Management of Vegetation

PREFACE

Society creates structures and landscapes with enthusiasm, and allocates money and resources to them with a liberal hand, but it pays less attention to their subsequent management and maintenance, which often fall victim to economies of every sort. In the UK the landscape and the vegetation have largely been deliberately created by man, or have developed as an incidental result of his activities. The significant areas of natural and semi-natural vegetation that occur on land not used for productive agriculture and forestry are often managed on an *ad hoc* basis, or not at all.

It is the first proposition of this introduction that in a country so densely populated and with growing intensity of pressures for the optimum use of land, that the management of these non-productive areas, including the vegetation they support, should be the subject of much more attention, planning and management skills than they are.

In addition, many different central and local government bodies, public companies and private organisations control large areas of land, whose management for the primary landuse might be modified at little or no additional expense to benefit other interests such as amenity, wildlife conservation,recreation, and sport, where these are not themselves the primary landuse. The banks of motorways for instance are engineering structures, but coincidently the vegetation on them can be managed for amenity and nature conservation. In this way areas of land not directly used for agriculture and forestry (many of which however do occur on farmland or in forestry plantations) have a multiple use potential, and it is desirable that this should be taken into account in their management.

Management of land generally involves management of vegetation, and it is the management of this vegetation that was the primary concern of the meeting at Wye College. The planning and organisation of vegetation management operations vary widely, and it is probably fair to say that whilst some organisations go into the matter in a great deal of detail, others are less interested. In whatever way land and vegetation is managed, costs are involved at some stage or another, but it is often difficult to value the benefits in cash terms. Sometimes the costs of management are precisely budgeted for, and accounted for, but in other circumstances they are combined under general budgetary heads that include operations such as snow clearing and litter collection that conceal the actual costs of vegetation control, and so deny any assessment of what is actually being spent.

The benefits of managing vegetation for a primary landuse, such as an engineering embankment for a road or a water impoundment, where soil erosion, fire control, accident prevention, pest control or public liability might be the objective, can be calculated in terms of the costs of any of these events occurring. An income can also be derived from the management and use of land for other purposes, such as sport and recreation (spectator events, shooting, golf) and, here the benefits can be measured in terms of what the

public is prepared to pay. But, in other cases, where land is being managed for amenity or especially for wildlife conservation, the benefits have defied many attempts at objective valuation, so that the value to be put on these operations can only be judged in terms of income foregone by not managing for production (agriculture and forestry), or by measuring the additional costs incurred by not managing in the most economical way for the prime use of the land. Benefits but not in monetary terms, can be judged in terms of public response to an amenity, or by the public's actual use of an area; and in conservation terms by success in maintaining populations and communities of plants and animals. However, no generally acceptable method of accounting has been proposed that enables the value of these benefits to be compared with the costs of providing them. Yet money is a resource in exactly the same way as land and water, or any of the other natural resources, and the practicality of matters is such that natural resources cannot be managed without money. As a consequence, consideration of economic factors is as fundamental to the management of natural and semi-natural vegetation as it is to the practice of agriculture and forestry. However, the detailed analysis of costs and benefits (however estimated) of the management of non-productive land is often lacking, and evidence for this is apparent in the papers that follow.

Whilst money is one of the resources, the success (or benefit) of its use is measured in terms of the achievement of objectives. Objectives can only be reached by defining standards of management that satisfy them. Thus if the objectives of managing a woodland are amenity and conservation, these might be defined in terms of the structure of the wood (ground flora, under-storey and canopy), its species composition, and the distribution and the age classes of its components. On the other hand the standards for herbage by roadsides for the objectives of the highway engineer might be height of vegetation and control of scrub; or for the Country Park manager at picnic sites the control of nettles and thistles. In some circumstances it will be perfectly acceptable to do nothing and to let vegetation develop in its own way. Nevertheless this should be a positive management decision related to agreed objectives for the land in question, and taken with full understanding of the longer term ecological and economic implications. Too often areas are allowed to go 'wild' by default, with the result that expensive and destructive restoration programmes eventually have to be undertaken. Thus the objectives of management and the standards required to meet them need to be thought out, critically taking into account ecological factors such as the dynamics of development of vegetation and the growth patterns of the species involved.

It is therefore the second proposition of this introduction that ecology and economics should go hand-in-hand in the management of natural and semi-natural vegetation, and that the understanding and practice of these two should be basic skills for land managers. Further, that the importance of an understanding of ecology allows the manager to take advantage of natural processes at little expense, rather than try to oppose them at great expense.

Although there are many organisations, large and small, together with private individuals, who have an interest in managing land, the types of plant growth to be managed, the objectives, standards and methods of management are limited. At their simplest these can be set down as lowland and upland wetlands, grasslands, scrublands and woodlands; managed for functional reasons (prevention of fire, pest control, public liability), and additionally, or primarily, for amenity, recreation, wildlife conservation and sport; by mowing, grazing, burning, cutting, fertilising, draining, or spraying; using animals, hand labour, various kinds of machine, and chemicals.

These are matters that it was thought would be of interest to a meeting of senior representatives of national organisations that either own land or have responsibilities for managing it, or (like the Countryside Commission) have a statutory interest in its management, together with representatives of professional Institutes and Associations, advisors and research workers. In the event 76 delegates representing 53 organisations attended the meeting, providing an unique gathering of varied experiences and responsibilities. The speakers were provided with a brief in order to give a common framework to the papers, and were asked to consider in addition to the particular aspects of their own topics: the objectives and standards of vegetation management; economics; methods of management, successes and failures; problems; new developments and needs for research. The programme was arranged to provide time for formal and informal discussions. These proceedings record the papers and the formal discussions but unhappily the informal discussions, which probably included as much again of interest, cannot be presented. Nevertheless it is hoped that these proceedings of a meeting that was deliberately kept small in numbers to encourage discussion between all the participants, may act as a catalyst to provoke much wider discussion of the topic of the management of natural and semi-natural vegetation that is of importance, and has had too little attention paid to it.

J M WAY
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ACKNOWLEDGEMENTS

Thanks are due to the Institute of Terrestrial Ecology and subsequently to the Ministry of Agriculture for giving me the opportunity and facilities to organise the meeting, and to members of their staffs who helped me in so many ways. And again to the Programme Committee who turned a *pot-pourri* of ideas into a practical programme and provided encouragement at every stage. Mrs Rosemary Bishop and her staff at Frank Bishop Conference Planners, and Mr Alwyn Austen and the staff at Wye College used their considerable experience to muster the delegates and provide the domestic arrangements, which were, I think, thoroughly appreciated. Further thanks are due to the British Crop Protection Council for sponsoring the meeting, especially to Mr Dennis Higgons for advice at critical moments, and to Dr Ken Woodford the Managing Editor for help and technical advice in the production of these proceedings. I should particularly like to thank Professor John Fryer, Chairman of the Weeds Subcommittee of BCPC and Director of the Weed Research Organisation for the personal encouragement that he gave me right from the beginning, and the members of the Weeds Subcommittee for their support. I also wish to thank the speakers for all their trouble in the preparation of their papers in the hope that they will feel that this publication does justice to them. Also to the five Chairmen for so ably conducting the sessions, and to all the delegates who collectively made the meeting a success.

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The order in which the papers have been arranged in the proceedings is different to the programme at the meeting. Please see CONTENTS page. Addresses are given in the list of delegates.

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Chairman	I A M Lucas	The Principal, Wye College (University of London)
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SESSION 1		
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SESSION 3		
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SESSION 4		
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SESSION 5		
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SESSION 6		
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INTRODUCTION

The Ecology of Management of Vegetation

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Natural and semi-natural vegetation: what do we mean? I think I can do no better than reiterate what Tansley wrote in 1939 –

> "Over nearly the whole of England we have now only much modified remnants of the original covering of plants that had adjusted itself to the sub-Atlantic climate 2000 years ago; and the same is true of the "Highland zone" of the west and north of the British Isles up to a considerable height on the hills".

Thus, by implication very little of the vegetation can be defined as strictly natural.

> "Nevertheless much of the country is still occupied by communities of native plants, though no longer moulded by "nature" alone . . . . . This form of semi-natural vegetation is joined by a second category . . . . . of communities deliberately initiated by man for his own purposes, but consisting of native plants".

THE RESOURCES

But how extensive are these resources? To answer this question I have resorted to information provided by (i) Callaghan & Jeffers, and (ii) derived from surveys linked to a system of land classification evolved by Bunce. Callaghan & Jeffers (personal communication, 1980) indicated that 92.6% of the land area of Great Britain (England, Scotland and Wales) or 22.6 million ha, could be designated as rural. Of this area 13.5 million ha were regarded as being cultivated with 9.1 million ha having natural and semi-natural vegetation. The latter area, 9.1 million ha, was arranged in 4 subdivisions – (i) rough grazing, 6.6 million ha or 27% of the total land area of Great Britain, (ii) woodland, 0.6 million ha, (iii) inland water, 0.3 million ha and (iv) other semi-natural, 1.6 million ha (Table 1).

While giving a useful overall appraisal of the situation, these figures lack ecological detail. The manager of vegetation needs to know how the different

land-uses are geographically distributed and how they are related to environmental factors. Fortunately these questions can be answered, at least in part, by reference to the system of land classification (or habitat characterisation) which my colleagues in the Institute of Terrestrial Ecology, notably Dr R.G.H. Bunce, have recently devised making use of existing maps concerned with climate, topography and solid and drift geology and to some extent human artefacts (see Bunce & Last, 1981). For the central $1km^2$ of each of the 1,228 squares, individually measuring 15km x 15km into which Great Britain was divided, it was possible to obtain, from existing maps, the mean numbers of days with snow falling, the mean daily duration of bright sunshine, maximum elevation, the distances to the south coast (a measure of latitude and associated changes e.g. daylength), the presence of sand, boulder clay . . . . . and many more comparable pieces of information. These were then subjected to Indicator Species Analysis (Hill *et al*, 1975) which successively separated the 1228 squares (15km x 15km) into 2, 4, 8, 16 and 32 land classes, the decisions at each stage of the analysis being reached after considering a range of critical attributes (i.e. polythetic). For instance the first division depends upon (a) numbers of days with snow falling, (b) daily duration of sun, (c) maximum elevation, (d) distance to south coast, (e) height of hill behind and (f) length of minor roads. As can be seen from Fig. 1 land classes 1 to 8 inclusive are mainly, but not exclusively, located in Wales and the southern half of England with land class 1, the most abundant, accounting for 7.2% of Great Britain. Groups 9–16 are located in the Midlands and northern parts of England and Wales, land classes 25–32 are concentrated in Scotland while classes 17–24 range from Dartmoor in the south of England to the Shetland Islands in the north. As is obvious the characterisation of land classes 17–24 is dominated by high altitude which brings together the Welsh mountains, the Pennines of England and the Borders and Highlands of Scotland.

Land class 1, typical of the South downs of England, includes gently rolling country with moderate relief:

> with 93% at altitudes ranging from 0 to 198m, a slope of 3°, a mean minimum January temperature of 0.6 – 2.0°C, a mean number of days on which snow falls of 10–25, and a mean daily duration of bright sunshine of 5.6 – 6.5h.

In contrast Land class 32, typical of bleak and windswept areas of Northern Scotland and the Shetland Islands, has the following characteristics:

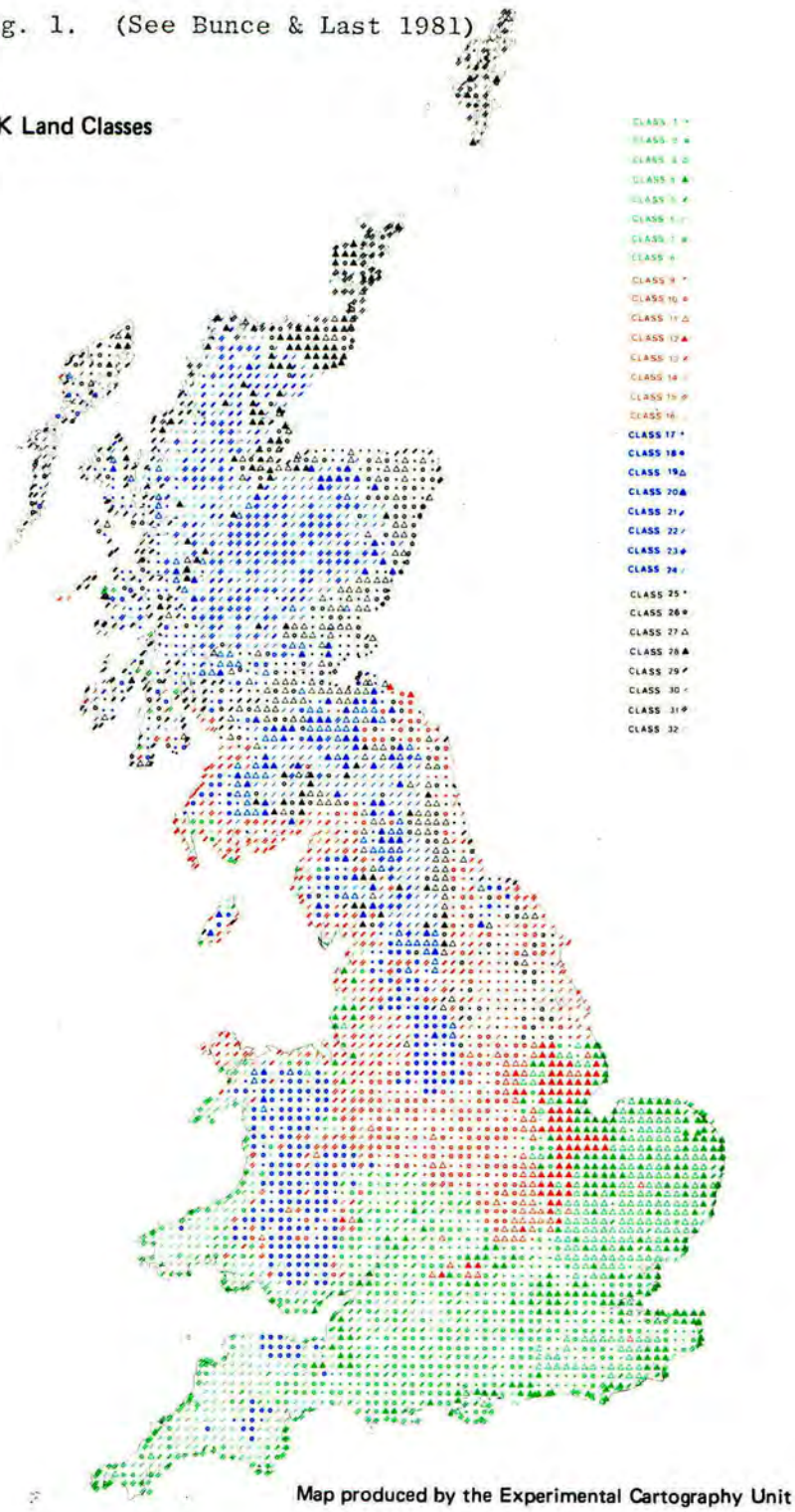
> 69% is at altitudes ranging from 0 to 76m, with a slope of 7°, a mean minimum January temperature of 0.6 –2.0°C, a mean number of days with snow falling of 41–55, and a mean daily duration of bright sunshine of 4.0 – 4.5h.

To enable a vegetation survey to be made, a similar approach was adopted by my colleague Dr Sargent to the classification of British Rail land adjoining the permanent way. Based primarily on altitude, climatic variables and a blend of soil and geological data, she separated 32 classes which were subsequently aggregated to 25 (Fig. 2).

Table 1
Areas in million ha of different land uses in Great Britain (England, Wales, Scotland) (after Callaghan & Jeffers, personal communication, 1980) (Percentages of total area of GB in italic type)

- **TOTAL** 24.4 *(100)*
  - Rural 22.6 *(92.6)*
    - Cultivated 13.5 *(55.3)*
      - Grassland 7.2 *(29.5)*
        - Leys 2.1 *(8.6)*
        - Permanent pasture 5.1 *(20.9)*
      - Arable 4.8 *(19.6)*
        - Cereals 3.7 *(15.1)*
        - Root crops and vegetables 0.7 *(2.8)*
        - Fallow 0.4 *(1.7)*
      - Forest 1.4 *(5.9)*
        - Coniferous 1.4 *(5.8)*
        - Coppice <0.1 *(0.1)*
      - Orchards <0.1 *(0.3)*
    - Natural and semi-natural 9.1 *(37.3)*
      - Rough grazing 6.6 *(27.0)*
      - Woodland 0.6 *(2.5)*
        - Broadleaved 0.3 *(1.3)*
        - Scrub etc 0.3 *(1.2)*
      - Inland water 0.3 *(1.2)*
      - Other semi-natural 1.6 *(6.6)*
  - Urban 1.8 *(7.4)*
    - Amenity 0.5 *(2.1)*
    - Other 1.3 *(5.3)*

Fig. 1. (See Bunce & Last 1981)



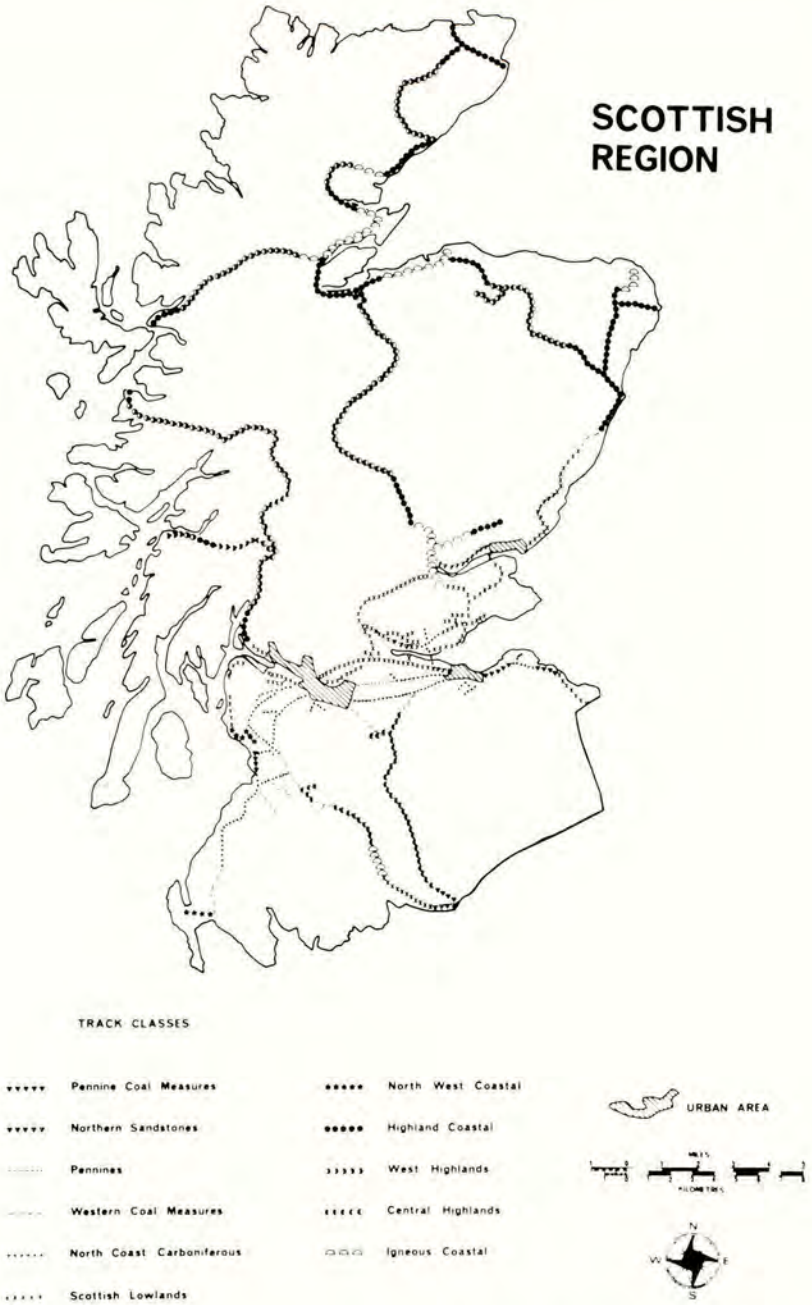


Figure 2. Map showing the location of different habitats, 'track classes', in the Scottish Region of British Rail where 11, of the 25 classes found in the UK, occur (Sargent & Mountford, 1980).

Reverting to the land classification of Great Britain: having divided the country into 32 land classes (or habitats) the next step was to make detailed surveys of randomly chosen replicate squares (1km^2) within each land class. Details were recorded of the occurrence of different breeds of cattle and sheep, of field boundaries, buildings . . . . . and, more importantly for our immediate purposes, the distribution of different soil types and the occurrence of different types of vegetation. Thus we know that 53% of the soils in land class 1 are brown earths, 25% gleys and 15% gleyed brown earths whereas in land class 32 peats are the predominant soils (55%) with the remainder (45%) being more or less equally divided among peaty podsols (8%), gleyed brown earths (8%), brown earths (8%) etc.

Something similar has been done with types of vegetation with, for the purpose of this talk, the 67 categories being arranged in 4 groups –

I Leys and permanent pasture (*Lolium perenne, L multiflorum, Dactylis glomerata,* Hay/silage, *Phleum pratense)*

II Crops (wheat, barley, potatoes, orchards, oil seed rape etc.)

III Woodland ('natural' and man-made, deciduous, coniferous and mixed, shelterbelts and scrub)

IV 'Natural and semi-natural' (*Calluna vulgaris, Pteridium aquilinum, Deschampsia flexuosa, Juncus effusus, Erica tetralix,* herb rich grassland etc.) (Fig. 3).

