosion.

As soil is removed, erosion and runoff may increase further, as some underlying soils can be less resistant to water erosion and rain may infiltrate into them at a lower rate (e.g. iron pans, Evans, personal communication, 1997). Langlands and Bennett (1973) identify that the reason for low rates of infiltration of water is due to compaction of the soil surface by trampling and grazing. The impacts of this are likely to be particularly pronounced over the winter months when vegetation is not growing and the season is wet.

Mwendera and Saleem (1997) assessed the hydrological response to cattle grazing in the Ethiopian Highland using study plots and multiple grazing regimes. They determined that heavy to very heavy grazing pressure (3.0 animal unit months (AUM) $ha^{-1}$ and 4.2 AUM $ha^{-1}$ accordingly) significantly increased surface runoff and soil loss, as well as reducing the infiltrability of the soil.

Butcher *et al.* (1989) note that rainfall runs off bare peat much more quickly than peat covered by dense cotton grass. Burt and Gardiner (1984) identify that peak discharges runoff volumes and sediment loads are all higher from a small eroded peat catchment than an un-eroded one.

Evans (1990) examined the effect of a rise in sheep numbers in the Peak District and found that the intensive grazing pressure occurring there led to the exposure of bare soil and a compaction of the soil surface. These features are likely to increase the amount of rainfall that runs off rapidly over the land surface. Evans (1990) noticed that the increased stocking of the moors fringing the Derwent Valley in the Peak District led to significantly higher stream flows (Figure 28). Evans also found that in Hey Clough (Peak District), rates of infiltration of rainfall into saturated bare soil are very low compared to adjacent grassed surfaces.

*See Figure 17.*

Evans (1990) examined streamflow data for the upper North Derwent catchment and describes a "plausible scenario". He describes low infiltration rates in the catchment in the 1930s when an extra 1250 sheep were stocked. In the 1940s and 1950s a series of dry years were recorded and severe winters reduced sheep numbers. This ties in with a reduction in runoff as a proportion of rainfall and in the 1960s and 1970s the data shows there is a marked relationship between increasing numbers of sheep and increasing levels of runoff.

Orr (1997) has looked at rainfall, discharge and land use in the River Lune catchment in Lancashire. Since 1900 the total annual rainfall for the catchment has shown either a static trend or a slightly downwards trend. However, when seasonal rainfall is examined there is a clear upwards trend in total winter rainfall, and a downwards trend in total summer rainfall. These trends are reflected regionally and there is evidence to suggest that there is even greater variability over the last twenty years. Discharge records for the catchment began in 1976 and while the mean daily flow in the lower and middle part of the catchment has been decreasing over the last 20 years, the trend in the higher parts of the catchment is upwards.

In the upper catchment the discharge is increasing at a higher rate than the rainfall so that if discharge is subtracted from the rainfall (which removes the need to separate seasonal evapo-transpiration and ground water storage fluctuations) groundwater recharge shows a strong downwards trend. Information researched on local land use shows that since 1860 when records began, sheep numbers in the Lune catchment have risen from about 7,000 to 50,000. Literature suggests that grazing densities greater than 1.5 sheep per hectare are liable to cause erosion in sensitive upland areas (eg the Lake District). Grazing densities in the Lune catchment are generally greater than 4 sheep per hectare and in some parishes more than 7 sheep per hectare (1988 figures) have been recorded. Orr surmises that the increased grazing densities may account for the increased runoff observed in the upper catchment due to compaction and reduced vegetation cover.

Evans (1990) identifies another land use change in the north Peak District that may explain the increase in runoff. This is the decline of heather and bilberry moors and their replacement with grassland (a phenomena widespread throughout British Uplands), in particular wavy hair-grass and mat-grass. These changes are attributed to overgrazing by sheep and reduced levels of moor management. It is the wavy hair-grass covered slopes that Evans (1990) states are especially vulnerable to overgrazing and erosion.

Where a higher biomass of vegetation is removed (eg scrub or heather), and replaced by short grasses or bare earth, the insulating properties of thick vegetation are lost and the soil is more likely to become frozen. Frozen soil is impermeable to snowmelt or rainfall and thus the amount of water running off the land surface may be increased. Frost-heave is common on bare soil and this can lead to increased soil and peat erosion.