As can be seen (Fig. 1, Table 2), natural and semi-natural forms of vegetation predominate in the wet and hilly regions of northern Britain, occupying virtually the whole of land class 23 (generally high land with many steep and rocky slopes (North-east Highlands of Scotland)), and being more or less totally absent from land class 3 (almost flat plain with intensive arable farming predominating; some copses and hedgerows but usually few trees (East Anglia and central plains)).

I am very much aware that this contribution could become a catalogue but, with succeeding contributions touching upon 'natural' woodland, hedges and roadside verges, it is perhaps permissible to include estimates of their land occupancy (Tables 3 and 4).

The total areas of broadleaved, coniferous and mixed woodlands, given at the foot of Table 3, differ slightly from the areas estimated by Callaghan & Jeffers, but nevertheless the trends are obvious. Small areas of mixed woodland are sporadically distributed throughout Britain, whereas productive conifers are concentrated in the uplands, wherever they occur, and other locations in north and north-eastern Britain: most of the assemblages of broadleaved trees are found in England and Wales. It will come as no surprise to find that the lengths of hedgerows and roadside verges differ greatly in the different land classes (Table 4). The density of hedgerows (km km^{-2}) seems to be greatest in land classes 6 (South-west of England and Wales), 3 (East Anglia and Central plains) and 9 (Midlands and North Wolds of England) while they are virtually absent from the high, rocky and exposed areas (land classes 19, 21, 22, 23, 24, 29, 30,

Table 2
Proportions of different land uses in the 32 land classes within Great Britain.

Land class	Land class as proportion of total area of Great Britain †	Proportion (%) of the area of each land-class occupied by different vegetation types *			
		Crops	Leys and permanent grass	Woodland	Natural and semi-natural vegetation excluding semi-natural woodland
1	7.2	24	45	2	8
2	5.1	18	30	18	5
3	5.2	64	22	2	0
4	4.8	29	15	0	0
5	3.7	17	30	6	8
6	4.6	17	57	8	2
7	0.8	9	25	3	18
8	0.8	8	17	1	12
9	4.6	29	34	5	3
10	4.5	35	34	10	5
11	1.8	57	22	1	0
12	1.8	68	11	1	0
13	3.0	19	32	3	18
14	1.1	25	16	0	6
15	2.1	27	36	8	9
16	2.2	22	47	2	14
17	6.8	4	56	13	21
18	3.8	0	8	5	69
19	2.2	2	20	26	49
20	2.0	4	41	2	45
21	2.9	0	0	19	77
22	5.9	3	7	35	44
23	3.5	0	0	0	99
24	2.3	0	0	7	80
25	3.9	45	38	2	6
26	3.4	19	42	6	11
27	3.8	29	40	9	9
28	2.7	3	31	9	46
29	1.4	0	1	3	42
30	0.6	0	0	6	78
31	0.6	4	14	1	44
32	1.0	4	11	7	56

† Total land area of Great Britain, 23.3 million ha

* Across the table totals would add to 100% if areas of roads, railways, footpaths, bare rock etc. were included.

Table 3
Distribution (1,000s ha) of broadleaved, coniferous and mixed woodlands in Great Britain as related to land class

Land class	Types of woodland			Land class	Types of woodland		
	Broadleaved	Coniferous	Mixed		Broadleaved	Coniferous	Mixed
1	33	15	1	17	33	172	31
2	95	102	<1	18	7	38	1
3	10	<1	<1	19	<1	138	<1
4	10	<1	<1	20	3	2	1
5	71	30	9	21	6	128	<1
6	39	69	3	22	<1	478	7
7	<1	<1	<1	23	<1	<1	<1
8	2	<1	<1	24	11	36	<1
9	35	39	7	25	<1	<1	1
10	23	58	37	26	4	23	12
11	<1	<1	<1	27	18	82	2
12	11	<1	<1	28	<1	48	4
13	11	17	<1	29	9	5	2
14	1	<1	<1	30	<1	8	<1
15	21	9	24	31	<1	<1	<1
16	16	3	3	32	<1	15	<1

Total areas – c. 470,000ha, broadleaved
1,500,000ha, coniferous
150,000ha, mixed

31 and 32) of Scotland. Overall it is estimated that there are c. 810,000km and 930,000km of hedges and roadside verges occupying c. 160,000ha and 93,000ha or 0.71% and 0.41% of the area of the UK respectively. But, so what? There is virtually no end to the figures that my colleagues and I can generate, some of the estimates being more accurate than others. We could give the botanical details of the different hedgerow assemblages and types of roadside vegetation found in the different land classes and possibly these pieces of information could influence management procedures in predictable ways. But *surely we should be concerned with change?* As is well known the numbers of different species of shrubs and trees are good guides to the ages of hedgerows (Pollard *et al.* 1974).

ATTITUDES TO MANAGEMENT

In the last two or three years it has become only too obvious that we urgently need a *comprehensive method of monitoring our rural environment.* In the increasingly political and sometimes emotive 'field' of atmospheric pollution (including acid rain) we tend to deduce what occurs in rural areas from concentrations of pollutants measured in towns and cities – a less than desirable

Figure 3. Distribution of vegetation, natural and man-made, in Great Britain (Lawson & Callaghan, personal communication).

Table 4
Lengths and areas of hedgerows and roadside verges in different land classes within Great Britain

		Hedges			Verges		
Land class	No. km² in GB	Mean length (km)/km²	Predicted total length (km)	Predicted total (ha) area	Mean length (km)/km²	Predicted total length (km)	Predicted total (ha) area
1	16875	5.74	96863	19373	5.25	88590	8859
2	11970	3.94	47162	9432	5.50	65835	6584
3	12240	8.06	98654	19731	7.75	94860	9486
4	11379	2.28	25944	5189	2.50	28448	2845
5	8550	3.04	25992	5198	5.50	47025	4703
6	10845	10.61	115065	23013	7.25	78626	7863
7	1755	2.81	4932	986	3.50	6143	614
8	1901	1.20	2281	456	3.75	7129	713
9	10755	6.50	69908	13982	4.00	43020	4302
10	10440	4.87	50843	10169	6.00	62640	6264
11	4320	5.71	24667	4933	7.50	32400	3240
12	4230	5.13	21700	4340	4.25	17978	1798
13	7020	5.22	36644	7329	4.25	29835	2984
14	2538	2.37	6015	1203	3.75	9518	952
15	4815	5.05	24099	4820	5.75	27686	2769
16	5040	4.41	22226	4445	4.50	22680	2268
17	15750	4.43	69773	13955	2.00	31500	3150
18	8865	0.13	1152	230	1.50	13300	1330
19	5130	0.00	0	0	2.50	12825	1283
20	4590	0.02	92	18	3.75	17213	1721
21	6660	0.00	0	0	0.00	0	0
22	13680	0.00	0	0	0.50	6840	684
23	8235	0.00	0	0	0.00	0	0
24	5310	0.00	0	0	1.00	5310	531
25	9090	2.84	25816	5163	5.00	45450	4545
26	7830	2.91	22785	4557	9.25	72428	7243
27	8910	1.03	9177	1835	4.75	42323	4232
28	6210	1.00	6210	1242	2.75	17078	1708
29	3326	0.00	0	0	1.00	3326	333
30	1490	0.00	0	0	0.50	745	75
31	1332	0.00	0	0	0.50	666	67
32	2226	0.00	0	0	1.50	3339	334
Totals (rounded to 2 significant figures)			810000	160000		930000	93000

situation which, as far as acid rain is concerned, has been corrected by the establishment of a rural network of rain collectors in northern Britain. But we shouldn't adopt a restricted definition of "rural environment". We should be broadly concerned with changes in all forms of land-use. I suggest that repeated total enumerations of the replicate squares, 1km^2, already surveyed by Bunce and his colleagues, at intervals of 3, 4, 5 (?) years might effectively provide indicators of change enabling us to set events in land classes 1, 2, 3 . . . . against the overall perspective of Great Britain – we would be in a position to consider the implications of change. We are all aware of the continuing loss of hedgerows and the consequent depletion of wildlife habitat but how many of us appreciate that there has been a 30% loss of broadleaved woodlands in Scotland in the period from 1945 to 1975 (Parr, 1981) – we have been concerned with local details, tactics, rather than strategy; we have also been overridingly concerned with the *meritorious*, namely Nature Conservation Review grades 1 and 2, rather than the *ordinary*.

As a forester wishing to ensure that scientifically interesting assemblages are retained, as a tree improver concerned with the conservation of genetic resources and as a member of Society concerned with the maintenance of landscape, I question whether we always use the full range of arbiters for deciding what should or shouldn't be protected. We rightly get "worked-up" about the retention of sites graded highly in the Nature Conservation Review while accepting, often without demur, the loss of sites less prized in a strict conservation sense, but which in reality may have a much bigger landscape, aesthetic impact. But "Rome was not built in a day". However I think that it is now important to increasingly stress the value of the ordinary without minimizing the importance of conserving sites graded 1 or 2.

With Tansley's definitions of natural and semi-natural vegetation in mind, our attention usually first turns, when we are concerned with aspects of management, to nature conservation. In the *Nature Conservation Review* (Ratcliffe, 1977), it is indicated that –

> "Nature conservation in Britain should centre around the safeguarding, through statutory scheduling and appropriate control and management, of a fairly large number of key areas representing all major natural and semi-natural examples of important habitats with their characteristic and carefully selected communities of plants and animals".

Later on I want to refer to the distinction between conservation and preservation, but for the present I wish to press two points, one, the truthful statement made in the Review *viz.* that the Review relates to the intrinsic scientific or nature conservation interest of *known* sites and second, the early emphasis on the designated conservation of sites in the top two (1 and 2) of 6 grades. With the powers incorporated in the newly enacted Wildlife and Countryside Act (1981), it is hoped that the genuine inclinations of conservationists to embrace the "ordinary" in addition to the "meritorious", so safeguarding landscape, will be expressed.

In the Conservation Review, nine criteria are listed as guides to site selection – extent, diversity, naturalness, rarity, fragility, "representativeness", recorded history, position in an ecological/geographical unit and potential value. But what should be the objectives of conservation? Shouldn't there be an explicit reference to the conservation of genetic resources and in particular the range of variation within-species – the course of British agriculture and horticulture would have been vastly different had the wild sources of our domesticated plants, mainly originating from Mediterranean environments, not been available to us. Does our method of designating National Nature Reserves and Sites of Special Scientific Interest give us adequate 'cover' – I'm sure the answer is likely to prove to be "no". In the meantime it is desirable to extend our knowledge of ecotypic variation highlighted by the observations made on heather (*Calluna vulgaris*) by Grant & Hunter (1962) and Bannister (1978), and the common salt-marsh grass *Puccinellia maritima* by Gray & Scott (1980). When grown together (collaterally), heather from northern sites flowered sooner than plants from more southerly locations; collections of common salt-marsh grass from the west, of both Scotland and England, grew less than those from the east while Scottish populations produced plants with larger proportions of flowering tillers than English plants. Is it conceivable that ecotypic differences exist between silver birches (*Betula pendula*) growing in land class 2 (Long rounded slopes particularly associated with the chalk downs of south east England) and land class 22 (Rounded moorland hills of the Southern Uplands of Scotland)?

How do you as managers select your plants? Do you ever consciously think of their growth strategies, their responses to stress, disturbance and competitive exclusion (Grime, 1979)?

Although I suspect that most of you are practical managers I wonder if you have ever stopped to think about the relevance of nucleic acids, which your biologically inclined schoolchildren will know about, to the different plants that you manage, recognising that nucleic acids fundamentally control plant form and function. We tend to think of our plants as being annuals or perennials, members of the Ranunculaceae or Compositae but additionally it seems that we could classify them by the sizes of their nuclei, plants such as bluebell (*Endymion non-scriptus*), creeping buttercup (*Ranunculus repens*), sweet vernal-grass (*Anthoxanthum odoratum*), which start shoot expansion early in the season (March/April), having large amounts of nucleic acids whereas those starting late in the season (June) e.g. birdsfoot-trefoil (*Lotus corniculatus*), butterbur (*Petasites hybridus*) and rosebay willow-herb (*Chamaenerion angustifolium*), have small amounts. What is the ecological significance of these differing amounts of nucleic acid? Large amounts (= large genomes) seem to be associated with the capacity for early and rapid expansion of relatively short-lived shoots, formed in cold weather, whereas small amounts are associated with plants whose entire growth is more or less restricted to the summer season (Grime & Mowforth, 1982). For the future we may identify different populations of the same species by the amounts of nucleic acids within their nuclei.

VEGETATION DYNAMICS AND THE TOOLS OF MANAGEMENT

At this stage I would like to revert to the objectives of management: are they concerned with maintaining the *status quo* (preservation) or should they be aligned to conservation, always accepting that doing nothing could be a perfectly acceptable approach to management in some circumstances. But we shouldn't imagine that things will stand still. I would like to refer to the study of a detached part of the Salisbury Plain, namely the Porton Ranges on the Hampshire/Wiltshire border (Wells *et al.* 1976).

Table 5
Indicator plant species in chalk grasslands of different ages (after Wells et al. 1976)

Indicators characteristic of chalk grasslands less than 50 years old	Indicators characteristic of chalk grasslands more than 130 years old
Arrhenatherum elatius (Oat-grass)	*Asperula cyanchica* (Squinacy wort)
Acinos arvensis (Basil-thyme)	*Carex caryophyllea* (Spring sedge)
Anthyllis vulneraria (Kidney-vetch)	*Filipendula vulgaris* (Dropwort)
Agrimonia eupatoria (Common agrimony)	*Helianthemum chamaecistus* (Common rockrose)
Cerastium arvense (Field mouse-ear chickweed)	*Helictotrichon pratense* (Meadow oat)
Linaria vulgaris (Toadflax)	*Pimpinella saxifraga* (Burnet saxifrage)
Pastinaca sativa (Wild parsnip)	*Polygala vulgaris* (Common milkwort)
Potentilla reptans (Creeping cinquefoil)	
Silene vulgaris (Bladder campion)	
Vicia cracca (Tufted vetch)	
Vicia hirsuta (Hairy tare)	
Vicia sativa (Common vetch)	

It is part of the largest block of semi-natural vegetation in southern England, namely 16,190ha of chalk grassland, and was the focus of an important historical investigation of vegetation changes. By studying the Tithe Commutation Surveys (c. 1840), the Ordnance Survey of 1856/85, the Land Utilization Survey of the 1930s and other records, Wells *et al.* were able to identify the dates when different parts of the Porton Ranges were last cultivated. With this information, and records of the floristic composition of the different areas of grassland, they have been able to identify the successional stages in undisturbed chalk grassland listing 12 species that were characteristic of chalk grasslands less than 50 years-old, whose frequency thereafter declined, while 7 other species started to appear in grasslands more than 50 years-old (Table 5). In considering the management of the different assemblages within the Porton Ranges, do we wish to allow the 'young' grasslands to mature and if we do, are we taking steps to ensure that other new areas, which would not, in themselves, be considered to be particularly meritorious, are brought into the succession? On the other hand is it our declared intention to maintain the present *status quo*, preservation? But in either instance do we know sufficient to achieve our

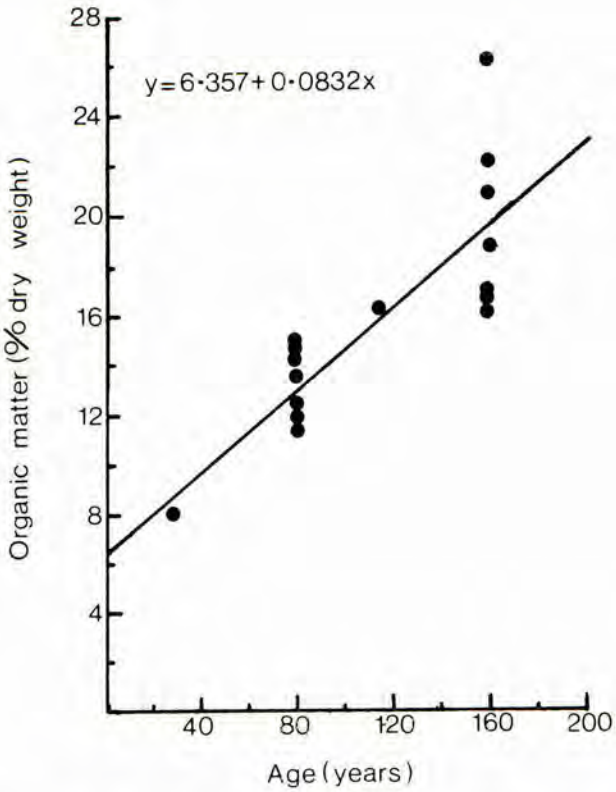


Figure 4. Mean percentage organic matter in the 0–10cm depth from chalk soils on seventeen transects on the Porton Ranges plotted against mean age of grassland (Wells *et al.* 1976).

declared objectives? In the time available to me I cannot possibly deal at length with plant succession but I would however like to reflect on the schematic relationship proposed by Wells *et al.* for the Porton Ranges (Fig. 5). Plant succession depends upon complex interrelationships in which soil nutrients have a major influence. As inferred in their scheme, nutrients progressively accumulate as swards get older. Wells and his colleagues found the proportion of soil organic matter was larger in old, than in young, grasslands (Fig. 4), the mean annual increment, 0.08%, being similar to that in chernozems (Kononova, 1966), but larger than that in Broadbalk wilderness at Rothamsted (Jenkinson, 1971). Further, Wells *et al.* found that the rankings of soil organic matter and an NPK index were directly proportional. Are these changes 'driving' the succession of plant assemblages or *vice versa*, a matter of great importance if we wish to preserve existing assemblages. What is the role of ants; although *Lasius flavus* feeds largely on aphids and coccids colonising foliage can we be sure that they are not 'driving' the plant succession? 14–16 ant mounds

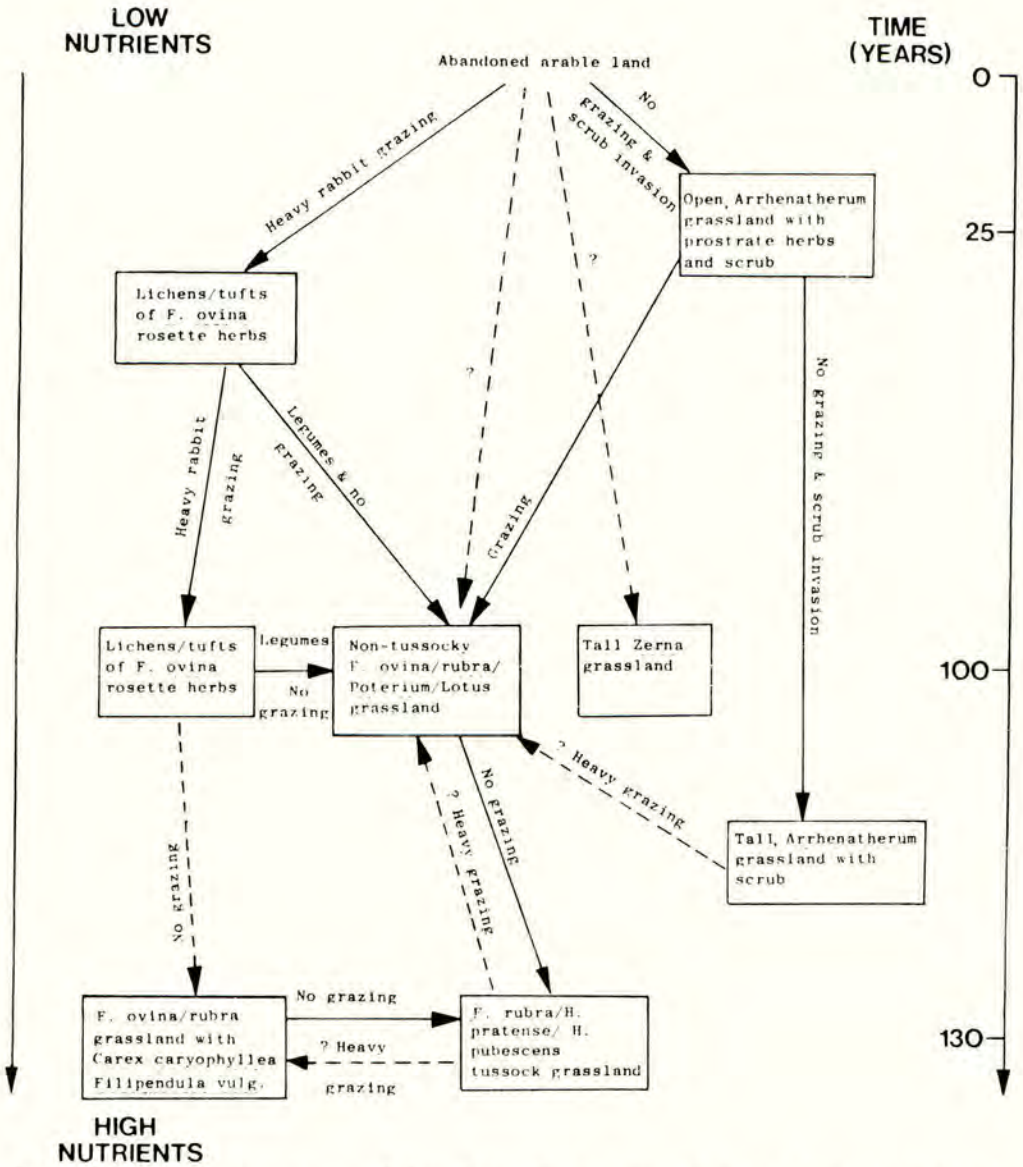


Figure 5. Schematic summary of the relationship between chalk grassland-types, management and soil nutrients (Wells *et al.* 1976).

per $6m^2$ were found in grasslands more than 100 years-old; <1 per $6m^2$ were recorded in grasslands less than 50 years-old. In addition to nutritional factors, the species composition of plant assemblages was strongly dictated by the activities of herbivores (primarily rabbits). Thus, open *Arrhenatherum elatius* grassland with prostrate herbs and scrub "progressed" to non-tussocky *Festuca ovina/F. rubra/Poterium sanguisorba/Lotus corniculatus* grassland if grazed,

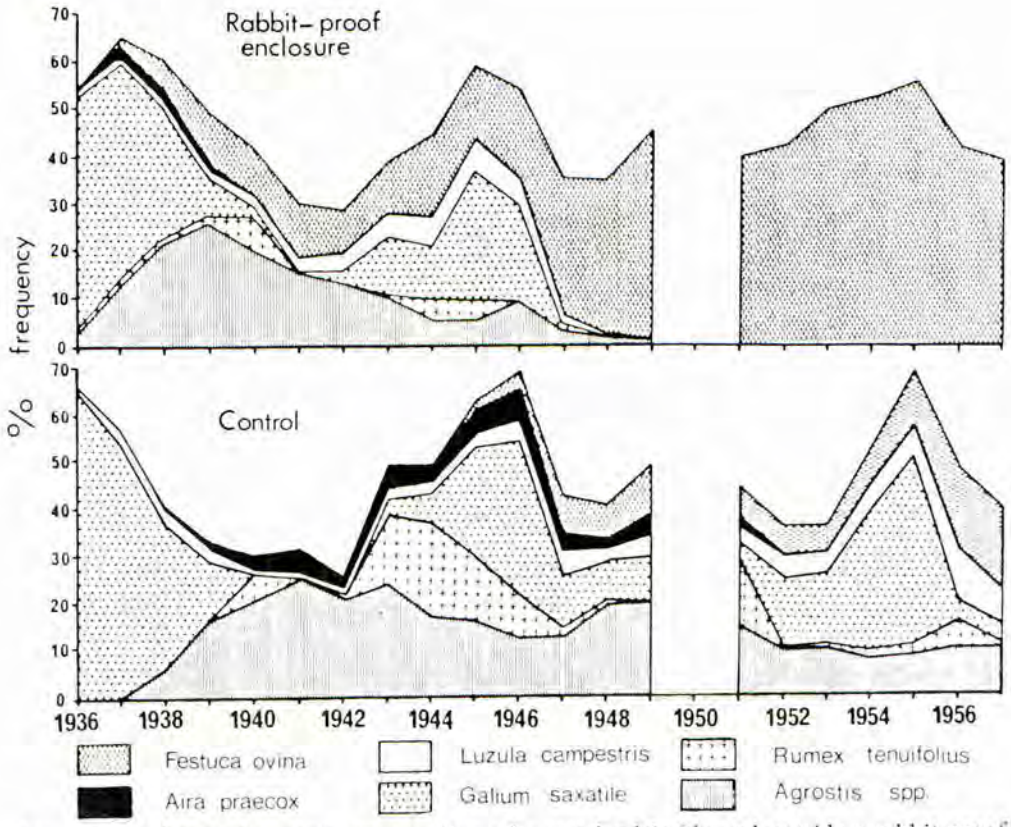


Figure 6. Changes in species composition of a grassland inside and outside a rabbit-proof enclosure in the English Breckland (Watt, 1960).

and to tall *Arrhenatherum elatius* grassland with scrub when herbivores were absent. Significantly most of the young stands of juniper (*Juniperus communis*) have developed since the outbreak of myxomatosis in 1954.

Despite the evidence for the effects of grazing I still think that we are reluctant to accept that herbivores play a probably overridingly important role in fashioning our vegetation. Most of us are aware of the classic set of circumstances described by Watt (1960) when an area of the English Breckland was protected from the damage done by rabbits. The exclusion of rabbits very soon favoured the build-up of *Festuca ovina* to the more or less virtual exclusion, within 12 years, of all other plant species. Watt's observations also served another purpose, namely to highlight the annual variations with strong seasonal differences in the amounts of *Aira praecox*, *Galium saxatile* and *Rumex tenuifolius* (Fig. 6).

As a forester I might be expected to say a few words about the impact of grazing by deer and squirrels on the growth and regeneration of our native woodlands. However, I can't attempt to be comprehensive and for this reason I have decided to turn instead to the management of unenclosed rough grazings

for hill sheep, viz. blanket bog (*Calluna/Eriophorum/Trichophorum*), dwarf shrub heath (*Calluna*), grass heath (*Nardus/Molinia/Deschampsia*) and acid grassland (*Agrostis/Festuca*), all of which have strongly seasonal cycles of production with 75% of their annual biomasses being produced in 6 – 8 weeks in the early part of the growing season (Newbould, 1981). While I might wish to argue that the land occupied by these assemblages might be advantageously converted to the production of timber, my colleagues at the Hill Farming Research Organisation would wish to press the argument in favour of sheep (Newbould, 1981).

> "Many tonnes of utilizable dry matter are available in a relatively disease-free environment on relatively cheap land of which significant parts are improvable . . . . . In fact if all available knowledge was applied, one is led to believe that the major limitations to overall production are not climate, plant species and soil fertility but the availability of expanding markets" (Cunningham, 1980).

But what is the available knowledge that is not being applied fully? It is the need to establish improved areas of grass to provide the quality of feed to ensure that the nutritional requirements (i) of ewes during lactation and (ii) for body weight recovery during the summer, are met. But this recommendation doesn't lessen the need to rigorously manage the rough grazings. It is well known that recently burned patches of moor, bog or heath are grazed in preference to unburnt vegetation. However, if the burnt area is too small, grazing pressures may become too intense with subsequent irreparable damage. Similarly if the heather is too old when burnt it may be killed, being substituted by purple moor grass (*Molinia caerulea*) and deer-grass (*Trichophorum cespitosum*) which, because they die-back in the autumn, don't provide winter grazing. Obviously there is a delicate balance to be observed regarding the frequency of burning and the mosaics of burnt and unburnt heather in relation to each other and to reseeded areas, remembering that heather, but not reseeded grass, provides sheep with their essential trace elements, notably cobalt.

I don't think that I can overemphasize the role of grazing or simulated grazing as a management tool – it can have, however, some surprising side-effects which are worth mentioning as they have an impact on the cycling of nutrients. In recent years there has been a move to add white clover to improved grass swards. If, however, these swards are frequently defoliated to less than 3cm above ground, nitrogen fixation, by legume nodule bacteria, is greatly curtailed with roots and nodules simultaneously disintegrating with the release of 'nodule' nitrogen (Chu & Robertson, 1974). On the other hand 'moderate' defoliation (infrequent, with herbage cut to no less than 5cm) favours the clover component of the sward, the greater amounts of available light maximising clover productivity.

Having described the resource of natural and semi-natural vegetation it seems ironic that I, a forester by adoption, should be asked to consider its management, foresters being the main consumers of natural/semi-natural vegetation.

Why not afforest it? A glib suggestion but one that gives me an opportunity to stress the potential importance of atmospheric pollution when considering land management. In 1980, Harriman and Morrison found, in minicatchments in the head waters of the River Forth, that streams draining areas afforested with Sitka spruce (*Picea sitchensis*) were more acid than those from unafforested minicatchments (Fig. 7) with amounts of aluminium (200μg l^{-1}) and manganese (90μg l^{-1}) being doubled. Interestingly this effect on water quality, which didn't appear for some years after site preparation and planting, has been associated with a decrease in the diversity of benthic invertebrates, particularly mayflies, but not their biomass. Elsewhere a diminuition in plant diversity has been observed with effects on phytoplankton, mosses and aquatic macrophytes. Further, and very importantly, fish are no longer to be found in the acidified streams, a story very reminiscent to those of us familiar with the acid rain story in Scandinavia and North America (Last, 1982). While many steps in the jigsaw remain to be solved, it seems that evergreen conifers are efficient concentrators or pollutants. At a site not more than 80km from that studied by Harriman and Morrison, Nicholson and his colleagues (1980) found, in a stand of Scots pine (*Pinus sylvestris*) that the average pH of throughfall was 3.7 compared with 4.2 for incident rain, a x3 increase in acidity; in stemflow the pH was 3.3, an increase of x8. Acid rain is not a local problem – it is widespread. We know that rain on the eastern seaboard of Scotland is more acid (pH 4.2, 60μ equiv. H^+ l^{-1}) than that on the north-west (pH 4.7, 20μ equiv. H^+ l^{-1}) (Fowler *et al.* 1982). Our records for England and Wales are less complete (Barrett *et al.* 1982) but we shouldn't be carried away by a consideration of pH *per se*. Instead it seems that quantities of hydrogen ions deposited (Kg H^+ ha^{-1}) are of more significance. Thus, by integrating pH and amounts of rain, it seems that the largest H^+ inputs are received in parts of Cumbria (the Lake District) and the Southern Uplands and West Central Highlands of Scotland. This being so, it may become desirable to question the appropriateness of afforestation in those localities where acid rain is falling on inherently acid soils, a decision that would have obvious relevance to the management of rough grazings, heather moorland and freshwater ecosystems. Setting aside this 'special case' the management of aquatic plants is primarily concerned to ensure the efficiency of systems of land drainage with the removal of excessive, but not the total elimination of, plants from ditches and rivers. It is desirable to manage aquatic weeds to ensure effective drainage while maintaining habitat for aquatic animals, notably fish. It is essential to avoid the pitfall of creating deleterious decreases in oxygen concentrations and for this reason the recent development of spot herbicide treatments with diquat formulated with 3% alginate is to be encouraged (Barrett, 1981). Although we have had local problems with the introduced Canadian pondweek (*Elodea canadensis*), they have never reached the intensity of that posed by water hyacinth (*Eichornia crassipes*) in tropical and sub-tropical regions. In those regions a great deal of effort is being devoted to methods of biologically controlling water hyacinth, alligatorweed (*Alternanthera philoxeroides*) and others using fungal pathogens

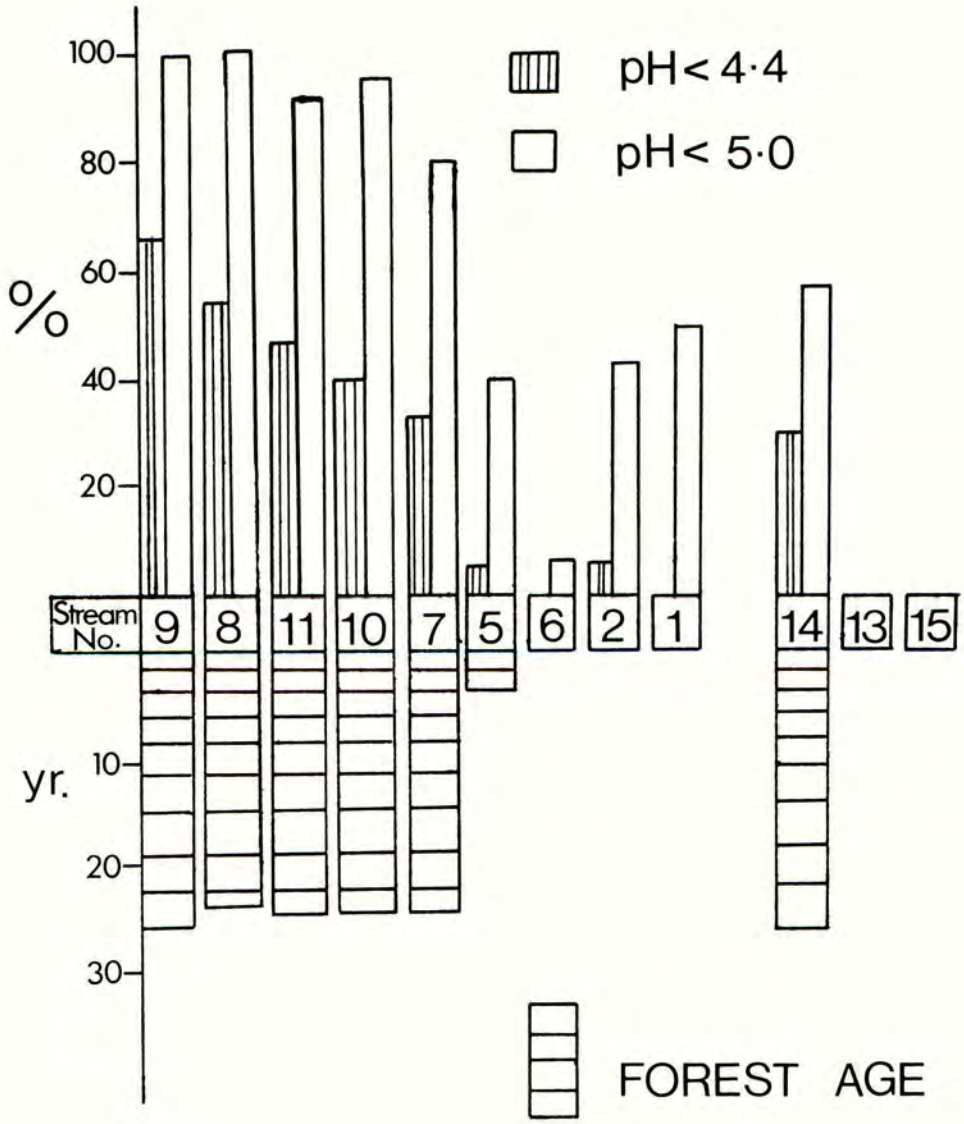


Figure 7. Relation between pH of freshwater streams and age of adjacent Sitka spruce plantations in minicatchments in the Duchray and Loch Chon catchments (Harriman & Morrison, 1980). (Annual deposition of hydrogen ions 0.6–0.8kg ha^{-1}).

(see Last, 1981) whereas interest in biological agents of weed control in Britain are centred on the possible exploitation of the grass carp (*Ctenopharyngodon idella*). By being herbivorous this fish can fill an unoccupied niche in British freshwater ecosystems, presumably with the minimum of disturbance (Robson, 1977).

Nobody today can be unaware of the "energy crisis". Are there ways in which natural and semi-natural vegetation can be managed to contribute to our supplies of energy without drastically changing the landscape? Desk studies and field experiments done by colleagues at Merlewood Research Station (Callaghan *et al.* 1978, 1981*b* and Lawson *et al.* 1980) suggest that bracken (*Pteridium aquilinum*) could become a natural energy crop. "It occurs over much of Great Britain; it gives large yields of dry matter in generally poor environments; it could be harvested immediately without costly cultivation and its harvesting would not significantly alter the use, amenity value, conservation role and landscape quality of the areas where it currently occurs". Very little is known about the longterm stability of bracken yields when subject to different harvesting regimes. Delaying harvest from summer to autumn is likely to decrease biomass yields from 9t (dry matter) ha^{-1} to 4.7 to 7.9t ha^{-1}; on the other hand it is likely to greatly decrease the removal of N, P and K whose tissue concentrations are maximal in the summer (Callaghan *et al.* 1981*a*). *A priori* it would seem, therefore, that summer harvesting would lead to ultimate extinction if for no other reason than nutrient exhaustion. In contrast harvests in the autumn are likely to ensure that the resource would be maintained. But, of course, the different harvest dates would yield materials of different sorts, the senescent material harvested in the autumn would probably be burnt directly or gassified to methanol whereas biomass harvested in summer would be digested anaerobically. Thus management practices, in this instance dates of harvest, are likely to have profound effects on the selection of conversion processes.

To some, this may seem fanciful, but is it, or will it be, in years to come – WASTE NOT, WANT NOT. Callaghan and his colleagues (1981*a*) made the following calculations for a northern farm measuring 100ha (Table 6).

Of course all sorts of criticisms can be thrown at these figures, but can we truthfully say that we have considered all the options available to us. Remember that there are 3,200km^2 of bracken in Britain not to mention the area of heather. Can they, or part of them, be used to minimize the energy problem in some districts of Britain without endangering or radically altering the landscape. Is it conceivable that attempts to sustain bracken yields for energy conversion are likely to be more rewarding than pasture improvements by its elimination. If not today, how about 5 years hence? Are there other candidate species?

At the beginning of this paper I referred to Tansley's definitions of semi-natural vegetation including "communities deliberately initiated by man for his own purposes, but consisting of native plants". With interest heightened by the inexorable decline in floristically rich and attractive grasslands, there has been recent interest in enriching newly formed grasslands. As is apparent there are

Table 6
Possible energy yields from the natural vegetation of a 100ha farm in northern Britain (Callaghan et al. 1981a)

	Area (ha)	Yield (t/ha)	Energy (TJ)	
Energy yield				
Dense bracken	20.7	8	3.48	
Sparse bracken	5.6	2	0.24	
Heather	17.2	1	0.31	
Scrub	9.2	5	0.83	4.86
Less				
Harvesting energy (300MJ/ha)			0.03	
50% conversion inefficiency			2.43	2.46
Net energy yield				2.40
Energy use on cattle and sheep farm (Fuel and electricity at 7.65GJ/ha)				0.36
Percentage energy self sufficiency				670%

many opportunities, for example the grasslands sown specifically for amenity in Country Parks, the verges of motorways and other roads, the areas requiring vegetation to ensure soil stability. Many of these opportunities have, however, been missed either by default or because the specialist amenity market was not considered sufficient to warrant the inputs needed to ensure dependable supplies of seeds. Times, however, are changing. Wells *et al.* (1981) enumerated the following criteria for species that may be considered:

i They should be regular members of grassland communities.
ii They should not be rare.
iii They should be relatively abundant in a variety of grasslands and preferably have a wide distribution in the British Isles.
iv They should be perennial, preferably long lived and with an effective means of vegetative spread.
v A high proportion of the species used should have colourful flowers, and these should preferably also be attractive to insects.
vi Highly competitive and invasive species, known to form single-species stands in the wild, are to be avoided e.g. *Brachypodium pinnatum*, 'Heath false-brome'.
vii Seed of these species should germinate readily over a range of temperatures and without special treatments to break dormancy.

Wells and his colleagues were also very much aware of the need to avoid tall growing species that might obscure roadside sighting lines. In the event their work has encouraged the development of many mixtures including, among others:

Anthyllis vulneraria (Kidney-vetch),
Chrysanthemum leucanthemum (Marguerite),
Galium verum (Lady's Bedstraw),
Hippocrepis comosa (Horse-shoe Vetch),
Lotus corniculatus (Birdsfoot-trefoil),
Lychnis flos-cuculi (Ragged Robin)
Primula veris (Cowslip).

Development has been rapid during the last few years with the requirement for a nurse crop being identified, for example Westerwolds rye-grass (a form of *Lolium multiflorum*) which germinates quickly and then dies back to allow the other sown species to establish themselves. Mixtures for different soil types e.g. heavy clay, limestone and alluvial, have been detailed but much remains to be done to increase precision and predictability. How should management practices be evolved to minimize the element of undesirable plant competition; are some species more difficult to handle than others, etc.? Is it possible that the future exploitation of short-herb mixes will parallel recent developments in agriculture where permanent (*Fustuca rubra/Agrostis* spp./*Poa* spp.) grassland has been enriched (in terms of quantity and quality (digestibility)) by the introduction of seed of perennial ryegrass (*Lolium perenne*) cv. Melle using a slot seeder (see Haggar & Squires, 1979 and 1982)? Would such a technique be appropriate for the introduction of short-herbs into amenity grasslands – a possibly fertile field for future experimental work bringing together agricultural developments and amenity interests. The possibility of tackling comparative studies with the agricultural white clover and the amenity birdsfoot trefoil, also a legume, appears attractive.

CONCLUDING REMARKS

Recognising that many of the succeeding contributions would deal in detail with the management of specific types of habitat I decided to range widely, choosing examples that illustrate many of the interacting facets that should be considered by managers. Essentially *ecosystems*, unless they refer to climax vegetation, *are dynamic* – it is "un-natural" for successions to be halted. In thinking about the role played by grazing or simulated grazing, when used as a management tool, reference was made to effects on the (i) *cycling of nutrients* and (ii) *competition between plant species.*

Based upon a series of land classes which reflect different ecological niches, the nature of the resource of natural and semi-natural vegetation has been elucidated. Although an enumeration of different land-uses linked with the distinctive environmental characteristics of different land classes is of value, this value would be greatly enhanced if *enumerations were to be repeated* at intervals so as to assess change. Such an approach would fulfil one of our major requirements, namely a *system of rural monitoring.*

In the past, attention has been focussed on the conservation of 'meritorious' examples of different plant assemblages; to ensure that our landscape is conserved it is recommended that more *attention* is *devoted* to the *'ordinary'*. The *conservation of genetic resources*, particularly within-species variants, should be an overt objective.

The management of natural and semi-natural vegetation does not preclude the *judicious exploitation of native plant species*. There is evidence to suggest that bracken could be a locally useful source of fuel, while many species of short-herbs could, with advantage, be sown to provide colour where the value of the sward is not judged by the yield of nutritious foliage.

In conclusion I would like to leave a series of keywords which should help to focus attention upon important facets of the management of natural and semi-natural vegetation – *resource, monitoring the rural environment, management objectives, temporal changes, competition, growth strategies, plant nutrition, grazing, energy* and *species diversity*.

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ESTATE MANAGEMENT and ECONOMICS

General Requirements for the Management of Vegetation

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I speak to you today as a Chartered Surveyor who has been associated with the management of large country estates for some 25 years or so. I have been concerned with the management of the large estate or the large farm, generally in the ownership of an individual or Trust although latterly I have been associated with the management of in-hand farms in the ownership of the Institution or Pension Fund.

It is axiomatic therefore that I must speak to you as an Agent for the private owner or major landowner. I cannot speak for the Statutory Authority or Government Agency, many of whom exercise control over large tracts of land. Nor indeed can I speak for the conservation lobby because I have no experience in serving those organisations other than in the field of negotiation for rights over a private estate.

In endeavouring to establish the general requirements for the management of vegetation there must at times be conflict between the owner and the conservationist. Interests are diverse and objectives varied. The art of compromise must prevail. It is on the problems of trying to reconcile these views that I address you today.