*See Figure 18.*

Owens, Edwards and Van Keuren (1997) have studied the runoff and sediment losses from a small pastured catchment in eastern Ohio (US) for twenty years. For the first period of 12 years, beef cattle grazed the water-shed rotationally during the growing season, but were fed hay during the dormant season. For the second period (3 years) there was summer rotational grazing only. For the final period (5 years) there was no animal occupancy. The annual runoff was more than 10% of precipitation during the first period and less than 2% in the following periods. The decrease in annual sediment loss was even more pronounced, each period yielding 2259 kg/ha, 146 kg/ha and 9 kg/ha respectively. Over 60% of the soil lost during the first period occurred during the dormant season.

Low amounts of grazing on adjacent summer-only grazed catchments supported the conclusion that the increased runoff and erosion in the initial 12 year period resulted from the non-rotational winter feeding on the pastures. However, Owens, Edwards and Van Keuren believe that the impacts of the grazing do not last long and that soon after the management regime was changed, runoff and sediment loss decreased markedly. It is suggested that if winter feeding must occur, it should be undertaken on areas with less severe slopes (i.e. off the moortops and slopes) and rotational grazing should be employed to prevent one area being subjected to an entire dormant season of intensive grazing.
Greenwood *et al* (1998) examined the potential for the degraded physical properties of soil to regenerate naturally after exclusion of grazing animals at a long-term stocking rate trial in Australia. The unsaturated hydraulic conductivity (a property of both the porous soil and of the

water flowing through it) was measured before grazing was excluded, and after 7 months and 2.5 years' grazing exclusion. These data were then compared with controls at 10, 15 and 25 sheep/ha.

After 2.5 years, there were significant increases in unsaturated hydraulic conductivity at 5 and 15 mm tensions (similar to the depth of water in the soil horizon) in the ungrazed plots compared to the grazed plots. In addition, the hydraulic conductivities and bulk densities of the surface soils under the pasture that had been ungrazed for 2.5 years were comparable to those where the pasture had been ungrazed for 27 years. Therefore, it is suggested that the exclusion of grazing animals has a significantly beneficial impact on soil structure and drainage even over a relatively short period of time and *vice versa*.
Haygarth and Jarvis (1997) determined that runoff from grassland soils are a significant source of diffuse phosphorous to surface and estuarine waters and may cause eutrophication. Both the runoff rate and levels of phosphorous are elevated in the presence of cattle (or sheep) due to grazing pressure, excretal returns and poaching.

## 4.3 Discussion

Existing evidence supports the theory that increased stocking rates can cause an increase in run-off rates and soil erosion, however more work is needed to document the impacts and quantify the extent of the problem.
As Orr (1997) surmises the most likely causes of the increasing run-off rates are likely to be the trampling and puddling effect of hooves and the reduction in biomass of the vegetation. Once vegetation is reduced it is easier for the soil surface to be exposed and damaged, reducing porosity and increasing surface run-off and soil erosion. Winter grazing will reduce plant biomass further still during the dormant part of the year. This is also the time when frost heave can significantly affect poorly insulated ground. With reduced insulation against the elements and winter temperatures the ground surface is more likely to freeze reducing soil porosity.

Stocking during the winter is when the greatest damage to heather and grass can occur and thus has the greatest impact on run-off rates and erosion. Reducing stocking over the winter is likely to have a beneficial effect and reduce rates of run-off and erosion. Removing stock from land will aid its recovery in a relatively short period as long as this is over the growing season as well as over the winter. Vegetation is unable to recover when it is not growing.

It is likely that any identified sustainable carrying capacity will vary for individual fields, holdings and common land, according to the elevation, aspect, soil etc and even the breed of sheep. If the carrying capacity of an area is sustainable (presuming no other variables) then there should be little variation in the biomass or species composition of the area over a period of time such as 50 - 100 years. The decline in upland vegetation seen in many areas today is likely to be the cause of insidious changes over a considerable period of time measurable in individual lifetimes and in hundreds of years. Overgrazing is consequently difficult to measure and has gone relatively unnoticed.

In the past the uplands needed to be self sufficient in food and the carrying capacity was measured by the amount of fodder that the holding or dale could grow in a season. It was prohibitively expensive to bring feedstuffs from outside the area and thus the carrying capacity of the area was limited. Today feed can be transported in easily and inexpensively and this has meant that more stock can be fed in a catchment and also fed on the hill with all-terrain vehicles transporting fodder to some of the most inaccessible areas. This can cause localised hot spots of more intensively grazed land.