In the first instance let us consider the requirements of the landowner himself. He or she will have acquired the land by inheritance, gift or purchase. The unimproved grazings, meadows, dykes or ground cover will inevitably form part of a larger and much more intensively managed unit. Unless the owner is affluent or philanthropic, he will inevitably look for some sort of a realistic return from his property. Furthermore, the pressures to secure a return will be onerous, costs in all enterprises on the estate will have escalated, inflation will have taken it's toll and we have not seen a similar increase in terms of income.

On the contrary, the returns from the forestry enterprise at the present time are extremely low, margins on livestock enterprises have been squeezed, the returns from arable farming have been reduced and returns from House Showing (where applicable) appear to be in decline. Thus, it is not difficult to see that the large landowner has been under pressure to utilize all his resources to the full.

Let us now consider the requirements of the conservationist. He or she will be anxious to conserve and to effect management to preserve the natural vegetation of unimproved grazings, meadows, vegetation and so forth. This anxiety will not be subject to the pressures of a requirement to balance the books or to hold a property intact without recourse to sales for capital monies. The disciplines will be very straightforward, namely to preserve and conserve land with it's natural vegetation – not for the conservationist the problems of taxation or the problems of the maintenance of the whole estate.

The requirements are indeed diverse for if we are effectively to secure a successful management of natural vegetation then there has to be a meeting of the ways and an acceptance of, and respect for, the wishes of both parties. Fortuitously in different ways all parties share an inherent love of the countryside, a respect for stewardship and a desire to improve the heritage for the next generation. There are exceptions but I think the majority would accept my premise.

What are the general management requirements? In the first instance we must identify the parcels of land. In so doing we must be quite clear as to the area to be preserved, the reasons for the preservation and agreement as to the special dictates of management required. It is important in designating areas that owners are aware of the special needs of management and the need for conservation. Owners object most strongly to large tracts of land being designated as areas where normal commercial management is not acceptable and their own powers are restrained. In an age where preservation and conservation have become so cherished excessive zeal in requirements for conservation has done much to hinder the relationship between the landowner, the farmer and the conservationist. Better that a smaller area be managed well after a full and adequate discussion with the owner rather than to see conflict and subsequent neglect of management over the larger area. Goodwill on both sides will achieve so much. Identification of parcels of land be they hedgerows, unimproved grazings or dykes is therefore of paramount importance.

I would make a plea for understanding. Here I am looking for an acceptance and respect of the owners position and that of the conservationist. It is important that an owner should be made aware of the necessity to employ special managerial skills to particular areas of his property. The advantages of such a management application will not always be of immediate or financial benefit to the owner but the longer term benefit to the estate and countryside in particular will be immense. Owners will respond just so long as they feel that the demands of such a management are not unreasonable and that there are very special reasons for the management of these unimproved areas. The conservationist or advisor will in turn have to accept and respect that the owners and occupiers of land must make a living, that unimproved grazings or similar make little or no direct contribution to the estate or farm. However, with a measure of understanding on both sides I feel that an agreement by way of a compromise will be achieved.

In areas of unimproved grazings or herbaceous and woody vegetation the flora or fauna, particularly if there are rare species, might well be of interest to the general public. Access is therefore of prime importance. Information irresponsibly relayed to the media might well result in large numbers of people visiting a site and the management of an area of natural vegetation can be damaged or destroyed in a very short time. Natural vegetation lends itself to a habitation by wildlife and nothing is gained by over-promotion in the media. Owners do not welcome hoards of people visiting their estates or farms and the control of access is a major consideration.

I would suggest that if these areas are to be managed and preserved effectively it is essential that the owner should seek advice on techniques of management. Objectives of that management will have to be defined. The management of the unimproved areas must be reconciled with the more intensively managed parts of the estate. Management of the unimproved areas will be equally demanding and will exercise disciplines of techniques beyond the normal management of the estate or farm.

The staff on the estate or farm must be aware of the management needs of the hedgerows and unimproved vegetation. The requirements of such areas must be fully explained. In a similar way staff must be advised that treading with vehicles or the poaching of land by livestock can cause considerable damage. Ill considered drainage schemes on adjacent land may well affect the natural vegetation of unimproved grazing or woodland. The misuse of fertilisers and sprays on adjacent land may well occasion irreparable damage to such areas. For instance drift from spray applicators in high winds can be a major problem.

If the staff are made aware of the problems they will usually respond. There is no doubt that the management of such areas will occasion difficulties. Communication and education are of major importance. I recall one estate on which I enjoyed management responsibilities and which enjoyed at one time a good reputation for a partridge shoot: the property was well endowed with grass banks either side of the numerous roads. In an effort to improve the shooting we adopted a policy of not cutting the grass banks until after harvest and no sprays were utilized in close proximity to the banks. The net result was that the partridge shooting improved, but only to a degree, we had a proliferation of well grassed banks with an abundance of wild flowers and weeds and worst of all an encroachment into the fields of sterile brome! So much for the management.

I would suggest that the management should be monitored. Nothing will be achieved by ignoring these particular areas. Regular inspections should be made to see that fences are in good order, hedges cut as required, ditches cleaned and maintained and the areas generally meeting the objectives of management. Regular meetings of all parties will help – there is a constant and ongoing requirement for monitoring management.

However we must ask just what are the objectives of management: the owner of the large farm or estate will be looking for a return from the intensively

managed part of the estate and, subject to the adequacy of that return, may well be prepared to accept that other parts of the estate will contribute little or nothing to the profit and loss account. Such areas of necessity will centre on hedgerows, unimproved grazings, road and rideside verges and other areas that are not cropped.

These areas can make a positive contribution to the amenities of the property and thus to the capital value of an estate or farm although by their very nature they have a limited use and thus will make only a minimal financial contribution.

Finally there is the situation on the larger estates or farms where the immediate management has been taken out of the hands of the owner. We have seen already that the increased financial pressures on landowners and farmers has necessitated further intensification of land use and with it a greater pressure on the appearance of the countryside. This agricultural change has been accompanied in turn by the upsurge of an increasingly vociferous group of conservation bodies with their own proposals for the protection and management of the countryside ranging from planning controls to outright purchase of the land. Between these extremes falls the management agreement. This is a relatively recent innovation which has attracted considerable comment be it favourable or otherwise. I think it is a fact that following Lord Porchester's 'Study of Exmoor' these agreements have become the principal means by which the shrinking acreage of moorland on Exmoor has been maintained. The Halvergate Marshes in Norfolk were the subject of considerable heated and at times acrimonious debate where it was suggested that annual payments of up to £80.00 per acre should be paid to farmers as compensation for fore-going the benefits of improved drainage.

Agreements can be costly, but they do appear fundamental to Government thinking in terms of the conservation of the countryside and indeed form an important part of the Wildlife and Countryside Act. However by definition a management agreement must be an arrangement between an owner of land and a public body under which the owner will accept reservations, restrictions and obligations upon the management of his land in return for a compensatory payment. Nothing could be calculated to upset a landowner or farmer so much as the hint or threat or indeed the imposition of reservations and restrictions on the management of his land for the benefit of the community at large.

It is a bitter pill for the owner or farmer to accept and whilst every consideration has been given to the payment of compensation this is more often than not insufficient to appease the owner or farmer against the loss of total control over his own land. However, management agreements are here to stay and under the Wildlife and Countryside Act 1981 Section 39 wide powers are given to county and district planning authorities to make them. The aim can be for the conservation or enhancement of the natural beauty or amenity of land or the promotion of its enjoyment to the public. The conservation of natural beauty is widely defined by the Act and embraces flora, fauna and geological and physiographical features. Furthermore, there are positive powers to restrict

agricultural operations. The agreements will be binding on successors in title unless they state otherwise and owners should wherever possible ensure that his interest will be free of this continuing encumbrance. Furthermore, the 1981 Act either offers agreements to owners who are refused a Ministry of Agriculture capital grant in a National Park or other designated area. Compensation for these agreements must be calculated in accordance with ministerial guidelines. The Nature Conservancy Council has powers under Section 15 of the Countryside Act 1968 for the protection of sites of special scientific interest. An amendment under the Wildlife and Countryside Act formalises the use of these agreements for nature reserves where another agreement has already been made (Section 72 (8)). There is no doubt that there has been a marked increase in the use of Section 15 agreements as confirmed in the Annual Reports of the Nature Conservancy Council from 1973 onwards. Finally under the National Parks and Access to the countryside Act 1949 Section 64 there is provision for an access agreement to be made by a planning authority to allow public access to 'open country' which by definition can consist of mountain, moor, heath, down, cliff or foreshore. Provision is again made for payment of compensation.

Landowners and farmers must appreciate that there are now principal powers to make agreements for the conservation or preservation of certain features of the countryside. The reconciliation of opposing views – often so very strongly held, will not be easy. Nonetheless by a measure of understanding by both parties some form of compromise will be necessary and is feasible. All parties must try and make them work because, given the adequate funding, management agreements are here to stay. The management agreements will however relate only to those parcels of land where the sites are generally to be of very special or scientific interest. There will remain many, many areas of open space often in the form of roadside waste, odd corners of fields, tracks and rides or even woodlands where a management agreement will not be made nor indeed is one required. It is to those areas where in my opinion the owner must devote some of his energies and expertise in maintaining the existing vegetation. Alternative uses will present themselves to an owner but it is my experience that if the vegetation will not stand the treading from the feet of the general public, and if you try to generate income from these parcels, then sooner or later people will be involved. It is to control the numbers and of necessity to restrict the access which will make the demands on management.

I have spoken deliberately on the question of generalities of management. I have not endeavoured to encroach on the papers to be presented by the other speakers. They will have the expertise and special knowledge available to them to deal with specific managements. As a Land Agent I feel it is one of my duties to try and reconcile the wishes of the owner and conservationist.

It is a daunting challenge but if we readily identify the areas, achieve some objectivity in management and secure good communications then I feel that effective management of natural vegetation can be accomplished. The management agreement proposed by the Nature Conservancy Council or a Local Authority need not be too difficult for an owner to accept if prior to securing

the agreement every opportunity has been taken to understand and respect the points of view of both parties. If the conservationist has not been too zealous and avaricious or the owner too conservative then management agreements can be made to work. Owners will never completely enjoy them but at least the owner will be relieved of his management responsibilities and in theory will be recompensed for the loss of his interest. However, how much better if both parties can agree a basis of management between themselves without recourse to formal documentation. That must remain the course to be followed.

DISCUSSION FOR MR CLEGG

Dr. Holdgate May I make a plea that we recognise that this meeting is not just about the management of semi-natural vegetation for wildlife. As Professor Last pointed out, when we talk about such semi-natural systems we are talking about 37% of the surface area of the country. Mr Clegg's paper discussed the problems of managing such habitats in the lowlands, but most of this vegetation is in the uplands. There we are talking about how management, enlightened by ecological science, can be more cost effective, yielding useful crops to the community in the form of sheep, deer, grouse – or even bracken – in a fashion that does not destroy either the attraction of these areas for the tourist, or those parts of them that are of high scientific interest.

The challenge is much more substantial than the resolution of conflict over parcels of semi-natural land in the intensively managed lowlands, important though that may be.

Mr Cobham I was rather surprised that lowland habitats and non-farmed areas were virtually dismissed by the speaker as only making a minimal financial contribution through generating income, either by way of habitat or cover for game, timber production, recreation, or shelter for crops and livestock. It is all too easy to polarise attitudes and say that such and such an area should be for production, and such and such another area for conservation, whereas really in the lowlands (as in the uplands) we need to be looking at the use of the land in an integrated manner.

Mr Clegg (Speaker) In fact income generated from these areas has been very limited, and this is one of the difficulties. I would like to ask you (Mr Cobham) for a bit more elaboration on how you see the income potential from the areas you mention. I don't frankly see it is a particularly large one, and I don't think it is a major contributing factor to the future well-being of an estate.

Mr Cobham In connection with sport, well managed cover is important, be it for rough shooting or for game. Even on unmanaged shoots some income can be generated from casual sporting days, at least to the point of making a contribution to the cost of management. There may not be a profit, but we should be looking at all possible ways, however small, of making a contribution to costs. In connection with timber, scrub oak can, for example, be extremely useful for on-farm fencing, if there is labour available. It may not be income generating, but there is material produced for farm or estate use, thereby saving money. There is also evidence, particularly concerning vegetable production in the fens, that significant yield improvements can be obtained from the provision of shelter. The management of vegetation specifically to provide shelter can yield tangible benefits.

Mr Lucas (Chairman) Would anyone else like to contribute on the thesis that by managing natural vegetation on estates, you can generate more income than has perhaps been suggested by the speaker?

Mr Barber Too much emphasis is given to the potential income to a landowner from the peripheral, non-farming, parts of estates. Small scale shooting, or opening parts of the estate to the public, for instance, have to reach a threshold point in income terms before they begin to offset the disadvantages (such as the costs and the irritations) of public access. Once a landowner opens parts of his estate to other people, he loses some of his autonomy, and the threshold level in terms of income set against irritation will be different for different people.

Mr Parker Will management agreements really satisfy both the owners and the conservationists? Will owners still feel that they want more money, and the conservationists more control; and do calls for understanding on both sides sound too much like industrial relations negotiations?

Are management agreements second best for full ownership by the conservationist (excluding the complications of compulsory purchase orders and so on)? I am thinking specifically about the lowlands, where there are many small pieces of land to which perhaps the public would like to have access, or where the conservationist would like to protect wildlife. Wouldn't it be better to just buy these pieces, and isn't a management agreement second best?

Mr Clegg (Speaker) On the question of purchase, the situation of the land must be of paramount consideration; there would be no point in a landowner disposing of a particular parcel of land that was in a critical position, for instance in the centre of an estate, where access would create all sorts of problems.

The anxiety about management agreements is that, at the end of the day, they are a form of compromise, and they are an imposition on somebody's autonomy. In theory the owner agrees and the other party agrees, but the question is just how far that agreement is achieved in practice. The funding of acquisitions is not easy, but I would presonally welcome purchase as the more acceptable alternative to management agreements, always depending on the location of the parcels of land involved.

Mr Lucas (Chairman) In a sense the whole theme of the paper was about education. So far as the public in general is concerned, there continues to be a good deal going on. But is there also a need for more formal education, for land agents for example. Is there a knock-on effect on the understanding between the competing interests when courses such as those at the Royal Agricultural College highlight the problems?

Mr Clegg (Speaker) I think so, because I don't think that in its entirety the 1981 Wildlife and Countryside Act is working as well as people might have wished. It is still in its infancy, but I think that as with all things, compromise was an important feature of the Act and that we have not yet got the complete answer. There is a further need for study, and certainly for education. I think that these matters will be part of the curriculum for future estate managers.

The Economics of Vegetation Management

R. O. Cobham
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"I often say that when you can measure what you are speaking about and express it in numbers, you know something about it, but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind."

Sir William Thomson (Lord Kelvin), 1889

INTRODUCTION

The challenge

As a nation we possess substantial natural and semi-natural areas. One report of the Institute of Terrestrial Ecology (ITE) 1981, estimates that these areas account for over 37% of the total UK land and inland water surface; and for almost 40%, if urban amenity land is included.

The components – rough grazing (26.9%), woodland (2.5%), inland water (1.3%) and other semi-natural areas (6.6%) – are regarded as valuable resources (Helliwell, 1969) : as visual assets; as part of our archaeological and historic heritage; as sources of food and revenue from hunting, fishing etc; as genetic reserves for Man's survival; as a biological "buffer" against pests; as a wildlife refuge; as educational material, as recreation facilities . . . . . In short, these areas are frequently expected to fulfil not one but a multiplicity of functions, as in the case of moorlands, chalk downland and primary woodland.

However, despite the fact that these areas are large, we do not know precisely, either at any one time or more importantly from time to time, how much of them we possess as a nation. Furthermore, we do not appear to know how much is spent upon their management and therefore whether or not what we do spend is too little, too much or –by coincidence, intuition etc. – 'just right'. In short, we are surprisingly ignorant about the extent of our semi-natural vegetation, about its condition nationally and about the total resources which are devoted each year to its management.

The brief

The brief for this paper requested that attention should focus on 'the costs and economics of vegetation control, together with the possibility of deriving some income from the operation'. Against that background a number of topics were

specified: 'analysis of the methods and units of costing; the comparative manpower, machinery and material costs of management operations; cost: benefit appraisal allowing for conservation and amenity aspects; the control of costs and the influence of costs upon objectives and standards'. Some – with whom the writer has some sympathy, might reply 'that is a tall order!', whilst others might feel that they are being invited to eat a highly indigestible meal without the aid of any liquid refreshment. However, initial impressions can be misleading!

Indeed arising out of this introduction there are a number of important and provocative questions which need to be identified and answered, at least in part.

THE KEY QUESTIONS

'What is the economics of vegetation management'?

This can be described briefly as the study into the allocation of scarce – be they national or local – resources between the competing ends or objectives of management.

'So what!' some may exclaim.

'Why should we be interested in the economics of vegetation management'?

An interest in economics implies a quest for the 'optimum' resource allocation, where 'optimum' usually means 'the most efficient' or 'best' in terms of total welfare and its national distribution. Unfortunately in most branches of economics the summit is rarely ever accurately perceived, let alone achieved. That, however, is no reason for ceasing the quest. Indeed in the case of vegetation management there are good reasons for accelerating the activity.

Economists, as advisers to policy-makers and decision-takers, are interested in at least two types of allocation, namely:

i The allocation of scarce land, labour and capital for the purposes of managing semi-natural vegetation *in competition with* alternative claims for the use of those same resources, e.g. for the further intensification of agriculture, additional afforestation, the development of high technology industries, the maintenance of social services to help the aged or handicapped . . . . . .

ii The allocation of whatever public and private funds are designated to vegetation management *between* the different types of vegetation (marsh, primary woodland, etc.) and the different forms of management (high technology, labour intensive, etc.).

If an economic case is to be made for altering one or both of these allocations, then a series of further questions needs to be posed.

'How, as is often asked (Whitby et al. 1974), can the choice of more appropriate allocations be made in the face of uncertainty about the outcome of each potential allocation'?

The starting point must surely be to measure the present 'state of the art'.

First, despite the publication of annual and other reports by the statutory agencies, such as the Nature Conservancy Council (NCC), the Countryside Commission (CC), the Forestry Commission (FC) and ITE, we do not know the extent and condition of our semi-natural vegetation areas. Indeed, were it not for data collected and handled with the aid of informed guess-work by a few researchers, notably Peterken (1981) into semi-natural woodlands and Blackwood & Tubbs (1970) into chalk grassland, the picture presented in Table 1* would be even more rudimentary.

The figures in Table 1 are, of course, inadequate on their own for resource planning purposes. Additional information about the geographic distribution of the areas, the levels of change in terms of gains as well as losses, their condition, their types of use whether for single or multiple purposes and the methods and levels of management, is required. Armed with this fuller picture, an economist can begin to help with choices, concerning for example the location and type of additional afforestation and the impacts which it can have upon upland and lowland wildlife.

Secondly, with few exceptions (Royal Society for Nature Conservation, 1981) until recently the decision-takers and their advisers appear not to have recognized that the management of semi-natural vegetation is a subject worthy of consideration in its own right, rather than being subsumed by a variety of other subjects, e.g. the management of national parks and country parks; public expenditure on parks, pleasure grounds etc. (CC, 1979). Even where figures are quoted, they need to be treated with great caution as was recently highlighted (MacEwen & MacEwen, 1982) concerning the £680,000 expenditure on 'conservation and estate maintenance' by the ten national park authorities in 1979/80. The authors point out that the classification of *"expenditure between functions made by the Association of County Councils is arbitrary and, in the view of several National Park Officers, it seriously understates the expenditure on positive management and the conservation of landscape. One officer went so far as to say to the authors that in his view his entire budget contributes towards conservation in one form or another through management, administration, deer control, wardening, tree planting, the educational effect of the information services and so on. There is substance in the argument and allowance must be made for it."* This comment provided the basis upon which the figures presented in Table 2 were compiled.

Table 2, containing unfortunately large numbers of question marks, indicates that information about the costs of vegetation management is not only fragmented, but scanty. The figures displayed in Table 2 represent the results of an

* Tables are presented at the end of the paper.

attempt to assemble the best possible estimates through extensive searches of published sources, supported by correspondence. Even then the accuracy of some of the figures is open to doubt. For instance, the guesstimate given for the private sector is based upon extrapolation of the figures obtained from an intensive survey of only nine lowland farms. It could therefore be significantly wrong. Also the figures may include expenditure on some vegetation which is not strictly semi-natural. Furthermore the picture is only a partial one, since it does not include all of the public sector organizations. It should, however, be borne in mind that the absence of some organizations is due to the fact that, although they are responsible for large annual expenditures on the management and maintenance of amenity areas, much of this is not associated with semi-natural vegetation.

When any further attempts are made to obtain a comprehensive expenditure statement for all semi-natural vegetation areas in Great Britain, it will clearly be necessary to present the statistics using a common base date.

The total estimated cost displayed is surprisingly low when compared with the annual expenditure by consumers for instance on parks and pleasure grounds (£457 million), on countryside sports (£958 million) and on admissions and recreational services (£1,461 million). Clearly accurate figures are required in order that rational choices can be made about the deployment of national resources.

The lack of comprehensive financial information raises a big doubt about the extent to which discussion and planning takes place between the major Government agencies (Ministry of Agriculture, Fisheries and Food (MAFF), FC, NCC, CC, etc.) concerning the allocation of scarce resources for vegetation management. There is no evidence of an annual or periodic national expenditure review or round-the-table discussion. Instead sectoral views seem to be the norm and over-views tend to be confined to public enquiries, at which the discussion is often of a competitive rather than a co-operative or complementary nature.

The compilation problems arise not only from the lack and inadequate definition of financial statistics, but from the fact that there are so many organizations involved in one or more aspects of vegetation management (Harrison *et al.* 1977; MacEwen & MacEwen, 1982). Those listed in Table 3 are but a generalised summary. They also arise because there is no mandatory, universal requirement for public landowners/managers to prepare management plans detailing the resources required and actually used in managing the semi-natural vegetation for which they are responsible. However, the problems of such measurement pall into insignificance when it is realized that a high proportion of the economic decisions concerning vegetation management are taken in the private sector, about which there is relatively little information. It is unusual for those in the private sector to record the costs directly associated with managing semi-natural vegetation. They are usually subsumed as part of the functional costs involved in running either the business or estate. With the trend towards owner-occupied holdings and the pre-occupation with

farm business considerations, as distinct from estate management, there is evidence (Newby, 1978, 1980) that the conservation and management of semi-natural areas are increasingly disregarded by certain types of farmer. It is important that the motives and constraints which affect management in *all* the different facets of the private sector should be better known.

Having highlighted the handicap, from which those concerned with improving both national resource allocations and vegetation management suffer, it is important to emphasize the need for remedial action. A Government initiated and sponsored project is required to achieve three essential tasks:

i To define the physical and economic data which requires to be recorded regularly for the benefit of all those concerned with the allocation of budget funds.

ii To identify the administrative adjustments required to enable the data to be assembled and to be made readily available to those responsible for the 'public purse', as well as advisers, landowners and their managers.

iii To oversee the implementation of improved resource evaluation and decision procedures and to monitor the impact which these have on the use and management of semi-natural vegetation areas.

In concluding this recommendation, it is important to indicate some of the large-scale benefits which should accrue, namely a better understanding of:

i The resources and funds required to achieve the present management tasks.

ii The management improvements that could improve the cost-effectiveness of those resources.

iii The levels of state intervention required in future to optimize cost-effectiveness and to ensure that as many of the existing semi-natural areas as possible are conserved.

iv How to re-allocate resources most successfully, in the face of continuing economic restraints.

Against this background a series of guidelines, examples and suggestions are offered concerning the type of economic data which needs to be collected and prepared to aid the decision-takers. At the same time it is important to point out the types of information which can mislead.

These suggestions are based on a major piece of R & D work – the Demonstration Farms Project – undertaken by the author for the CC in England and Wales since 1975, supplemented by experience on various public and private estates, including Blenheim.

ECONOMIC GUIDELINES AND PITFALLS

Cost concepts and yardsticks

For the unwary, calculating costs is paved with pitfalls (Reid, 1963; Price, 1978), especially since the task concerns five different professional interests –

the cost accountant, the economist, the business manager, the valuer and the work study officer – each of which has devised particular concepts and measurement methods. Consequently the number of terms used to describe costs rivals the varieties of Mr Heinz: *inescapable, unavoidable, fixed, common* and *joint; overhead, indirect* and *supplementary; escapable, postponable* and *variable; direct* and *prime; public* and *private; historic or true . . . . . real, unit, subsidized, net, 'knock-on', hidden, shadow, social, opportunity, discounted* and *imputed* costs are but some of the terms which could be used to describe the financial resources involved in establishing and managing vegetation.

One of the main 'battles' which previously occupied the different professional interests concerned the means of fairly apportioning *overhead* costs (rent, rates, depreciation etc.) between the various items being measured. For the business manager such apportionments are often thoroughly misleading, with the result that today they have been almost totally discarded. The same, to a lesser extent, is true of *historic* costs, though in the case of vegetation management the summation and comparison of the direct costs incurred, say since Doomsday, in managing the main countryside features –primary woodland, Saxon hedges . . . . . – would make interesting reading, especially if adjusted for inflation.

In this somewhat confusing and arid arena, there are, however, thankfully only a relatively few main cost considerations which need to concern those involved with vegetation management. These are now described.

First, there are the costs which are directly attributable to managing an area of land or water from year to year, e.g. the casual labour, fuel and materials specifically involved in hedge-cutting or ditch and bank cleaning. (Depending upon whether or not the permanent labour involved is a fixed cost or not, it should be excluded from or included in the figures.) These costs vary directly with the number of units (hectares or kilometres) of the particular vegetation feature being managed. Compared with the costs involved in managing land for commercial cropping purposes, the *variable* and *direct* costs of managing semi-natural vegetation are normally low, as shown in Table 4. Whether the direct costs are of the *variable* or *avoidable* type depends upon whether or not they have to be carried out by contract, casual or permanent labour. In the latter case, the direct costs shown for semi-natural vegetation in Table 4 are likely to be much lower, since the *variable* cost is usually confined to the purchase of materials such as fuel.

Secondly, the 'opportunity' cost incurred in managing land in a particular way compared with the most lucrative alternative. This in effect is the 'margin' or profit foregone per unit of land, for instance in conserving a hectare of primary woodland rather than in using the land for soft-wood or wheat production. The magnitude of these costs varies greatly, ranging from zero or even negative values (Price, 1978; Warren & Harrison, 1978) for many sites, and indeed for large areas of land where commercial agricultural or forestry operations would not be economically justified, to very substantial sums: *"through sterilization of productive activity on the land. These high costs mean that the*

total commitment to landscape preservation is only rationally pursued in very few areas of densely populated countries" (Price, 1978). Examples of the high costs are shown in Table 5.

The opportunity costs displayed relate solely to those areas where production is foregone. Their magnitude indicates the level of goodwill towards conservation that still exists in many sectors of the landowning and farming population. Indeed the figures may surprise some people whose attitudes towards farmers have been influenced by the strident comments of certain landscape 'journalists'. Whilst to many occupiers such opportunity costs are academic, since they have no intention of converting the areas to commercial use, there are others in the Halvergate Marshes and Somerset Levels, for instance, for whom they are of major importance. It is suggested that such costs need to be borne in mind whenever new capital or management grants and incentives affecting landowners and occupiers are being devised.

Thirdly, the 'discounted' costs which it is expected will be associated with managing an area of land for the foreseeable future using a number of methods. Discounting is based on the well acknowledged maxim that 'a bird in the hand is worth more than two in the bush' i.e. the requirement to spend £1 in the future is less painful than a similar commitment today. The process of discounting enables the usually dissimilar annual cost profiles of a variety of management methods to be compared more realistically than is achieved by just totalling the annual costs for the timespan under consideration. Discounted costs tend only to be calculated on special occasions, when investment decisions or choices between management strategies or methods are being made, for example:

i Whether and when it is economically justified to buy a precision fertilizer spreader which will conserve cereal production costs as well as the botanical value of hedge bottoms.

ii The choice between labour intensive and capital (machinery) intensive methods, which can amount to the same as the choice between a high-maintenance-cost solution (car parking on grass) and a high-initial-capital-cost solution (construction of a hard standing area).

Finally, the principal 'fixed' cost resources (permanent labour and machine hours) directly associated with the management operations. Initially they are expressed as the number of standard man or machine days involved in achieving one or more levels of maintenance. In order to compare the effectiveness of different management methods or systems, it is usually necessary to present the figures in financial terms using the appropriate unit costs, as shown in Table 6. The choice between managing an area of semi-natural vegetation, using direct or contract or voluntary labour or various combinations of these, is dependent upon the correct calculation of the combined variable and fixed costs. All too often it is not possible to arrive at the actual variable and fixed costs associated with the management of semi-natural areas, since they are entangled in the accounts of one or more of the following: the farming, forestry, sporting and recreation enterprises and the overall estate. The figures

in Table 6 have purposely been presented in physical terms, so that their expression as variable or fixed costs can accurately reflect whether the work is undertaken by permanent, contract or voluntary labour.

However, despite the importance of the four cost considerations outlined and even when they can be measured, pre-occupation with them should be avoided. They represent only part of the picture.

Cost effectiveness: macro-scale

The primary consideration, it is contended, should be 'cost effectiveness'. This is the relationship between the actual or predicted expenditure on the one hand and on the other the actual or predicted value of the benefits; in short, the estimated 'value for money'.

Assessment of cost effectiveness is a complex subject. The measurement of value (for whom and over what time period) is not only fraught with difficulties. It is made harder because of the intangibles involved, such as the different wildlife, visual or cultural values, or lack of them, associated with the range of land management methods (semi-natural vegetation as compared with plantation or commercial crops). Despite some ingenious and sophisticated attempts to express such values for areas of semi-natural vegetation in monetary terms, for example using the travel expenditures by visitors (Clawson, 1959), the stated willingness of a randomly selected sample of people to pay for conservation, a seven category system for evaluating wildlife resources (Helliwell, 1969), and comparison of the average annual costs between a) providing 100 m of good thick hedge per nesting bird attracted, and b) putting a pheasant over the guns, there are some values which defy credible, financial quantification, e.g. for someone to derive pleasure from semi-natural areas does not require perpetual or indeed frequent use of them by the individual. There are values associated with knowing that the opportunity to enjoy them exists and indeed that they are being directly enjoyed by others.

In addition to these limitations there are differences of 'expert' opinion concerning the most appropriate methods of cost/benefit analysis, even in the case of those elements which can be measured. For instance it is the normal practice to discount all changes of value to the present for purposes of comparison, based on the assumption that consumers place more emphasis on consumption now than in the future. However, the validity of discounting the costs and benefits associated with conservation issues has been seriously challenged, on the grounds that the views and values of future generations are largely ignored and that the future is uncertain.

In coming to terms with the measurable items, especially where major land use or investment decisions are concerned, experience (Whitby *et al.* 1974) has shown that it is advisable to employ a number of economic yardsticks: the return on investment, cost/benefit ratios, the net present worth, the internal rate of return. To use only one effectiveness yardstick can be thoroughly misleading.

It is especially important to ensure that the time perspective is taken into account. For instance, the investment of £2500 on a 200 ha farm over ten years in replacing dead trees in semi-natural areas might be unacceptable to the owner, when viewed in isolation. However, when the expenditure is regarded in relation to the time over which the investment is likely to be enjoyed (say 150 years for lime, 200 years for beech and 250 years for oak), it can pall into insignificance, especially when seen in the context of the farm landscape as a whole. In simple expenditure terms the investment amounts to pence rather than pounds per hectare per year over the life of the appreciating and appreciated feature. The growth in real values with the passage of time and indeed the opportunity for the addition of new values cannot be over-emphasized. For example, when our historic parks like Blenheim were created, involving the retention of semi-natural areas along with the establishment of 18th century features, the values which would be derived from public recreation were not contemplated or foreseen. Even if economists had foreseen these values, the application of discounting procedures applied to revenues earned 150 years in the future would have rendered them virtually valueless. Yet how wrong that would have been. Thankfully economists – as we now know them – were not around then to influence the decision. It is to be hoped that the high 'costs' associated with the present vogue for achieving instant results, be they revenues or trees, will be recognized. A diverse and better balanced portfolio of semi-natural and man-made features would then be more easily achieved.

Part of the 'effectiveness' appraisal should, of course, include measuring or estimating any revenues associated with the various management options for the semi-natural areas. At the macro-scale there is unfortunately very little published information on the revenues earned in the management of even publicly owned or administered semi-natural areas from such sources as farm crops (hay and silage in particular but also cosmetics and dyes); construction materials (osiers, reeds and straw); timber (fuel, fencing, hurdles and turnery products . . .); livestock grazing; insect products (honey); country craft products; sporting licences, rents and game produce; sports on open water areas which are compatible with wildlife interests; recreation facilities (country parks, interpretive centres, trails, picnic and camp sites, literature sales) wildflower and tree seeds, etc. Most probably the reason for the lack of national or regional information is that the total revenue is:

i Largely regarded as incidental to the main commercial farming, forestry or recreation enterprise, i.e. it does no more than make a modest contribution to the overall costs.

ii Subsumed under other sources of income (visitor receipts for all rather than semi-natural vegetation areas).

However, if at a macro-scale the recreation and other revenues are to be included in the evaluation, so also must be the costs involved. These are not just the costs incurred in managing the semi-natural area but also in using it, for example as a recreation facility which involves private and probably public travel expenditure to and from the facility.

Thus, sadly again this paper can do little more than highlight a further important subject area where fact-finding, analysis and development planning is required. In view of the problems both experienced and facing those responsible for the conservation of semi-natural areas it is surprising that:

i This information has not been forthcoming to date; and furthermore,
ii The potential for improving revenue earnings and thereby reducing the demands on the public purse has not been identified.

In the final analysis, despite all the endeavours of the economist or the management adviser, the decision-taker is faced with having to make a value judgement. This does not invalidate the work of the economist, whose task should be to:

i Assess as accurately as possible those items capable of measurement.
ii Compile a comprehensive list of the immeasurable factors.
iii Describe as explicitly as possible, with the help of other disciplines, the intangible benefits and disadvantages associated with each of the alternative management regimes.

Table 7 provides a simplified example. It is a summary of the costs and benefits assessed in the course of preparing the integrated land use and management plan for the CC's Chalkland Demonstration Farm. This table has been prepared without reference to any standard procedure, since experience suggests that, as with issues concerning landscape aesthetics, the yardsticks for assessing vegetation management options need to be devised on a case by case basis. There is likely to be a core of yardsticks which are similar for all cases, but the characteristics of the sites themselves and the issues concerned will determine how best to proceed thereafter. The example given in Table 7 is for a relatively small exercise compared with the appraisals undertaken for issues of national importance: the Third London Airport, Amberley Wildbrooks . . . . . However, the principle of tailor-making the appraisal approach applies equally to such large projects.

In conclusion, it is suggested that biologists and land managers should not fall into the trap of trying to express all the repercussions of management changes in financial terms. Indeed economists themselves recognize (Price, 1978) that the financial evaluation of nature conservation values 'is at least as intractable as that of landscape'. Yet there was a strong feeling some years ago that the conservation interests would only gain the ear of decision-takers if they quantified everything in monetary terms. This it could be claimed is but a fashion. Decision-takers throughout time have been required to make 'value judgements' of a difficult nature, and have been required to weigh the philosophical as well as the political implications along with the economic. Thus, the writer recommends that in place of the search for optimizing economic expression we should seek to describe and where possible to quantify clearly, even in physical terms alone, as shown in Table 7A, the implications of the issues at stake. To attempt to simplify and to pander to the fashion for financial precision is to debase the roles of both advisers and decision-takers.

In short, experience has *somewhat* tempered the author's pursuit of Sir William Thomson's challenge! There can be no absolute evaluation technique especially where natural features are involved, as landscape architects have come to realize from trying to devise all-embracing scales for measuring beauty.

VEGETATION MANAGEMENT METHODS: EVALUATION OF OPTIONS

The micro-scale

Whereas the evaluation of the vegetation management options at the national or macro-scale is charged with problems, the appraisal of the alternative management methods and operations at a local or site specific scale is more straightforward. Indeed in the case of commercial land uses there are a variety of handbooks (e.g. Nix, 1981) available to assist the landowner and manager in choosing the most appropriate management method.

Unfortunately, to date, in spite of the growing volume of information on amenity land management, there is no comprehensive counterpart for semi-natural vegetation and amenity areas. However, despite the problems which arise because of differences between site conditions; latitude, longitude, soils and many other variables, the writer and colleagues are attempting to prepare one. This it is hoped will assist not only managers, but their professional colleagues who are involved in the important initial design work. The latter has often suffered greatly in the past from not being exposed to constructive criticism in relation to the longer-term management and maintenance implications. The distinction between capital and revenue expenditures (and budgets) is an unreal one and can lead to decisions, which, had the predicted expenditure patterns over the whole life rather than the first say five years of a project been examined, would have been taken differently and to greater advantage.

Table 8 provides examples of the comparative costs involved in using different management techniques for a variety of vegetation types. The data presented supplements that quoted by other contributors to the seminar and is drawn from both the Demonstration Farms Project and a selection of recently published reports. It is interesting to compare the costs presented in this table with the much higher opportunity costs shown in Table 5. However, it must be pointed out that the direct costs exclude the thinking time which is required on the part of the managers, which often is the scarcest resource!

To complete the picture, Table 9 lists some data collected on the levels of revenue which have and can be earned both as the main and by-products of managing semi-natural areas. For some landowners and occupiers who find difficulty in undertaking the management of valuable, semi-natural habitats there can be another solution. These areas can sometimes be let for a "peppercorn rent" on a long lease to a conservation organization, such as a County

Naturalist Trust. They can as a result be actively conserved through implementing a management plan specifically prepared by Trust members.

Most of the data given in these last two tables is related to land which is privately owned. There is no statutory requirement for private landowners to declare these costs and revenues in any accounts to the Inland Revenue. Thus the figures quoted are indicative of those from which national data will have to be derived for the private sector if at anytime they are required.

Motivations

It is to the private sector that we need to look when considering ways in which the effectiveness of management methods need to be improved. From working with a large number of landowners over the past ten years, four broad conclusions and recommendations emerge:

i 'Effectiveness' to the landowner, farmer or manager usually means *simplicity* and *convenience*. Often the direct costs and potential revenues involved are of secondary importance. Thus as many as possible of the vegetation management operations need to be capable of being performed in the less busy periods of the year. That usually means the winter months: machinery and herbicide manufacturers, please note.

ii The likelihood of conserving semi-natural features is greatly enhanced, if they can be managed as part of normal estate or farming operations. It has been shown that integration of commercial and conservation interests can be achieved at little cost, if full consideration is given to the main functional needs of the business.

iii Whereas the provision of direct management grants may not influence landowners greatly and indeed may not prove feasible within the European Economic Community machinery, the fulfilment of management agreement compensatory payments and the provision of fiscal reliefs are likely to be increasingly important. This relates, of course, to situations where the opportunity costs are high.

iv If landowners are to derive full value from the potential revenues, they will require significant help in marketing the produce. This was highlighted in particular by DART in the Small Woodlands Study sponsored by the CC for England and Wales.

Until recently the powers which existed to control management standards in the private sector were limited. These have been significantly improved, in theory, through the reform of the MAFF grant system and the provisions of the Wildlife and Countryside Act, 1981. However, this influence could be greater – and indeed could include a measure of cost control – if fiscal reliefs were to be extended, conditional upon the preparation and implementation of conservation plans. However, it is not just the private sector which is in need of carrots and sticks, the management practices of some of the public bodies are well recognized to require attention.

RECOMMENDATIONS

The investigations made in the course of preparing this paper suggest that the custodians and owners of semi-natural vegetation should not receive positive response to claims for more resources until it can be demonstrated that:

i The resources already allocated for the purpose are being efficiently used. This entails knowing the extent and nature of the basic land resource and the associated management inputs.

ii There is a capability exceeding that of competitors to use additional management resources more effectively on behalf of Society.

In general terms this paper has identified that a minimum of £103 million is expended annually on the management of some 6 million hectares of semi-natural vegetation. However, in the absence of comprehensive data, the paper has been unable to answer in what ways the allocation of national resources could be significantly improved. Instead an attempt has been made to indicate the levels of costs and revenues entailed in conserving and managing a selection of semi-natural areas using a variety of methods. However, whether and how, in the event of a continuing recession, we should face up to the possibility of having to relinquish additional semi-natural vegetation areas has not been attempted. That is another large issue beyond the scope of this paper. It too should not be answered by events or expediency, but by research.

Throughout the paper various explicit and implicit references have been made to the need for R & D expertise to be devoted to remedying the short-falls in our knowledge. Table 10 attempts to set a framework for discussion on the sequence of research, development, communications and decisions which need to be taken.

There is one further aspect of such work which from a simple economic standpoint deserves a mention, namely the need to find additional ways of effectively harnessing the surplus manpower resources potentially available. We have a variety of statutory and voluntary employment schemes. Is there scope either through these or additional initiatives to improve the management of semi-natural areas? The cost to the nation of unemployment is high. If more of the resources devoted to meeting that cost could be directed towards such management works, especially towards those areas capable of generating revenue, we should not only make economic, but social progress as well. It would be naive to ignore the real political and other obstacles preventing such progress. However, it is the economists' role to highlight the scope for resource re-allocations, recognizing of course the possible implications for the chemical and other service industries of a swing towards more labour intensive management methods.

CONCLUSIONS

The economics of vegetation management is largely 'virgin forest'. Whether it is semi-arid scrub or semi-tropical rain forest is left for the reader to decide. It is hoped that this paper has made the forest appear a little less like a jungle.

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DISCUSSION FOR MR COBHAM

Mr Cobham was questioned about some of the figures quoted in Table 2 of his paper, and agreed to amendments proposed by representatives of the organisations concerned.

Table 1
Estimated areas of natural and semi-natural vegetation in Great Britain

Habitat	Area x10^3 (rounded)	Proportion as NCR site † (%)	Year	Source
Coastal – mud flat, marsh, dune, shore, shingle beach	119-263*	100	1960 –	Ranwell (1982) (Pers. Com.) Ratcliffe (1977)
Woodland – ancient and recent semi-natural woodland	339	20	1978	Peterken (1981)
Lowland grass and heath – institutional ownership	289	13	1974 adjusted	NERC (1977) Ratcliffe (1977)
road verges and green lanes	214	–	1980	Dunball (1983)
Open water – standing, including reservoirs	244-310*	9	1977-1980	Moss (1981) ITE (1981)
Peatland	63-?	100	–	Ratcliffe (1977)
Upland grass and heath	1500-4057*	11	1956 1982	Lance (1982) (Pers. Com.). Bunce (1982) (Pers. Com.).
Lowland hedges – England and Wales only	135-174*	–	1963 –	Green (1981) Ratcliffe (1977)
Other – railway verges and tracks -	20	–	–	Ratcliffe (1977)
pipelines, wayleaves, mineral workings and tips, non-urban wasteland	– 421	–	1979	Moss (1981)
Total	3106-6087**	15		

* Where a range of areas is given the source of the lower one is quoted first.
**This figure agrees with estimates provided by Bunce (pers.com.) and represents 26.5% of the total area of Great Britain.
† Nature Conservation Review (Ratcliffe, 1977).