Whilst the moorland tops are often flatter and consequently less prone to erosion and increased run-off, the valley sides maybe steep and therefore have the greatest potential to suffer from increased erosion and run-off. Intensive grazing pressure on the slopes is likely to have greater impact than on the moortops, particularly where the valley sides contribute large areas of land within the catchment.

*See Figure 19.*

If grazing levels remain too high the decline in habitat quality and quantity will continue, as will increasing levels of erosion (including the extent of bare areas). If the stock numbers remain the same but the amount of vegetation available is gradually reducing, additional pressure will be put on the remaining vegetation. The rate of upland degeneration is likely to increase and once soil and vegetation is removed it is extremely difficult to get it back again.

The following conditions are likely to increase runoff:

- The reduction in biomass or surface area of heather/grassland will reduce the water storage capacity on the surface of the vegetation and thus any evaporation rates.

- The reduction in biomass or surface area of heather/grassland will reduce the water storage capacity within the vegetation itself and the amount of transpiration it is capable of.

- Reducing the amount of plant biomass above the ground also reduces the root depth below the ground. This is likely to reduce the porosity of the soil profile, reduce the volume of rain required to saturate the soil and cause increased runoff.

- Healthy robust vegetation retards surface flow and provides good insulation against extremes of temperature (frost and heat). Frozen or sun-baked ground is likely to lead to increased runoff and increased rates of erosion.

- Robust vegetation can store and insulate snow, delaying the time taken for meltwater to reach watercourses and so reducing run-off rates.

*See Figure 20.*

Of the total agricultural land use in the UK, it is estimated that as much as 27%, being rough grazing, is only suitable for dedicated sheep production. Less Favoured Areas (LFAs) account for most of this rough grazing land and almost 70% of the total flock numbers (nearly 44 million) in the UK are found in LFAs. This proportion rises to 88% in Wales and 85% in Scotland, indicating the extent to which sheep are mainly found in areas difficult to farm (National Sheep

Association 1995).

If runoff rates are increasing over such large areas, then it follows that groundwater recharge and baseline flows may also be significantly affected.

The uplands contain some of our most precious water resources, headwater streams, soils, vulnerable habitats and species diversity; and significant amenity areas. If overstocking is leading to increased run-off rates, reduced ground water recharge and soil erosion on about 30% of Britains land surface, (the majority of the uplands), then the extent of the problem is likely to be significantly.

# 5. THE IMPACT OF OTHER UPLAND MANAGEMENT PRACTICES.

## 5.1 Burning

Many authors document an association between peatland erosion and either burning or grazing, or both (e.g. Ratcliffe, 1959; Mallik, Gimingham and Rahman, 1984; Fullen, in NYMNP, 1986; Anderson, 1986; Anderson and Yalden, 1981; Tallis, 1987; Anderson, Tallis and Yalden, 1997).

Anderson (1986) cites Farey (1815) who describes how (in the late 1700s) some moorland in the Peak District had burned for a number of weeks and then collapsed. Bad burning practice is, therefore, not a new phenomenon.

Controlled seasonal burning can lead to the regeneration of vegetation which, in turn, can sustain a larger population of sheep (or grouse). However, the resultant exposed surface from this practise (or from light uncontrolled fires) can be degraded by natural agents of erosion and the mechanical effects of trampling by livestock. Grazing of these areas can lead to reduced levels (or an absence) of vegetation. The removal of stock increases the likelihood and rate of natural regeneration of vegetation.

The more devastating impacts from large accidental fires can lead to the ashing of the peat layer and the exposure of the mineral soil which, due to its physical and chemical characteristics, is extremely hostile to recolonisation. This can be compounded by the presence of livestock.

Once a bare surface is exposed, "natural erosion" (e.g. from frost heave) can be far more effective. This can be enhanced by the presence of grazing livestock which have been reported to target such areas due to the ease of access to vegetation at the margins of the burnt area (Grant *et al*, 1978).

*See Figure 21.*

Due to little vegetation being present to intercept rainfall and prevent the potential desiccation of peat (from droughts and wind), the ability of exposed peat to retain moisture is severely diminished. As a result, rainfall (particularly if it is intense) will exacerbate the loss of material as rills and gullies develop. In addition, runoff rates may increase.

Research has suggested that the severe burning of the peat surface reduces the water storage capacity of the soil and lowers dry weather flows and may increase the rate of runoff in drainage ditches. This has negative consequences for water resource management in potable water gathering areas such as moorlands. Peat and other eroded materials are transported into reservoirs, thus reducing their storage capacity. These materials also colour the water that then requires treatment.