Table 2

Estimated annual direct and associated expenditure on semi-natural areas by selected owners of land and way-leave rights in Great Britain

	Expenditure				Notes		
	Management	Education/ Interpretation	Research	Total	Year	Source	
	£(M)	£(M)	£(M)	£(M)			
CENTRAL GOVERNMENT							
National Park Authorities (NPA)	4.85	1.05	–	5.9	78/9	CC(1979A)	Revenue Expenditure: Recreation, Conservation, Estate Management, Administration
Nature Conservancy Council (NCC)	5.19	1.65	2.01	8.85	80/1	NCC (1981)	Revenue Expenditure: Reserve Establishment and Management and Advice
Department of the Environment (DOE)	–	–	0.25	0.25	81/2	Pers. com.	Centrally administered activities only
Countryside Commission (CC)	7.84	0.93	0.65	9.42	80/1	CC(1979)	England and Wales and CC for Scotland. Revenue expenditure
Forestry Commission (FC)	3.9	?	?	3.39	80/1	FC(1982)	Recreation and Amenity Subsidy
Ministry of Defence (MOD)	?	?	?	?			
Department of Transport (DTp)	29.76	–	–	29.76	79/80	Dunball (1983)	Grass cutting and siding only, excluding urban. England and Wales
Sub total	51.03	3.63	2.91	57.57			Compares with £457M (1978) Public expenditure on parks and pleasure grounds
LOCAL GOVERNMENT							
County Councils	8.92	?	0.86	9.78	81	Royal Society for Nature Conservation (1982)	
STATUTORY AGENCIES AND NATIONALIZED INDUSTRIES							
Central Electricity Generating Board (CEGB) and Regional Boards	8.00	–	–	8.00	81/2	Pers. com.	
Natural Environment Research Council (NERC)	–	–	5.00	5.00	80/1	NERC(1981)	Expenditure: Solid earth, inland waters, and terrestrial environment

Water Authorities/Drainage Boards	8.50	–	–	8.50	81/2	Cave (1983)	Personal estimate for cost of aquatic weed control + £2.5M other. England and Wales
British Waterways Board (BWB)	3.03	?	?	3.03	77/8	CC(1979A)	Revenue Expenditure: Recreation and Amenity
British Gas Corporation (BGC)	0.11	–	–	0.11	81/2	Pers. com.	Excludes mown areas
British Rail (BR)	0.21	–	?	0.21	74	NERC(1977)	Subject to error of +/– 25%
Sub total	19.85	?	5.00	24.85			
CONSERVATION ORGANIZATIONS Royal Society for the Protection of Birds (RSPB)	0.45	–	–	0.45	80	Pers. com.	
Royal Society for Nature Conservation (RSNC)	0.17	0.13	–	0.30	77	RSNC(1982)	Covering all County Trusts
National Trust (NT)	3.29	–	–	3.29	81	Pers. com.	
Sub total	3.91	0.13	–	4.04			
PRIVATE Private Landowners	6.80?	–	–	6.80	82	Cobham (1982)	Calculated from average annual expenditure from 9 lowland farms in England & Wales. Further investigation required.
Grand total	90.51	3.76	8.77	103.04			

Footnote: For the reasons given in the text (page) figures have not been included for the Sports Council, and other organisations such as the Property Services Agency (PSA) or the Scottish and Welsh Development agencies.

Table 3
Landownership in Great Britain: 1976/7

	Agricultural land* (Million ha)	Total land† (Million ha)	Semi-natural vegetation+ % of total land	Semi-natural vegetation (Million ha)
INSTITUTIONAL				
Local Government	0.37	0.42	5.1–10.7?	
Central Government	0.36	1.88	3.4–6.8?	
Statutory Agencies and Nationalized Industries	0.23	0.44	3.5–6.6?	
The Crown	0.17	0.22	3.3–6.6?	
Conservation Organizations	0.13	0.22	5.7–11.5?	
Educational	0.10	0.11	4.7–9.4?	
Financial	0.08	0.15	2.5–5.0?	
Religious	0.07	0.07	4.8–9.6?	
Total	1.51	3.51		
PROPORTIONS OF TOTAL AREA	%	%		
Institutional ownership	8	16.5	4–6? representing	0.14–0.23
Private	92	83.5	5-10? representing	0.87–1.74

Sources:
* Northfield (1977); Harrison *et al.* (1977).
† Harrison *et al.* (1977); Countryside Commission (1979).
+ Guestimate compiled from published figures for DOE, County Councils, BWB, Conservation Organizations; 5–10% of agricultural land assumed for others.

Table 4
Indicative annual direct and variable costs involved in managing different types of vegetation

Type of vegetation	Location	Cost (£/ha)	Year	Source
A. SEMI–NATURAL				
Long grass	South London Green Belt	0-23	1977/78	Warren & Harrison (1978)
Scrub		0-28	1977/78	id.
Heath		0-38	1977/78	id.
Woodland		0-65	1977/78	id.
Short grass		185	1977/78	id.
Woodland (coppicing 30 - 40 year rotation)	Essex	8	1981	Cobham (1982)
Woodland (coppicing 30 - 40 year rotation)	Essex/Suffolk	12	1976/77	id.
Hedges (av. 2 m wide)				
biennial flail	Hereford/ Worcs.	40	1980/81	id.
annual flail		75	1980/81	id.
coppicing		493-543	1980/81	id.
laying		920	1980/81	id.
Watercourse fringe (2 m wide)				
chemical	S./S.E. England	125	1981/82	Cave (1983)
mechanical		600	1981/82	id.
manual		750	1981/82	id.
Moorland –				
heather burning	Northumberland	5	1980/81	Cobham (1982)
heather cutting (contractor)	Northumberland	10	1980/81	id.
(Moorland Conservation Compensation Grant)	Exmoor	44	1981/82	MacEwen & MacEwen (1982)

Table 4 Cont'd.

B. CULTIVATED				
Commercial Forestry				
(conifer/broadleaf 120 year rotation)	Eastern England	5-13	1978/79	Forestry Commission (1979)(Pers. com.)
Commercial Agriculture				
grassland –				
sheep		14-45	1980	Nix (1981)
beef	England	30-78	1980	id.
dairying	& Wales	50-100	1980	id.
cereals		100-170	1980	id.
roots, veg, fruit		500-1,000	1980	id.

Table 5
Conservation areas and expenditures for nine lowland farms in England and Wales: 1981/2

Farm type		Total area	Total conservation area	Total area not intensively farmed/forested	Proportion conserved	Proportion intensive production foregone	Average annual extra direct expenditure on conservation		Average annual opportunity cost total	Income foregone as proportion of total gross income
							Unit	Total		
		A	B	C	D	E	F	G	H	I
		ha	ha	ha	%	%	£/ha	£	£	%
1	Intensive dairy plus arable	294	18.7	13.5	6.4	4.6	0.49	144	5805	10-12
2	Intensive arable plus livestock	691	98.8	78.8	14.3	11.4	0.29	200	5700	13-15
3	Intensive dairy and arable	267	9.4	1.8	3.5	0.7	0.24	64	1440	2-4
4	Intensive dairy	104	13.2	4.7	12.7	4.5	0.92	96	940	7-9
5	Intensive dairy plus arable	296	15.7	7.0	5.3	2.4	0.27	80	3521	10-15
6	Livestock plus arable	237	25.7	9.1	10.8	3.8	0.36	85	2457	13-15
7	Intensive dairy plus arable	187	4.6	4.6	2.5	2.5	0.67	125	3003	12-15
8	Intensive arable and stock rearing	223	9.1	5.1	4.1	2.3	0.78	174	1380	5-7
9	Intensive arable and dairy	1183	194.4	126.6	16.4	10.7	0.34	402	13610	15-20
Total		3482	389.6	251.2	11.2	7.2				

Source: Cobham (1982) Cobham Resource Consultants. Work in progress.

Table 6
Indicative manpower and machinery resources required for hedge maintenance

Shape of cut	Frequency of cut	Shape of hedge	Number of flail passes Tractor gear 1st	2nd	Manpower and machine time required Min./ Man	Machine
A-shape	Annual		–	4	0.16	0.16
Wispy A-shape	Annual		–	4	0.16	0.16
Chamfer	Annual		1	4	0.18	0.18
A-shape	Annual/biennial*		1	2	0.10	0.10
Chamfer	Annual/biennial*		1	4	0.18	0.18

Coppicing	Every 15 years	–	One pass with tractor and shape saw	5.49	5.49
			One pass with tractor buckrake	2.74	2.74
Laying (manual)	Every 15 years	–	–	28.5	4.5
Laying (mechanical)	Every 15 years	–	–	7.0 –12.0	1.6-12.0 (flail) 3.9-12.0 (chainsaw + foreloader bucket)

*Only one side of hedge is flailed each year

Source: Cobham (1982) Cobham Resource Consultants. Work in progress.

Table 7
Appraisal of expected benefits and costs associated with implementation of integrated land use plan for an 1183 ha chalkland farm

Impact on cultivated/semi-natural areas	Physical change		Financial impact		
	Commercial gain (£)	Conservation gain (£)	Revenue gain (£)	Opportunity cost benefit (£)	Capital outlay (£)
A. Short term					
1. Farming improvements – field rationalization	2	–	1,200	–	1,280
2. Downland S.S.S.I. Conservation	–	58	451	minimal	–
3. Other Downland Conservation for wildlife & aesthetic benefit in preference to arable conversion	–	47	–	6,580	–
4. Conservation of scrub for sporting and wildlife benefit in preference to arable conversion	–	9	–	3,678	–
5. Conservation of ancient monuments at 16 scheduled sites (+ 100 ha occupied by unscheduled sites)	–	1.5	160	741	–
6. Visual amenity improvements – streamside, corner etc, planting	–	minimal	–	–	1,950
7. Other farming improvements F.H.D.S. Plan	–	–	7,500-11,700	–	50,000 78,000

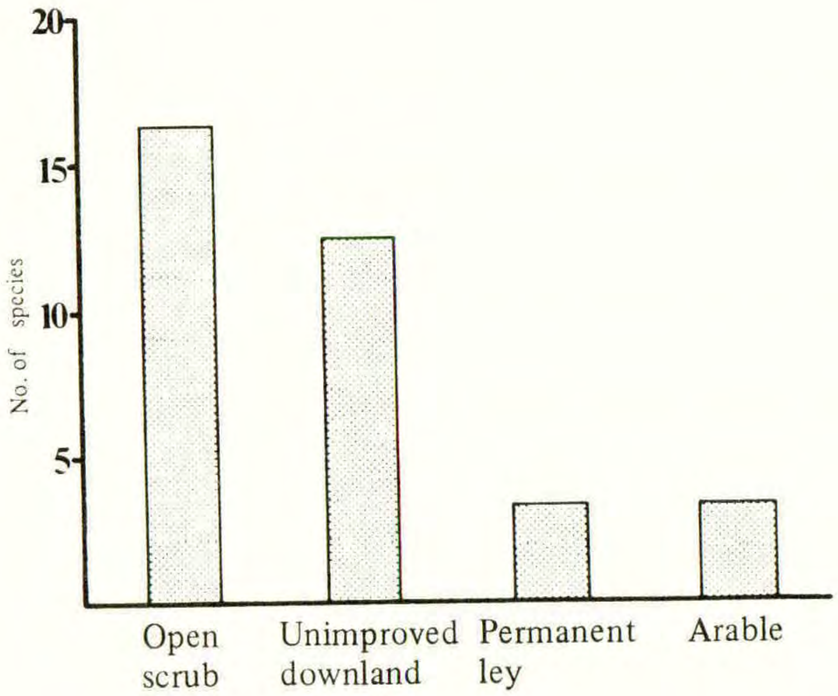
8.	New afforestation proposed	15.3	5.3	?*	–	6,120
9.	Improved management of existing woods	59.3	margins & rides	?+	–	–
10.	Improved sporting cover – hardwood margins/ rides	64	–	500	–	2,500
B. Longer term						
1.	Improved wildlife†	conservation of plant, bird butterfly etc species		?	?	?
2.	Enhanced visual amenity	conservation of landscape and historic features		?	CTT ex-emption substantial	?

* Predicted to be superior to returns from extensive livestock enterprise
+ Predicted to generate a return
† Source: see Table 7A Cobham (1982) Cobham Resource Consultants – Work in progress

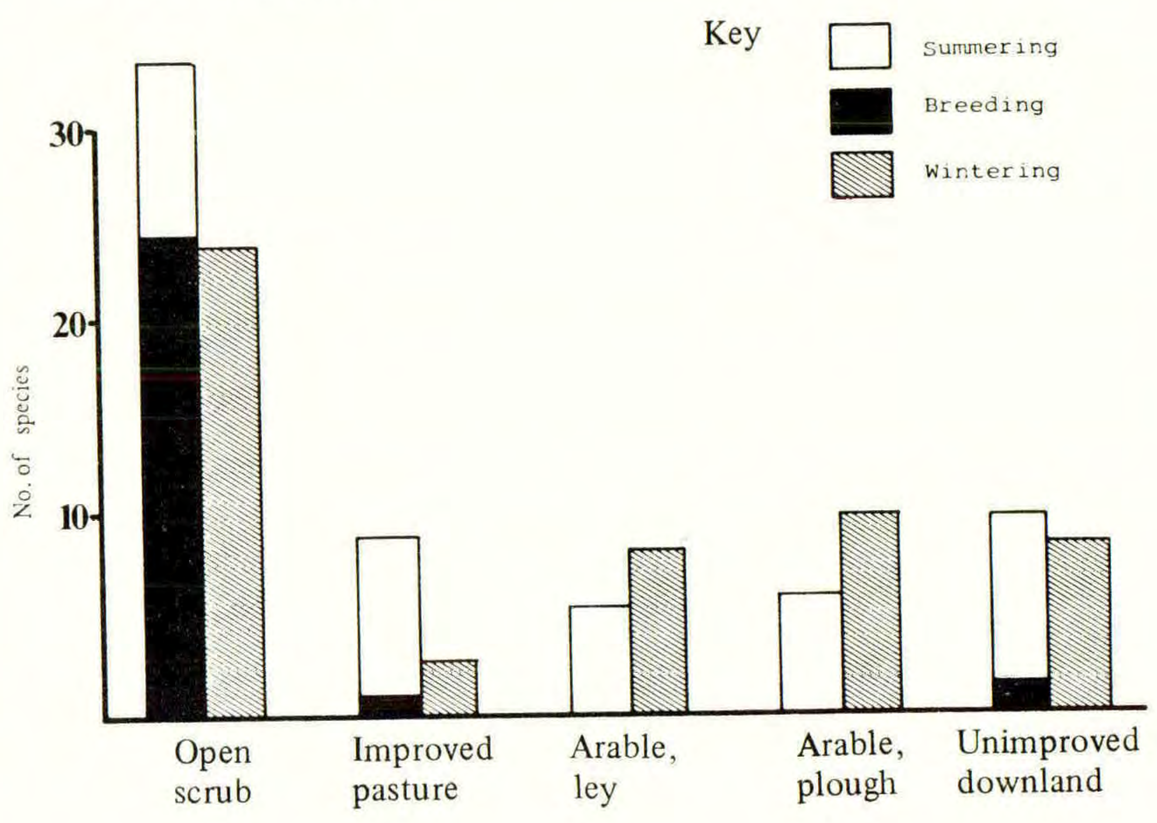
Table 7A

Appraisal of wildlife benefits associated with conserving 9 ha of scrub (initially for sporting purposes) on a chalk downland farm in preference to improving farm output.

1. No. of butterfly species (1980 averages)



2. No. of bird species



Note 1: The comparisons between the various habitats are based in all cases on an area of 9 ha.
Note 2: In the case of the Open Scrub, 11 pairs of breeding birds were found in the 1 ha plot at the extreme west end. This compared with a total of 125 breeding pairs in the 9 ha overall.
Source: Cobham (1982). Cobham Resource Consultants. Work in progress.
Rowe (1982) pers. com.

Table 8
Examples of comparative resource requirements for different management methods

Habitat	Condition	Method	Annual Costs Capital (£)	Annual Costs Variable (£/ha)	Comments
1. Moorland (<15° slope)	20-25 year old, leggy heather	Cutting with machine* – purchase	346	2.80	Litter delayed regrowth by approx one year
		Cutting with machine – contractor	–	10.00	Timing of operation very flexible
		Burning	90	5.00	High labour requirement Timing of operation less flexible

Notes:* Bomford Bandit 2500 (flail cutter) 2.5 m swath. Break-even point: Total cost of cutting (purchase) becomes cheaper than burning when heather area requiring treatment exceeds c.125 ha.
Source: Cobham (1982) Cobham Resource Consultants. Work in progress.

	Requirement	Method	Man h/10^3m^2	Comments
2. Hay meadow	1-2 cuts/year	Reciprocating cutter Tedding Baling Collecting	35-45	
		Forage harvester	0.5-2	To cut after flowering would require mowing first

Source: Wright (1979)

Table 8 Cont'd.

	Requirement	Method	No tree/ha	Establishment cost (£/ha, excl. fencing)	Incremental growth: 2 yrs) cm
3. Oak woodland	Regeneration	Transplants + rabbit fence + herbicide for 4 years	1200	653	12.1
		Container grown whips and poly-tube (mini-greenhouse) + herbicide for 4 years	450	1005	101.5
		Transplants + poly-tube + herbicide for 4 years	450	1170	97.8

Source: Cobham (1982) Cobham Resource Consultants. Work in progress.
Tuley (1982)

Note: The figures provided in this Table are site specific and should not therefore be used as a basis for extrapolation.

Table 9
Indicative revenues to be earned from appropriate areas of semi-natural vegetation

Habitat	Commodity	Revenue (£)	
1. Grassland	Grazing licences/hay cropping	50-100/ha/year	(net)
2. Woodland	Coppice products	0-370/ha/year	(net)
	Firewood*	0-125/ha/year	(net)
3. Lowland woodland and adjacent farmland	Driven pheasant shooting 300 birds/day full board	up to 1000/gun/day (8 guns)	(gross)
	Walked-up pheasant shooting	70-150/gun/day	(gross)
	Pigeon shooting	40/gun/day	
4. Moorland	Driven grouse shooting – 100 brace	300-625/gun/day	(gross)
	Walked-up grouse shooting – 20-40 brace	80-120/gun/day	(gross)
	Red deer stalking (excluding trophy fees)	100-125/stag	(gross)
	Roe deer stalking (excluding trophy fees)	100-160/stalker/day	(gross)
		20-40/non-stalker/day	(gross)
5. Open water and adjacent areas	Goose shooting	45/gun/flight	(gross)
	Duck shooting	25-30/gun/flight	(gross)
	Fishing (2nd quality)	40/rod/week	(gross)
6. All	Holiday accommodation	70-150/week	(gross)

* Three-bedroomed house can be heated with the produce of c. 3 ha of coppice woodland managed on a 15-year cycle i.e. c. 0.2 ha cut annually.
Footnote: These figures have been assembled from case study sources and should therefore not be used as a basis for extrapolation.

Table 10
Sequence of important research and development activities towards improving the management of semi-natural vegetation

Stage	Activity	Main Components	Units	Decisions Required	
1	*Recognition of improvements required* *Commitment to rectifying inadequacies*				
1.1	Inadequate data	BCPC Seminar plus other initiatives, say working party of government agencies, landowners, professional institutes	Time	Partial or comprehensive R & D programme: location and timing of research	*
1.2	Improvement potential —management of semi-natural vegetation —use of public/private funds				
2	*Research and Development: past/present*				
2.1	Extent of semi-natural vegetation areas	Habitat types, ownerships, management agencies	Ha		
2.2	Condition of vegetation**	,,	Ha		
2.3	Function of vegetation Single uses: conservation; public access; recreation/education; sport; crop or by product Multiple use	,, —	Ha		
2.4	Deployment of existing financial resources for management	Direct and indirect expenditure	£	Inter and intra agency action	
2.5	Management methods used: inventory	High-low management levels High-low capital intensities Habitat types, ownerships, management agencies	Ha, £		
2.6	Cost effectiveness of:** existing financial resource deployment existing management methods	,,	£		
2.7	Extra funding required for management improvements	Habitat types, ownerships, management agencies	IIa, £		*
2.8	Landowner/occupier motivations	Habitat types, tenure types	Ha, £		
3	*Research and development: future*				
3.1	Alternative management systems**	Community management supported by professional advice Conservation of semi-natural habitats linked to productive enterprises Management backed by multiple compared with single agency grants	Ha, £		*
3.2	Resource deployment improvements** based on: a) existing public/sponsor funding b) additional public/sponsor funding	Habitat types and functions, ownerships, management agencies	Ha, £	Inter and intra agency action	* *
3.3	Data collection/assembly and communications systems	Government agencies, landowning and management agencies	Ha, £		*
3.4	Continuous evaluation	—			

*Main items where choice involved; **May be measured by many different criteria

MANAGEMENT OF AQUATIC VEGETATION

Management of Vegetation in or Near Water

T. G. Cave
Association of Drainage Authorities

INTRODUCTION

The management of vegetation in or near water is a subject that in recent years has aroused a great deal of controversy, not only as a result of a quickening of public interest in nature conservation, but also concerning the various methods of control employed. This has been particularly evident in the use of aquatic herbicides.

The extent of aquatic weed control varies enormously in different localities, from the Highlands of Scotland and Wales where it is generally carried out only for sporting purposes, to the fen lands of East Anglia where it forms an indispensable part of the very existence of the area.

This paper attempts to assess the nature and extent of aquatic vegetation and the needs for its control both in relation to the uses of watercourses and to the statutory obligations of the responsible authorities.

Costs of vegetation management are examined, as are the effects of recent conservation legislation and other outside pressures.

Finally, future prospects in this field are discussed, together with the urgent need for further and continuing research and development of improved control techniques.

TYPES OF WATERCOURSE

Natural

The character of watercourses vary very much in accordance with the physical geography of the area through which they flow.

Mountain streams are invariably clear, fast flowing and shallow in contrast to the lowland rivers, which are slow flowing and usually turbid and comparatively deep. In the mountains and hills, valleys are steep sided containing even swollen streams within narrow limits. Down in lowland areas, rivers have wide flood

plains with extensive water meadows that are inundated when the rivers are in spate. In certain areas, either due to the pressures of urban development, or the requirement to extend arable farming within the flood plain, embanking and realignment schemes have been carried out, changing the character of the river and its margins.

The character of a watercourse also determines the nature of the aquatic vegetation within it. Young mountain streams flowing fast over rocky beds will allow little or no vegetation. The little that does appear during quiet summer periods is soon uprooted following heavy rain. As soon as the flow reaches the point that sedimentation begins, more permanent aquatic vegetation is able to establish itself. Growth can become very dense even in comparatively fast flowing rivers, as can be seen in the Spey, the Eden or the Dove.

Aquatic vegetation, like terrestrial plant species shows preferences for particular soil types. In addition, the chemical composition of the water body will control the species that can grow within it.

Man made

Man made watercourses were first constructed in Great Britain by the Romans for the transportation of troops and supplies through difficult terrain. Many more were cut in the Middle Ages to provide access by boat to towns and villages from the nearest navigable river. During the industrial revolution the bulk of the present canal system was built.

By far the most numerous man made watercourses however, are land drainage channels, the total length of which is estimated to be in the region of 128000 km (Price, 1981), of which approximately 15% are maintained by Internal Drainage Boards. They can vary in size from small field ditches to large arterial drainage channels, with water widths in excess of 30 metres. It is within this category of watercourse that the most stringent standards of aquatic weed control are maintained.

THE NEED FOR CONTROL

Most waterbodies in Great Britain, and particularly in England, are managed in a variety of ways in the interests of water supply, land drainage, navigation, angling or other recreational activities. Vegetation control to a greater or lesser degree is invariably a part of that management.

It is accepted that aquatic plants fulfil an important role as primary producers of food and dissolved oxygen, as well as helping to prevent bed and bank erosion. On the other hand they often interfere with man's interests (Robson, 1976). Obstruction to flow caused by vegetation increases the risk of flooding, reduces the effectiveness of land drainage works, causes siltation of channels and can block culverts and pumping station intakes (Table 1).

Table 1
Classes of aquatic vegetation

Type	Common examples	Problems caused
Emergent monocotyledons	*Phragmites communis* – Common reed *Sparganium erectum* – Bur reed *Glyceria maxima* – Reed sweet grass *Typha latifolia* – Reedmace	Resistance to flow Siltation in shallow channels Access for angling etc
Emergent dicotyledons	*Alisma plantago-aquatica* – Water plantain *Rorippa nasturtium-aquaticum* – Watercress *Hippuris vulgaris* – Mares tail	Resistance to flow Siltation Interference with angling and navigation
Floating leaved plants	*Lemna minor* – Common duckweed *Potamogeton natans* – Broad leaved pondweed *Nuphar lutea* – Yellow water lily *Polygonum amphibium* – Amphibious bistort	Resistance to flow Interference with angling and navigation Amenity Filtration of potable water and deoxygenation (*Lemna* only)
Submerged vascular plants	*Ceratophyllum demersum* – Hornwort *Ranuculus spp* – Water crowfoot *Callitriche stagnalis* – Water starwort *Potamogeton crispus* – Curled pondweed	Resistance to flow Interference with angling and navigation Danger to bathers
Filamentous algae	*Vaucheria dicotoma* – Cott *Enteromorpha intestinalis* – Bladderweed *Cladophora glomerata* – Blanket weed	Resistance to flow Blocking of culverts and pumping station intakes. Interference with angling and boating, including clogging engine cooling systems. Filtration Amenity competition with ornamental plants. Decaying mats cause de-oxygenisation of water. Danger to bathers
Periphyton and Phytoplankton	*Achnanthes spp* – Pennate-diatoms *Stephanodiscus spp* – centric diatoms *Microcystis spp* – Blue green algae bloom	Amenity Filtration Potable water taste and odour

Observations made by people involved in weed control before the Second World War suggest that the volume of aquatic plants has increased markedly in recent years. This can be attributed at least in part to the extra nutrients present in the water of lowland rivers and drainage channels resulting from sewage effluents and the leaching of chemical fertilisers.

Heavy weed growth interferes with navigation, sailing, angling and other aquatic sports. Floating plants can, by preventing light penetration, cause deoxygenation of water, and in the case of duckweek (*Lemna* spp.) and filamentous and unicellular algae are unsightly, particularly on amenity waters.

High populations of some phytoplankton are troublesome in potable water supply sources, affecting odour and taste and creating difficulties in filtration processes.

The extent and degree of aquatic weed control varies according to the purpose and use to which the watercourses affected are put. Natural watercourses with no navigation or flood prevention function, and remainder arms of the canals system are not likely to require extensive weed control, except to assist recreational pursuits.

Whilst boat traffic in commercial and cruising canals has been shown to reduce plant growth (Murphy & Eaton, 1981) most of these channels still require some form of regular weed control; but, as in the case of all classes of waterway, unnecessary removal of aquatic plants is undesirable both on account of wasted expenditure as well as from the point of view of nature conservation. Land drainage channels and channelised sections of rivers can be coupled together in that they are civil engineering structures, the size, depth and gradient of which have been carefully designed to collect and transport flood flows at acceptable levels, without overtopping of banks, to a point of outfall. In this way they can be compared directly with urban surface water sewers, which fulfil a similar function. In the fenland areas, a large proportion of which lie below mean sea level, the very existence of the life of the region depends on the proper function of these watercourses.

In order that they do function in accordance with their designed capacities, they must be maintained to a very high standard at all times of the year. Silt deposits and other obstructions must be regularly removed and, above all, aquatic weed growth must be kept down to insignificant quantities. Miles (1976) showed the disastrous effects on water surface gradients in fen drainage channels that failure to remove weed growth can produce.

In many fisheries, without some form of careful weed control to provide clear "swims", successful angling can become impossible. The invasion of emergent weeds into shallow channels encourages siltation, often to the detriment of a fishery. Kelsall (1981) describes how dense "jungles" of submerged weed will extract oxygen at night from the water through respiration in sufficient quantities to cause distress to fish populations.

It can be seen therefore that there is an enormous variation in the need for aquatic weed control, both regionally and between different categories of watercourse. This results in a corresponding difference in the extent of weed control operations carried out (see Table 2).

Table 2
Regional variations in the extent of Aquatic Weed Control.

Water Authority River or Land Drainage Area	Total length of maintained watercourses (km)	Artificial or embanked channels as a proportion of total (%)	Proportion of channels on which regular weed control is practised (%)
Anglian Water Authority	6592	18*	60*
North West Water Authority	3527	9	3
Severn Trent Water Authority	3500*	10	95
Southern Water Authority	2765	17	76
Wessex Water Authority	2355	25	25
Yorkshire Water Authority	1724	58	23
Forth River Catchment	560	3	2*
Tweed River Catchment	800*	14	1*
Middle Level Internal Drainage Districts	950*	100	100
Welland & Deepings Internal Drainage District	669	100	100
Southern W.A. Internal Drainage Districts	940	100	100
Middle Level Main Rivers	176	95	90

*Estimated figure

CHOICE OF METHOD

In making a decision on the method of weed control to be employed on a particular channel, an engineer has to consider a number of factors, including:

i The degree of control required
ii Species spectrum of target plants
iii Ease of access to the watercourse
iv Attitude of the Water Authority to the use of herbicides
v The presence, if any, of rare or protected plants

Hand cutting

The traditional methods of handcutting using scythes and shears have been in use for hundreds of years and are still widely used. Whilst this method of cutting is decreasing, it is somewhat surprising that it survives at all in these highly mechanised times, particularly since it is probably the most expensive method of control.

The answer to its continued use however, lies in the fact that hand cutting can be employed at any time of the year. In watercourses where herbicides cannot be used, or where this use would be unsuitable, access to the channel sides with machinery in arable farming areas is often difficult or impossible during the summer. It is during the summer period however, that growing crops are at their most vulnerable to flooding or waterlogging, and consequently land drainage engineers in particular are most keen that weed clearance should proceed without delay. The most recent examples of weed cutting machinery to come on to the British market have been designed with access problems in mind, and it is the introduction of these machines that may well result in the final disappearance of hand cutting as a viable method of control.

Mechanical cutting and removal

For the past 15–20 years mechanised cutting of aquatic weeds has meant either the use of weed cutting boats or weed cutting buckets mounted on to hydraulic or dragline excavators. These machines are often supplemented by tractor mounted flail mowers to cut bank vegetation above the water line.

In common with hand cutting, mechanical cutting of weeds has the effect of stimulating the regrowth of vegetation, particularly with perennial plants. As a result it is often necessary for the cutting operation to be repeated at least once, and in many cases twice or even three times during the growing season. Consequently whilst mechanical cutting is invariably cheaper than hand methods, the annual costs can still be very high.

As has been mentioned earlier, access to watercourses for land based machines in arable areas can present difficulties, and in addition problems often arise in the disposal of cut weeds removed from the channel.

The disposal problem is particularly acute with filamentous algae *Vaucheria spp*, the notorious Fen cott, which cannot be placed on adjoining arable fields, since, unlike other vegetation, it is extremely slow to decompose and will remain in fibrous mats for anything up to three years.

Filamentous algae are also hazardous to weed cutting boats which are unable to make progress through the dense floating blankets, and in these conditions the cutting mechanisms are totally ineffective. Since cutting is impractical the only mechanical method of dealing with filamentous algae is removal by specially constructed buckets, known as cott rakes, mounted on to excavators.

Apart from disposal difficulties already described, it is not possible to physically remove all the algae from the channels, and the remainder will quickly multiply to reinfest the waterway.

Price (1981) describes in detail the comparative advantages and disadvantages of individual weed cutting machines in regular use in Great Britain, together with more advanced machines recently developed in Holland and West Germany. These machines have been designed to overcome the problems of access in arable areas.

The first is a four wheeled vehicle fitted with two reciprocating cutter bars, and which operates within a small drain straddling the waterway. Cut weed is removed from the channel by a mechanical rake mounted on the same machine. The machine is extremely fast in operation compared with the traditional machines and is capable of speeds in excess of 400m/h. The second machine is a bicycle type tractor with a stabilising wheel mounted on an hydraulic arm situated on the channel batter. The machine carries a long reciprocating cutter bar and a rotary weed rake to remove the cut weed. The operating speed of this machine is extremely fast, clearing half the growth from a small channel at a rate of 1600m/h.

Within the limits of those channels for which these new machines are suitable, it is clear than they are likely to be of great benefit, particularly to Drainage Authorities, in reducing costs of weed control.

Aquatic herbicides

The introduction of aquatic herbicides over 20 years ago, and the development of improved products in more recent years, has had a marked effect on aquatic weed management, particularly in land drainage channels. Where access to watercourses was restricted by arable crops, they became an obvious alternative to hand roding in order to provide open watercourses during the summer.

Their success has been due, not only to their general efficacy, but also to the cost effectiveness of their use.

Aquatic herbicides, in common with agricultural products, require clearance under the Pesticides Safety Precautions Scheme (PSPS). The scheme consists of a formal agreement between Industry and Government under which manufacturers provide all necessary data to enable potential risks arising from the use of herbicides to be carefully assessed and appropriate safety precautions defined.

Full clearance, when given to a product, indicates that when it is used in accordance with the instructions displayed on the product label, it is considered safe for use in *all* categories of water.

Following PSPS clearance most products are submitted to the Agricultural Chemicals Approvals Scheme (ACAS), which is a voluntary scheme operated by the Departments of Agriculture in the UK to enable users to select appropriate proprietory brands of herbicide for their particular requirements and to discourage the use of unsatisfactory products.

For the users of herbicides, the Ministry of Agriculture, Fisheries & Food have published "Guidelines for the use of herbicides on weeds in or near watercourses and lakes" (MAFF, 1979).

Bearing these facts in mind, it is regretted by many users and potential users of herbicides that many Water Authorities in England and Wales ban them in potable water supply channels and discourage their use elsewhere.

The attitude of the Water Authorities has had, in recent years, an adverse effect on the development of new aquatic herbicides.

The ever increasing volume of test data required in obtaining clearance under PSPS has resulted in a rapid escalation of the cost of getting a new product on to the market. With the prospect of sales of that product being limited to use in non-potable water, there is little chance of the development costs being recouped from sales in the UK. Therefore, unless there are expectations of large worldwide sales, or a dual role of the herbicide in agriculture as well as in aquatics, then it is unlikely that development will be undertaken. This is a pity since in many ways herbicides have a less damaging effect on the aquatic environment than mechanical maintenance methods. Wade (1981) states that, contrary to popular opinion, "the use of aquatic herbicides over the past 20 years has had very few deleterious effects on the status of aquatic machrophyte species in Great Britain either nationally or regionally".

From an efficiency point of view herbicides are more suited to the requirements of land drainage engineers than mechanical methods. Whereas cutting of vegetation tends to stimulate regrowth, chemical treatment either kills completely or drastically reduces and weakens any regrowth. The use of herbicides in the early stages of growth not only prevents flood hazards developing through dense weed growth, but also renders unnecessary the cost and difficult problems associated with cut weed removal and disposal.

Nevertheless, there are practical problems faced by engineers in the use of herbicides. Most of the present range (Table 3) require virtually still water conditions. Unexpected water movement following heavy rain can either delay treatments or ruin treatments already carried out. The modern agricultural practice of overhead irrigation is causing problems in many drainage districts where the supply pumps can cause sufficient movement of water to affect herbicide treatments as much as 4 km away.

Only one cleared herbicide, terbutryne, will control *Vaucheria spp*, and even with this product it is classified as moderately susceptible. Unfortunately terbutryne is unsuitable for use in watercourses with an organic substrate.

The present range of herbicides for the treatment of submerged weeds and algae also suffer from the fact that treated water is unsuitable for overhead crop irrigation for at least one week and can, in the case of chlorthiamid, be as long as four weeks. Most of the herbicides are comparatively slow acting and consequently require near still water conditions in order to be thoroughly effective. Table 4 shows the comparison between the currently available herbicides.

Table 3
Herbicides cleared for use in or near water

Chemical	Type of application	Commercial clearance status	Approved under ACAS	Max. flow rate of water-course	Time of application	Plants controlled
Asulam	Foliar spray	Provisional	No	N/A	July/ August	Waterside plants, Bracken, docks
Chlor-thiamid	Granules into water	Provisional	Yes	90m/h	March/ April	Some sub-merged and floating weeds
2,4–D amine	Foliar spray	Full	Certain products	N/A	Early summer to September	Emergent broadleaved weeds and weeds on banks
Dalapon	Foliar spray	Full	Certain products	N/A	Spring to late summer	Reeds and some emergent mono-cotyledons
Dichlo-benil	Granules into water	Full	Yes	90m/h	Early spring	Some floating and submerged weeds
Diquat	Foliar spray or into water	Full	Yes	90m/h	Through-out the year	Some floating and submerged weeds and algae
Diquat alginate	Viscous gel direct to water	Full	Yes	1800m/h	Late spring early summer	Some floating and submerged seeds and algae
Fosamine ammonium	Foliar spray	Provisional	No	N/A	July/ September	Some deciduous woody plants
Glypho-sate	Foliar spray	Provisional	Yes	N/A	July/ September	Water lilies, reeds and emergent weeds
Maleic hydrazide	Foliar spray	Full	Certain products	N/A	March/ September	Suppression of grass growth on banks
Paraquat	Foliar spray with Dalapon	Full but poison rules apply	Gramo-xone S only	N/A	Spring to late summer	To enhance action of dalapon on reeds
Terbu-tryne	Granules into water	Full	Yes	20m/h	April/ May	Some floating and submerged weeds and algae

Table 4
Time required for effective control, and minimum safe period before use of water for irrigation

Herbicide	Still water period required for effective treatment (days)	Minimum period between treatment and irrigation use (days)
Terbutryne	7–12*	7
Diquat	½	10
Diquat alginate	Nil	10
Dichlobenil	7	14
Chlorthiamid	7	28

* 12 days required for moderately resistant species

The introduction of diquat alginate this year has provided for the first time a herbicide that can deal with submerged weeds in water flowing faster than 90m/h. The herbicide is formulated to contain diquat in a viscous solution which is sprayed on to the water surface. On contact with water the solution gels and sinks on to the submerged weed where it sticks to the foliage. In flowing water the gel is broken down into small strings which are distributed amongst the biomass. This herbicide is particularly suited to situations where localised treatments of weed clumps are required.

Biological control

Where watercourses pass through grassland, cattle and sheep grazing can be an efficient method of controlling emergent weeds at the water margins. This can only be achieved on unfenced banks and the trampling of the waters edge can have a deleterious effect on the channel which will outweigh the benefits of weed control.

A great deal of experimental work has been undertaken into the use of herbivorous fish, namely Chinese Grass Carp (*Ctenopharyngodon idella*) for the control of aquatic weeds. Numbers of fish are now being released in certain limited locations to test the effect of their grazing. It is thought that the chance of ecological damage occurring is slight, and in the UK climate these fish are extremely unlikely to be able to breed naturally.

Shading

The use of shading of a watercourse using hedges and trees planted on the southern banks is used extensively in Northern Germany and in other parts of Europe. The reduction of light reaching the water surface discourages the growth of water plants.

Dawson & Kern-Hansen (1979) have shown how shading can be used as a management technique. It is plain that on many watercourses such a plan can be used to good effect although the disadvantages arising from restriction of access and the accumulation of leaf and wood litter must be taken into consideration.

STATUTORY OBLIGATIONS

Water, navigation and drainage authorities as well as private and municipal managers of amenity waters are bound by a number of Acts of Parliament relating to their various functions.

Water Authorities and water companies have obligations under The Water Act 1945 to protect the quality of water abstracted for public supply and to supply only wholesome water. They also have to take steps to protect fish life under the requirements of the Salmon and Freshwater Fisheries Act 1975. The Control of Pollution Act 1974 extends wide powers to Local and Water Authorities. Part 2 of that Act required the Water Authority to be consulted whenever herbicides are to be used in water entering a river system.

The Wildlife and Countryside Act 1981 has added new responsibilities for all authorities to take into account the conservation of wild plants and animals when considering the management of watercourses generally. The Act enables the designation of Sites of Special Scientific Interest which may be watercourses or lakes. Where a watercourse is so designated its management must be agreed with the Nature Conservancy Council with a view to avoiding damage to the special interests of that particular site.

On the other hand Navigation authorities and Drainage Boards have responsibilities under numerous Navigation Acts and the Land Drainage Act 1976 to ensure that their watercourses are maintained in a fit state to fulfil their primary function.

Difficulties are expected to arise where the requirements of these Acts conflict with interpretations of the Wildlife and Countryside Act 1981.

Finally, the Conservation of Wild Creatures and Wild Plants Act 1975 which has been re-enacted by the Wildlife and Countryside Act 1981 lists very rare plants which it is an offence to destroy.

COSTS OF WEED CONTROL

Figures for the cost of aquatic weed control are not readily available but I estimate that in England and Wales the total cost at today's values would be in the order of £11 million annually. An approximate break down of this figure is as follows:–

Drainage Boards	£4 million
Water Authorities	£4.5 million
Other	£2.5 million

Whilst these figures are only a broad estimate, they do provide an indication of the size of the operations on a national basis.

The comparative costs of various types of weed control are very difficult to assess. Much will depend on the quantity of weed present in a watercourse, problems of access, the depth and width of watercourse and many other factors. In an effort to arrive at an equitable comparison, I have produced two tables (Tables 5 & 6) which compare costs for different methods given identical tasks. Figures shown are produced from costings provided by a number of drainage authorities in the South and East of England.

ENVIRONMENTAL ASPECTS

Irrespective of conservation legislation most managers of watercourses are keen to preserve wildlife habitats as far as possible within the limits allowed by their responsibilities, to ensure that the channels under their control carry out their proper function. This is clearly a much easier task in upland areas and in natural rivers and streams elsewhere. In fenland drainage districts and in channellised lowland rivers, where the channels have precise engineering functions, the opportunities are more limited. Nevertheless many authorities do take specific steps to aid conservation. In my own Authority's area for example, efforts are made to provide nesting sites for water birds by leaving isolated clumps of emergent weeds along the fringes of larger channels, the commencement of bank mowing is delayed until the ground nesting birds have reared their young, and redundant sections of drain are specifically managed to provide suitable spawning areas for fish. No aquatic weed control is carried out unless it can be properly justified.

The Wildlife and Countryside Act 1981 lays down hard and fast rules for the management of watercourses within Sites of Special Scientific Interest; but without a general awareness and a willingness to enhance the natural environment on any site wherever possible, the Act will not have achieved its purpose. It would be helpful if there was a better understanding on the part of conservationists, the public and the media, of the statutory responsibilities and the technical problems faced by river management authorities and drainage boards.

FUTURE PROSPECTS

Major strides have been made in recent years, sadly not in the UK, in the development of new sophisticated aquatic weed control machinery which will overcome some of the outstanding difficulties currently facing water engineers.