Burning can be detrimental at varying scales and good practice needs to be developed and linked more to stocking rates of individual sites. The prevention of uncontrolled fires will also depend on current management and historic management. Therefore, management needs to focus upon reducing the risk.

## 5.2 The Control of Bracken

The control of bracken is promoted for several reasons including its toxicity to livestock, the control of sheep ticks, the encroachment upon grazing land (leading to localised intensive grazing pressure) and an obstruction to recreational activities.

The control of bracken can be achieved through a variety of mechanical and chemical methods. These methods can themselves have negative impacts (either upon other vegetation or the soil) but essentially it is the exposure of non-vegetated areas of land that has serious ramifications on upland erosion and runoff rates. Expansion of bracken onto upland grazing areas will have the effect of concentrating livestock grazing effort. Some consequences of this are the removal of vegetation, trampling and compaction of the vegetation and soil, and ultimately, the exposure of bare soil and its erosion.

One result of bracken control is the formation of a deep litter layer that presents an inhospitable habitat to recolonising plants. The litter layer can also be washed or blown away, revealing bare soil. Erosion of the bare soil can then proceed, exacerbated by livestock trampling through the cleared area and grazing on any plant regrowth.

The decline of cattle and rise of sheep in the uplands has exacerbated the problem of bracken litter suppressing other forms of vegetation. Cattle are better than sheep at trampling down bracken litter and thinning out frond densities (Oates, undated).

The loss of bracken foliage has the impact of reducing the surface area available for the interception of precipitation, and despite a layer of bracken litter, runoff may become accelerated especially where the bracken grew on steep slopes.

*See Figure 22.*

It is essential that the correct form of aftercare is prescribed following bracken control to ensure a limit to erosion and success in bracken control. Fencing and exclusion of stock greatly enhances the natural regeneration ability of bare areas following bracken spraying.

The control of bracken has been promoted in the past, and still continues today, although the practise is perhaps more restricted due to concerns about erosion of moorlands stemming from loss of substantial areas of bracken cover (Thomas, personal communication, 1997). However, this is more likely to be due to the cost of bracken control, the lack of available grants and an increasing restriction on herbicide use (Rees, personal communication, 1997). The future availability of grants for bracken control is likely to be reduced or removed altogether (Brown, personal communication, 1998).

## 5.3 The Impact of Recreation

Essentially, the role of recreation in eroding the uplands tends to be linear and is modest in comparison to other agents (overgrazing, fires, climate etc.). Loxham (personal communication, 1997) has the view that when compared, the extent of erosion caused by recreational pressures is far superseded by that initiated and exacerbated by grazing pressures.

*See Figure 23.*

Short grazed swards encourage people to spread out from linear pathways, taking shortcuts and can result in a wider spread of footpath erosion. Impacts from this include loss of surface vegetation and soil/scree erosion.

Intensively grazed swards are already stressed. The extra trampling from people can tip the balance and cause soil erosion. Repair and regeneration is also more difficult.

Vigorous, well-developed vegetation will contain the spread of footpath erosion and paths running through robust vegetation is more favoured by walkers than the rougher areas adjacent to them.

Incised, gullied footpaths can act as a route for rainfall or snowmelt to run off down a slope as the path usually follows a direct route to the bottom. As well as increasing localised runoff, the water flowing down such paths can transport loose material and cause further erosion.

Attention needs to be given to the chronic effects of footpath erosion, rather than the visible, acute effects.

The politics of recreation e.g. "The Right to Roam" may well affect erosion caused by grazing animals. More visitors wandering away from defined paths can have the effect of dispersing herds, causing further damage from trampling.

Due to its acute nature, erosion from recreation attracts large sums of money to affect its repair. Typically, these are far greater then the budgets directed into enhancing stock control management (e.g. shepherding) or other methods of reducing the occurrence/impact of grazing animals and other agents of erosion due to upland management (e.g. uncontrolled fires).

## 5.4 The Impact of Forestry

Mature forests have been shown to reduce erosion within catchments and streams due to protection from the canopy, roots and surface litter layer. Runoff can be reduced in a similar manner, as forests have a high evaporation rate and also reduce storm discharge peaks by retarding the surface flow of water.

Before, during and for a few years after planting, forestry drainage increases runoff rates and if plantation drainage channels become eroded bedload transport can be increased. Such drainage channels have been found to reduce response times to rainfall events and increase peak discharges, thereby causing channel erosion.

Where clear-felling occurs, the resultant bare land becomes immediately prone to erosion and runoff problems.

## 5.5 The Impact of Upland Drainage

Moorgripping (upland drainage) has been shown to be ineffective in lowering the local water table (to improve conditions for grazing), other than immediately adjacent to the drain and as a result, grants are no longer available to undertake moorgripping and MAFF, English Nature, the Game Conservancy Trust and landowners are now blocking up grips.

Over the past 10 years the Game Conservancy have been carrying out 'The Hall Moor Study' in Swaledale in North Yorkshire to look at the effects of moorgripping. The research found that the water table was only lowered significantly within 0.5m of each drain. This represents a 4.5% reduction in the level of the water table (3% of the open ground) in a drainage system with drains set at 22m spacings. To significantly reduce the water table over large areas of moor, the drains would therefore need to be spaced at 1-2 m intervals. However, once water is within the drainage channel, the run-off rate of that water increased, as did its eroding capabilities. Large quantities of peat and soil/substrate can be washed downstream during this process with increased acidity and sediment in the water. (Newborn and Booth 1991).

Drainage will exacerbate the rate of runoff from areas of uplands where it is employed. Artificial drainage of the uplands will contribute to the increase in runoff rates. However, rivers still respond quickly to rainfall events even in areas where drainage (moorgripping) is being reduced (e.g Swaledale, Yorkshire Dales, where recent hydrographs for the River Swale illustrate that it can increase its discharge from 25 cumecs to 250 cumecs in an hour (Collins, personal communication, 1997).

*See Figure 24.*

Once in the drains, any water and sediment is rapidly conveyed to receiving arterial watercourses. In many cases, vertical incision of such 'moorgrips' is apparent. In this manner, moorgripping increases sediment input to riverine systems during storm events. Reservoirs are also affected and their storage capacity is reduced by infilling of eroded sediments. White *et al* (1996) found that a typical Yorkshire reservoir has lost 10% of its capacity to sediment over a lifetime of 100 years.

Increasing the drainage of the uplands is likely to reduce the amount of water available for aquifer recharge. Water quality problems can also occur (e.g. discolouration and acidity) from peat runoff, and these can cause serious problems for the water companies.

## 5.6 Summary

Land management issues such as burning, bracken control, drainage, recreation and forestry can have a significant effect on the removal of vegetation, erosion of soil and an increase in runoff. In some locations they are the sole agent of cause, in other areas there may be several of these factors overlayed. Where intensive grazing pressure occurs in the same location as other land management practices (e.g grazing on freshly burnt moor) then the stress put upon vegetation may be too great for it and either it will disappear and erosion will occur or erosion already occurring will be accentuated.

Factors such as burning, bracken control, drainage, recreation and forestry, do not tend to be catchment wide, whereas grazing is. Although vegetation growth depends on a wide range of natural factors such as climate, altitude and soil type, grazing management is a factor that is controllable. It is possible to prevent and reverse the detrimental impacts of intensive grazing pressure and thereby allowing nature to restore any damaged land, by reducing or removing livestock either temporarily or permanently.

# 6. THE INFLUENCE OF CLIMATE

Erosion is a consequence of the interaction of the material and physical relief of the Earth's surface with the overlying atmosphere. The influence of climate upon the erosion and weathering of soil and rock is limited by the protective layer of vegetation on the land surface.

## 6.1 Climate and Erosion

Evans (1993) suggests that although climate has changed since woodland clearance began, in comparison to woodland clearance and other land use changes since, this has had little impact in altering geomorphological thresholds and the sensitivity of the land to erosion. Periods exceptional to this general finding have been recognised, particularly during the Little Ice Age when mass movements of slopes were more frequent and, when wetter or more stormy climatic conditions prevailed (1000 BC to 0 AD, 1200 to 1300 AD and 1500 to 1750 AD) exacerbating the surface washing of slopes under arable cultivation (Lamb, 1988). Furthermore, climatic change to wetter conditions around 300 BC and 1000 BC may have triggered peat growth and the associated instability and erosion.

A wide variety of reports in both scientific journals and popular periodicals can be offered as a counter to the above argument, in as much as low frequency high magnitude weather events can be regarded as climatic. The effects of such events within catchments has sometimes been shown to be profound and long lasting particularly in the uplands where weather can be extreme.

Orr (1997, unpublished) is reviewing climatic variability and land use changes in the River Lune catchment, NW England. Her work suggests that general trends in rainfall variability show decreasing summer rainfall totals and increasing winter rainfalls. She describes how impacts from increased grazing densities (reduced vegetation cover and soil compaction) may account for changes observed in the rainfall-runoff relationships experienced in the upper reaches of the catchment. (See also 4.2).

The effects of climate will affect everything in a river catchment, very little can be done to mitigate climate regimes and any changes in them. However, an intrinsic factor in how climatic effects influence erosion is the presence of dense, robust vegetation cover. As stated earlier, vegetation will act as an insulator against temperature extremes (e.g. frozen ground and desiccation) which can make the soil more impermeable and increase runoff rates. Vegetation will also delay the movement of water down slope as well as binding soils, stabilising the ground. Where grazing and trampling (or other types of upland management) cause the loss or absence of vegetation, the likelihood of enhanced erosion and runoff occurring will be increased.

A wide scale change or loss in vegetation cover may have implications for local climatic conditions. A change in vegetation type or a change from vegetation to bare ground will alter the amount of solar radiation absorbed and reflected. In addition, plants return water back to the local atmosphere by the process of evapo-transpiration. A change in the input from plants to local atmospheric moisture recycling budgets may have implications for rainfall patterns. (Sansom, 1997).

## 6.2 Summary

Though identification and further analysis of detailed meteorological records is already being undertaken (Sefton & Boorman, 1997; Orr, 1997) this is an area for future study which could be expanded, paying particular attention to catchments thought to be suffering enhanced erosion.

The influence of climate needs to be viewed in two overlapping ways. First the long-term impacts of climate change such as little ice ages and global warming and secondly the accelerated erosion that climate can exacerbate if the soil is unprotected with robust, healthy, vegetation (e.g high intensity storm events).

Britain has a maritime, temperate climate with high levels of rainfall. Such a climate ensures that there is virtually nowhere in Britain, under natural conditions, where vegetation of some sort will not grow. Britain's uplands contain a variety of plant species, perfectly adapted to live in extreme conditions of heat, cold, drought and flood. The plants are only vulnerable when stressed. As Evans (1993) pointed out, although the climate has changed since woodland clearance began, in comparison to land use, these changes have had little impact in altering geomorphological thresholds and the sensitivity of the land to erosion. However, the impacts from upland overgrazing and other forms of land management have been occurring insidiously over the last few centuries, increasing in the last fifty years, and in particular the last twenty years when significant increases occurred in the in the sheep population.

# 7. CONCLUSIONS

Evidence highlighted in this report suggests that removal of vegetation (by whatever means) will lead to soil erosion, and is likely to increase runoff and reduce aquifer recharge. Overgrazing by sheep is a well-documented problem affecting large areas of Britain's uplands. Because overgrazing is a catchment wide issue the scale of the problem is likely to be wider than other factors such as moor-gripping, burning or recreation which tend to be more localised in their effects. Grazing also overlaps many of these other issues.

This R&D study has combined academic research, anecdotal and photographic evidence. A wide range of places has been visited and specialists spoken to which has led to the conclusion that upland erosion is widespread and increasing. The full extent of the problem throughout Britain has not been ascertained.

The net effects of accelerated erosion and increased runoff are likely to have severe impacts on the functions of the Environment Agency and on the wider economy, biodiversity and sustainability (refer to section 2.3.8 of this report).

**Although changes in stocking density are thought to be the major cause of overgrazing, changes in management have also occurred. These include overwintering large numbers of stock in the uplands when pressure on heather and grassland is at its greatest (ie when it is not growing) and reduced shepherding which leads to some areas being more intensively grazed than others.**

It is both winter and summer grazing which is putting the pressure on the hills, because if grazing pressures are high in the summer there is no chance for moorland vegetation damaged in winter to recover or bare soil to be recolonised by vegetation. Grazing pressures need to be reduced all the year round, and to a greater extent during winter.

# 8. RECOMMENDATIONS

All agencies concerned with this issue should focus on the wider aspects of the catchment, not just discrete areas (e.g. moorlands, ESAs, SSSIs, and LFAs).

**Work should be carried out to determine the full extent of upland erosion in Britain. Further work is required to:**

- **assess the impact of habitat changes on the local climate,**
- **determine how much run-off is due to changing rainfall regimes or changing soil conditions, and**
- **determine how much ground water recharge is affected.**

**Further work should be carried out to assess the impact of increased erosion and run-off on the Environment Agency and other organisations. The sustainable management of soil, water, habitats, species, economies and local communities should be the aim of any policy affecting Britain's uplands.**

In all aspects of upland management, good communication and interaction between organisations, farmers and landowners must be achieved. The way forward is through a partnership approach, and organisations such as the National Sheep Association and the National Farmers Union are more than keen to become involved in any future upland management objectives.

The decline in the quality and diversity of Britain's uplands is reversible if action is taken immediately. However, some of the steeper areas (eg in the Lake District and North Wales) have already lost their vegetation and are now losing their soil at a rapid rate. The extent of these denuded areas is likely to increase with stock still grazing them, and ultimately, the sustainability of the farming community is at risk. Appropriate action is urgently required.

CAP Reform will occur in some form and opportunities should not be missed to:

- Increase the proportion of agri-environment payments in the uplands.
- Change the headage payments to area payments.
- Provide incentives to remove stock from the uplands during the winter.
- Provide incentives to improve shepherding.
- Provide incentives to protect common land.

- Agri-environment schemes could also include more grants to promote best practice, for example, protecting riverbanks from stock, blocking moorgrips.

- Whole catchments or areas (eg LFAs, National Parks) should be designated as sensitive areas or ESAs and be eligible for agri-environment scheme support. The whole farm approach should also be encouraged.

- Support for farm incomes and rural communities are essential if the present decline in upland farming is to be reversed.

Following recommendation no. 1 in the Royal Commission on Environmental Pollution Report (1996) "The sustainable use of soil" the Departments of Environment and Agriculture are jointly drawing up a soil protection policy for the UK. It is recommended that this soil protection policy extends as much to uplands as to lowlands.

Following recommendation no. 27 in the Royal Commission on Environmental Pollution Report (1996), MAFF have put research in hand to explore how far erosion of upland peat could be halted or reversed by changes in land use practices. It is recommended that, although this study has already started, it be extended to cover soil erosion in general in the uplands. A holistic approach to the uplands should be considered, including any effects on in-bye land, tributaries and rivers downstream.

It is also recommended that MAFF make full use of their discretionary powers to prevent overstocking in vulnerable areas. This recommendation is also made in the Royal Commission on Environmental Pollution Report (1996), with reference to the non-mandatory Code of Good Upland Management as a condition of payment for HLCAs. Evidence in certain areas suggests that this code is not being policed or enforced very effectively at the present time. Where reduced stocking is required in ESAs, it is possible that there is increased stocking in other areas of the LFA.

MAFF's Codes of Good Agricultural Practice for the Protection of Soil and Water should also be more actively promoted in upland areas.

Common land remains particularly vulnerable to overstocking. It is recommended that more should be done to facilitate best practice and stocking levels on these areas. It is also possible that legislation may be required. Ideal stocking rates will vary according to altitude, climate, soil quality and nutrient status, season and include seasonal variations. It is recommended that sustainable stocking rates should be calculated per farm holding and according to the ecological carrying capacity of the land (ie the Code of Good Upland Management). Examples exist where upland farming and conservation schemes have been successfully run together. These should be publicised to show that they can work effectively.

**Progress will only be made on upland issues if all concerned work together effectively towards a common goal. It is recommended that the statutory bodies and individuals, from both agriculture and conservation, work closely together to facilitate this process.**

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# FIGURES

**Figure 1. Heavily grazed and eroding slopes are becoming a common feature in the UK uplands. Lake District.**

**Figure 2. When the erosion carrying capacity is exceeded, the soil becomes exposed and begins to erode. Lake District.**

**Figure 3. Today more stock and in particular sheep are overwintered in the uplands than in the past. This results in the enhanced removal of vegetation during a period of little growth. Yorkshire Dales.**

**Figure 4. Evidence of trampling and grazing resulting in a loss of vegetation and exposure of the soil. Lake District.**

**Figure 5. Wild woods, a stable landscape. Side Wood, Ennerdale, Lake District.**

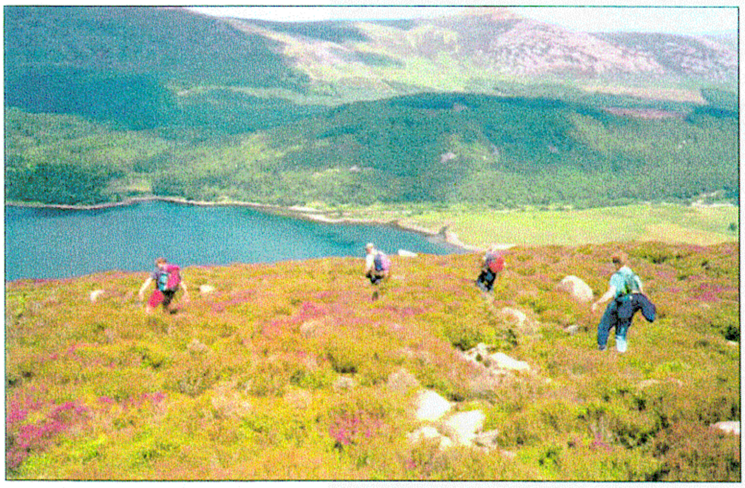

**Figure 6. Low grazing levels result in dense robust vegetation. A higher altitude slope than Figure 5, but still very stable and covered with dense stands of heather and bilberry The Side. Ennerdale, The Lake District.**

**Figure 7. Intensive grazing has removed dense vegetation such as heather and the sward is now mainly grasses. Kinneside Common, Ennerdale, Lake District.**

**Figure 8. The formation of unstable scree slopes on heavily grazed and trampled slopes. The Lake District.**

**Figure 9. Upland sheet erosion, a highly unstable landscape at the other end of the erosion spectrum. A large areas of the slope has had the vegetation grazed out, making the areas extremely prone to erosion. Lingmell, The Lake District.**

**Figure 10. River channels and banks can be buried under large quantities of coarse sediment deposits. Yorkshire Dales.**

**Figure 11. Grazing right up to the edge of river banks removes stabilising vegetation and increases the potential for erosion and bank collapse. Yorkshire Dales.**

**Figure 12. Movement of coarse debris can result in high levels of damage. The Lake District**

**Figure 13. Remobilised scree/soil can smother vegetation and kill it, resulting in a loss of biodiversity and habitat, and an increase in eroding ground. The Lake District.**

**Figure 14. A sheep scar. The Lake District.**

**Figure 15. Sheep grazing has helped to create an ideal habitat for rabbits. Yorkshire Dales.**

**Figure 16. Burnt areas of peat remain barren for a long period of time. Peak District.**

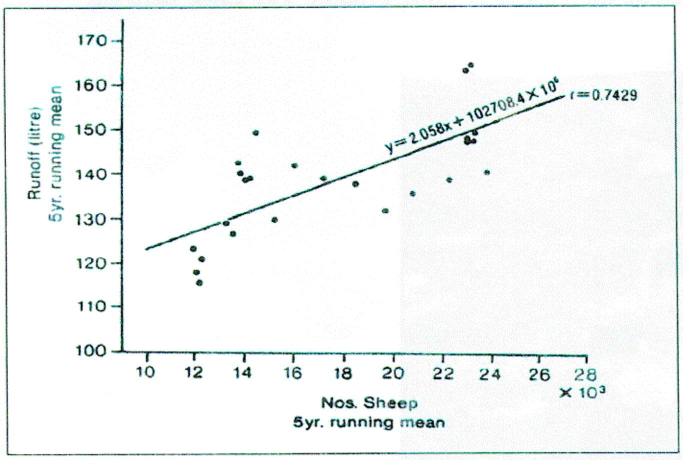


**Figure 17. Increased stocking of grazing animals results in increased runoff, (Evans, 1996).**

**Figure 18. Fencing off stock is effective in allowing vegetation to recover.
This will provide protection to the soil from weathering. Yorkshire Dales.**

**Figure 19. Where grazing occurs on slopes, the erosion effects will be greater. The Lake District.**

**Figure 20. Heavily grazed grass results in short root and shoot depths. This results in low levels of stability from the vegetation.**


**Figure 21. Fires are commonplace in the uplands and result in erosion, especially where stock remain present. Peak District.**

**Figure 22. Recovery from the clearance of bracken is slow, especially where grazing is still maintained.**

**Figure 23. Walking in the hills may result in the erosion of popular routes. The Lake District.]**

**Figure 24. Moorgrips erode vertically because of the action of water and laterally if grazing occurs. Yorkshire Dales.**