In many situations weed cutting is an inefficient way of removing weeds from drainage channels, acting as a stimulant to growth as well as being comparatively costly. It can also be argued that the removal of cut weed and its deposit, together with large populations of invertebrates, fish fry and other

Table 5
Comparative costs of controlling 2m wide fringe growth of reeds on one side of large water-course

Method of control	Cost of single treatment/ km (£)	Remarks
Weedcutting boat with dragline at intervals to remove cut weed	40	Maximum of two cuts for full control. No access problems
Hand cutting – weed raked to bank top	150	As above No access problems
Weed cutting bucket mounted on hydraulic excatator	120	In arable areas one cut only after harvest, unless compensation paid
Bicycle tractor with cutter bar and weed rake	50	Based on figures from one UK user only
Tractor mounted spray using glyphosate	25	Access problems in August where root crops are present
Hand spraying using glyphosate	30	No access problems but even application is difficult
Helicopter spray using dalapon	63	No access problems. 150 km can be completed/day

Table 6
Comparative costs of controlling submerged weeds in a drainage ditch with water width 3m/depth 1m

Method of control	Cost/single treatment/km (£)	Remarks
Weedcutting boat with dragline at intervals to remove cut weed	50	Usually 3 cuts/season required in drainage channels. Not suitable where piped culverts are present
Hand shearing and removal	175	2 to 3 cuts required in drainage channels. Labour intensive and slow
Weedcutting bucket on hydraulic excavator	140	Problems of access during summer in arable areas
Berkenheger 3001 wheeled excavator working within the drain profile fitted with cutters and rakes	100	Very fast and thorough. Limited to certain sizes of channel
Herbicide granules (dichlobenil)	86	Easy to apply. No weed removal. Single treatment lasts for year
Herbicide granules (terbutryne)	82	As dichlobenil but still water essential. The only herbicide effective against *Vaucheria spp.*
Liquid herbicide injection (diquat)	80	Contact herbicide Some problems of regrowth
Removal of filamentous algae by dragline excavator with cott rake	300	Expensive. Problems of disposal and regrowth

fauna on to adjoining land is not in the best interests of nature conservation. The early use of appropriate aquatic herbicides would seem to offer the prospect of controlling the weed without damaging other life. Unfortunately, the present range of cleared aquatic herbicides do not cover the full range of requirements. At present there are no herbicides for the following:–

i To control perennial submerged weeds and the more resistant filamentous algae in flowing water or in channels where flow can only be stopped for short periods.

ii Herbicides of all types with a rapid rate of chemical degradation allowing treated water to be safe for irrigation use much more quickly than at present (See Table 4).

iii Herbicides for the control of emergent plants in the early stages of growth.

iv An efficient algicide capable of controlling *Vaucheria spp.* and other resistant forms of filamentous algae, which is also effective in channels with an organic substrate.

It is clear however, that such new products are unlikely to be developed unless there is a prospect of a much wider use of aquatic herbicides. Such a wider use will only come about if there is a drastic change of attitude on the part of Water Authorities.

Until this happens there will be a heavy reliance on the use of cutting machinery which at present, despite comparatively high unit costs, is the method employed on about 85% of all aquatic weed control work.

CONCLUSIONS

It is generally agreed that in most watercourses, lakes and ponds the presence of aquatic vegetation of one kind or another will at some time run contrary to man's interests to a greater or lesser degree. Where this occurs it is desirable that the water engineer should take action to correct the problem.

Natural rivers and streams, together with lakes and other amenity waters are able to tolerate much greater quantities of water plants than those channels which perform a land drainage or flood prevention function. Consequently standards of vegetation control will be vastly different. Drainage and flood prevention watercourses are engineering structures and must be maintained as such. Very little weed growth can be allowed in these channels.

Despite the development of new improved weed cutting machines, there remains a pressing need for a wider range of aquatic herbicides than are presently available, but the prospects of this materialising are not good. Biological methods of weed control and shading of watercourses may be of use in the future but are unlikely to be widely used. In the meantime, the increased use of the current range of aquatic herbicides would improve the efficiency of weed control operations and greatly reduce costs.

When the optimum use is made of all types of vegetation control methods that are available, the benefits in both economic and environmental terms will be considerable.

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DISCUSSION FOR MR CAVE

Mr Small Referring to the use of Chinese Grass Carp, what happens when the fish have cleared the vegetation on which they are feeding, and what effect do they have on populations of other fish?

Mr Cave (Speaker) The Grass Carp can be managed in the same way as a flock of sheep on land. That is they can be brought to a watercourse, left there for a period, and then, when they have done the job, moved on somewhere else. Grass Carp are herbivores, and there has

been no evidence from experiments carried out over the last fifteen years that they affect other fish. It is virtually impossible for them to breed naturally in this country, because water temperatures are too low, so that they have to be reared under artificial conditions.

Sir Ralph Verney Could Mr Cave elaborate further on the question of the use of herbicides and of biological controls for weeds in watercourses. It is very attractive to develop chemicals and they can be varied enormously, but there is considerable uncertainty in the Water Authorities, and particularly by their lay members, about the safety and use of chemicals. Is there no scope for control by ducks, geese, invertebrates or fungi, which would be more acceptable to lay opinion. Is there not a case for putting more resources into research into biological control rather than chemicals?

Mr Cave (Speaker) Generally speaking the professional staff of water authorities, who have gone into the subject of the use of herbicides deeply, are not hostile to them. It is people who speak from the heart who tend to argue against herbicides without thorough knowledge, and it is a bit disturbing that emotional decisions are being taken that affect practical situations. At the same time drainage authorities live by their rates, and must do everything reasonable to make their operations as cost effective as possible.

The trouble with ducks and geese, and invertebrates, and that type of thing, is that with drainage channels one is looking after engineering structures which must be maintained to a standard to enable them to function properly. It is very difficult to use biological controls to give a guaranteed result, but I agree that more resources for research are certainly required.

Mr Guiver There are other reasons than water authorities's objections to the use of aquatic herbicides in potable water supply rivers and reservoirs, that have restricted the development of potentially effective products. The herbicides that are available do not eliminate the problems, for instance, of having to remove dead emergent weeds mechanically. Nor do they prevent the colonisation by unsightly algal growth of waters cleared of submerged weeds. Thus, even some land drainage engineers themselves have not adopted the use of herbicides because they are not wholly effective.

In any case it seems doubtful if the market for herbicides could be made much larger to justify the cost of their development (compared to their terrestrial uses), even if there was scope for use in potable water supply rivers.

Briefly on the use of Grass Carp, much work is still needed, and they should not be considered as the solution to all aquatic weed problems. A combined approach is probably needed for the future, with proper consideration being given to all three methods of weed control: mechanical, chemical and biological.

Mr Spencer-Jones In answer to earlier comments where the attitude of water authorities was said to have restricted the use of aquatic herbicides. Some authorities are relaxed and most co-operative, whilst others, as a matter of policy, altogether refuse to use them. Potential markets, which are very difficult to assess, owing to the lack of statistical data are inevitably affected.

All aquatic herbicides now cleared for sale through the Pesticide Safety Precaution Scheme (PSPS), have a worldwide large volume market on major agricultural crops, such as cereals, maize, cotton, rice, etc. Their additional development for aquatic use helps to cover the astronomical costs of toxicological testing, and companies increasingly are having to get the greatest 'mileage' out of each and every compound in order to obtain an economic return. If Water Authorities have a hardened attitude to the use of chemicals, this additional development is not encouraged.

There is also a need to avoid a 'them and us' attitude over herbicides. Herbicides, machinery, Grass Carp, shading – these are all tools of the trade, should be regarded as such and their use integrated. Herbicides are now being used in an increasingly sophisticated and responsible manner; an example is the 'Weed Wiper' for glyphosate, which provides control of emergent monocots, without the risks of spray drift, or of the herbicide even entering the water.

Dr Green The weed infestations shown in the slides as being representative of typical problems, all appear to be in highly eutrophicated waterways. Under more natural, less nutrient rich conditions the populations of these plants would be much smaller.

Isn't the management thus dealing with a symptom of the problem, and not the cause? In many places such eutrophication would be largely attributable to runoff of agricultural fertiliser. Why not control this? Are there not powers under the 1974 Control of Pollution Act?

If this is not possible, what about the possibilities of biomass harvesting as described by Professor Last in the first paper?

Mr Cave (Speaker) There was a study commissioned by the Department of Energy a few years ago at Sheffield University, to look into the question of using the biomass from aquatic weed control operations. The conclusion was that it was an impracticality. The problem is one of logistics, of getting the material from the site cheaply to a place where it can be converted into energy.

Mr Robson The control of submerged weeds with Grass Carp has considerable promise in some situations in the UK, as a background control agent supplemented with cutting or herbicides as required. In the Netherlands, use of these fish in this way is claimed to have reduced maintenance costs by 40%.

Classical biological control with insects has been successful to a limited extent in warmer countries on alien (introduced) weed species – e.g. on water hyacinth in the USA – using insects collected from stands of the plant in its country of origin. In Britain the mixed plant communities that we have, do not lend themselves to this kind of management, because as one plant is removed it is replaced by another, which may not be attacked by the same insect as the first species.

GRASSLANDS and HERBACEOUS

Management of Herbaceous Vegetation for Amenity and Recreation

W. N. G. Gilmour
Association of Metropolitan Authorities

When I agreed to present this paper giving some indication of the way in which we do or could make provision for natural or semi-natural herbaceous vegetation, the brief which I was given included the request to give some indication of the extent of each area presently managed by local authorities. This statistic was to exclude formal grass areas such as football fields. I do not know if such a statistic is available but I have not been able to trace one. Indeed it is difficult to be sure that such statistics as are available, for such classifications as 'Public Open Spaces' are all for the same kind of area.

The local authority, especially in the urban areas, is faced with the problem of having to provide for the majority of its ratepayers a standard of maintenance which is acceptable to them and to do so with an ever decreasing work force. This decrease in the number of employees over the years has been necessary in order to cope with the financial constraints placed upon local authorities both by central government and by the ratepayers.

The consequences of the reductions in manpower may be seen in the modifications which have taken place in parks and open spaces. They are generally changes to enable the area to be maintained by mechanical means.

Whatever the changes, when it comes to grass lands, and these must make up the largest proportion of natural/semi-natural herbaceous areas, there is no doubt that the majority of city dwellers demand that the grass is maintained in a mown condition – "That's what we are paying our rates for" is the oft heard statement if the grass is not mown to an acceptable level.

One should remember that to many thousands of people the areas of public open space around their dwellings is the nearest thing they will have to a garden and they expect to see it looking as though it belongs to them.

An unmown area is a piece of 'waste land' that does not 'belong' to anyone. It is a good place on which to get rid of rubbish.

Rubbish requires hand labour and vehicles to clear away and so it is cheaper to mow the grass in the first place.

Uncut grass areas also present a fire risk. One statistic which I do have is that in South Yorkshire during 1980 there were 1,162 grass fires and in 1981 1,061. The cost of dealing with these in terms of fire brigade cost is that one fire tender turned out for one hour costs £40 per hour. That is the cost over and above the cost of maintaining the unit on standby. To this can be added the costs of replacement of damaged property such as fences and trees.

Having said all that there are still some places and some ways in which the local authorities can encourage and positively plan for areas to be maintained to give natural or semi-natural effects.

In the organisation of mowing large grass areas, the larger the area cut in a single pass of the machine is generally the cheapest method. Large machines are, however, more difficult to manoeuvre especially into and out of sharp corners or through areas of young trees. It is, therefore, worth considering leaving difficult areas such as these and bankings unmown during the normal mowing cycle.

Some 'formal' sports areas require that certain areas be treated in this way. I have in mind the 'roughs' of the golf courses where a variety of different management programmes is not only acceptable but positively encouraged to give a variety of interests to the courses.

The traditional spring bedding displays have in many instances been replaced by large areas of naturalised bulbs such as crocuses and narcissi. In order to allow the bulbs to regenerate naturally the foliage must be left uncut until the latter half of June at the earliest. This enables many areas to develop a different flora from that of the general mown areas.

Woodlands as such are being dealt with in a separate paper but the floor of the woodland is another obvious area where the encouragement of natural vegetation is acceptable by the city dweller, though some plants such as the bluebell may need a positive protection programme in order that they may survive.

Another kind of area that has some potential for maintaining in a 'natural' state is the disused burial ground but even here the public prefer to see these in a 'maintained' state. The result of this is that more and more of them are being cleaned up and levelled so that they can be machine mown. The actual cleaning up is being carried out through the encouragement of the central government to use Manpower Services funds to employ men on hand labour type schemes of a creative nature. Schemes of a recurring maintenance nature are not acceptable!

On the fringes of the urban areas or in the rural areas it is less difficult to adopt a 'natural' approach to the management of grass areas. In Country Parks it is, for example, in keeping with the area to maintain by grazing and, by the selection of different animals, to have different pastures.

If maximising income is not an important criteria (with some authorities it is) then the grazing need not be of best quality grazing grass mixtures or be boosted with fertilizers. It is possible to arrange for such areas to be grazed by

local farmers at minimum cost to the farmer and also to build into the licence the right for the authority to use the fields for other purposes from time to time during the year.

Also in association with Country Parks some fields or parts of them can be cropped in the historical way, allowing the poppies to bloom and perhaps even re-introducing some of the other weeds of the arable fields killed out by the requirements of modern farming methods. Crops grown in such a way can be hand harvested and then threshed using the old mechanical methods thus providing a spectacle of living history.

Within Country Parks and like areas there is the possibility of setting aside areas to be managed as nature reserves. In these areas a variety of management programmes and techniques can be set up. Besides the ultimate results giving interest to the visitor to the park, the programmes and techniques themselves can provide a source of interest. These can be the basis for informative displays, leaflets and part of guided tours.

Within the urban areas small areas within school grounds can be similarly developed as nature reserves and here they can form part of the natural history studies within the school.

The creation of new open spaces from derelict and degraded areas is presenting the opportunity to experiment with the creation of different swards using new cultivars and minimum top soil. The establishment of these swards though slow is encouraging, but only time will tell if they are able to withstand the pressures that future use may demand of them.

From the point of view of the person interested in encouraging a diverse flora in a grassland situation it is, unfortunately, the case that the gang mower is the cheapest method of ensuring that the sward is maintained as the public generally wish to see it. It is also one of the most simple methods so far as training and supervision of staff is concerned. It should be appreciated that even with our present high level of unemployment there is little incentive financially or otherwise for men to accept manual work. The basic rate of pay for a manual worker with a local authority is £69.60 per week. Add to that the requirement for the authorities to employ as few men as possible and one can perhaps understand some of the difficulties facing the manager who wishes to adopt methods of maintenance other than routine mechanical mowing.

DISCUSSION FOR MR GILMOUR

Mr Small It was mentioned that the amenity areas were being managed for people, have you been able to enlist their support in any form of work force?

Mr Gilmour (Speaker) Yes, we engage the voluntary corps who are keen to come in and do some of the management work, and we can get small areas treated in this way. But it would not be possible to use voluntary labour for the bigger jobs. We have something like 300 volunteer 'footpath' wardens, who take part in a scheme to walk and report on things that

are going wrong, such as farmers ploughing where they shouldn't; or where things need doing, such as mending drains or stiles.

Other opportunities arise from the Manpower Services Commission schemes (MSC). We can get people from the MSC, but only for new work. We are not allowed to use them for maintenance. The problem here is that in a sense we are increasing our own difficulties by tidying up areas that we are not able subsequently to maintain. There is a wonderful sense of creation when people go in and do something, and frustration when they go back twelve months later and find that it has not been maintained.

Mr Lucas (Chairman) Do formalised Victorian parks really represent what people want now, or have tastes totally changed?

Mr Gilmour (Speaker) Over a period of time people will accept a certain standard, and come to think of that as normal. But if you show them how it could be improved they will appreciate it. One of my last slides was of a park in Holland where the Dutch people go in their thousands in the spring time, and pay to go in. If one was able to offer people something like that round their flats, rather than just monotonous green grass, or a wilderness of banking, then I am sure that is what they would prefer.

Mr Parker What is the attitude of staff towards the areas of unmown land that you are leaving around the edges of parks and playing fields, and do you save any money by leaving these areas unmown?

Mr Gilmour Where you have got a resident man, at a school for example, his attitude will be that to leave these areas to go wild is deplorable. But the number of places where we can afford to have a resident man or team is decreasing rapidly. We now depend more on mobile gangs, who move around from one school or housing site to the next, and there is no personal involvement.

But the other dilemma is that it is very difficult to explain to staff what you are trying to achieve, and with some of the unskilled labour to apply the more sophisticated management techniques that are being proposed.

Professor Moore In the course of carrying out a study on the effects of building a small new town in Cambridgeshire on the local fauna and flora, I have noticed that children have quite different requirements from grown-ups. It is very striking how children always make for places where there are still big trees, big slopes to run up and down on, and so on. Are you able to cater deliberately for the needs of the different age groups. What do you actually do?

Mr Gilmour (Speaker) I think the short answer is 'Yes', we do try and cater for the different age groups. It is a constant struggle really between designing a housing estate, and trying to put into it what you think the children will want and use. It's very nice if you have banks, and mature trees, and especially water. So you try to provide water, and leave areas for the children, and trees where they can put ropes and be able to swing about on them.

Management of Herbaceous Vegetation on the Sides of Roads and Motorways

A. P. Dunball
Department of Transport

CLASSES AND MILEAGE OF ROAD: TRUNK ROADS AND COUNTY ROADS

In 1937, with the passing of the Trunk Road Act, 4,500 miles of main road were lost to local authorities and became the direct responsibility of the then Ministry of Transport. These roads were the main arterial routes considered of national importance and essential for the economic life of the country. Subsequently, Central Government has retained responsibility for the development and maintenance of trunk roads.

From the mid 1950's the trunk road network has been enlarged and improved, and the motorway system has been developed – motorways being trunk roads where special design standards and traffic regulations apply. Additionally, since the passing of the Trunk Roads Act, the responsibility for roads in Wales has passed to the Welsh Office.

As at 1st April 1980 there were 6,210 miles of trunk road in England (which includes 1,335 miles of motorway). The increase in trunk road mileage between 1937 and 1980 does not represent the mileage of new road constructed as, where existing trunk routes are replaced by entirely new roads, the former lose their trunk road status and become the responsibility of the local Highway Authority.

Prior to 1st April 1967, the non-trunk roads – which are the responsibility of the local Highway Authority – fell into four categories: Class I, Class II, Class III, and Unclassified – the Classified Roads being supported by Government Grant for improvement and maintenance at rates of 75%, 60% and 50% respectively. The Local Government Act 1966 defined Principal Roads (roughly equivalent to the Class I Roads), Classified Non-Principal Roads and Unclassified Roads. As at 1st April 1980, the mileage of these roads in England was 15,259, 49,016 and 90,260 making a total of 154,535 miles of non-trunk road and an overall total of 160,745.

EXTENT OF VERGES AND MARGINAL LAND

Most roads have grass verges to accommodate drainage, underground public utilities and to provide passage for pedestrians. They are also needed for the storage of snow displaced from the carriageway and to accommodate signs, lighting columns and other street furniture. Verges are not merely marginal land, but form part of the design of a road and the Department of Transport's recommended verge widths (Table 1) are contained in the publication "Layout of Roads in Rural Areas" (HMSO, 1968).

Table 1
Layout of roads in rural areas. Recommended verge widths (HMSO, 1968)

Type of road	Recommended kerbside treatment	Minimum kerbside treatment
Dual carriageway and three-lane single carriageway roads	3.50m verge comprising edge lining on hard strip 1.0m wide and remaining width grassed	2.0m verge comprising edge lining on hard strip 1.0m wide and remaining width grassed
Two-lane single carriageway roads with a design year flows exceeding 6000 pcu's/day *	3.50m verge comprising edge lining on hard strip 1.0m wide or kerbs and remaining width grassed	2.0m verge comprising edge lining on hard strip 1.0m wide or kerbs and remaining width grassed
Two-lane single carriageway roads with design year flows between 3000 and 6000 pcu's/day	3.50m grass verge: edge lining or kerbing not usually required	2.0m grass verge: edge lining or kerbing not usually required
Two-lane single carriageway roads with design flows under 3000 pcu's/day	2.0m grass verge: edge lining or kerbing not usually required	1.50m grass verge: edge lining or kerbing not usually required

On motorways the recommended verge width is 1.50m

*Passenger carrying units

Roads constructed to high design standards have additional marginal land in the cutting and embankment slopes needed to provide satisfactory vertical alignment, and widened verges on curves to give the forward visibility necessary for the design speed of the road. The extent of the total grass areas, as distinct from verges, on roadsides varies considerable from an estimated 18.47 acres/mile on the M3 (Way, 1976) down to virtually nothing on narrow West Country lanes enclosed by Devon banks. Road mileages in England as at 1st April 1980, and estimated areas of marginal land associated with each class of road are set out in Table 2, and Table 3 gives similar information for England and Wales.

Table 2
Roads in England. Mileages and area of marginal land as at 1st April 1980.
Data: HMSO (1981); Way (1970, 1973, 1976).

England	Miles	Km	Average acres /mile	Average ha /km	Estimated total acres	Estimated total ha
Trunk roads	4,875	7,845.3	6.0	1.51	29,250	11,837.0
Trunk road motorways	1,335	2,148.4	12.6	3.17	16,821	6,807.2
Principal road motorways	61	98.0	12.6	3.17	769	311.2
Principal roads	15,198	24,453.1	4.0	1.01	60,792	24,601.6
Classified non-principal roads	49,016	78,881.4	3.58	0.90	175,863	71,169.5
Unclassified roads	90,260	145,255.4	2.7	0.68	243,702	98,622.8
Totals	160,745	258,681.6			527,197	213,349.3
			Totals adjusted to allow for urban streets (minus 16.8%)		438,628	177,506.6

Table 3
Roads in England & Wales. Mileages and area of marginal land 1st April 1980.*

England & Wales	Miles	Km	Average acres /mile	Average ha /km	Estimated total acres	Estimated total ha
Trunk roads	5,894	9,485.3	6.0	1.51	35,392	14,322.8
Trunk road motorways	1,410	2,268.4	12.6	3.17	17,769	7,190.8
Principal road motorways	61	98.0	12.6	3.17	769	311.2
Principal roads	16,724	26,914.5	4.0	1.01	67,171	27,183.2
Classified non-principal roads	56,728	91,292.4	3.58	0.90	203,480	82,345.7
Unclassified roads	99,434	160,020.0	2.70	0.68	268,884	108,813.6
Totals	180,251	290,078.2			593,465	240,167.3
*As Table 2 with additional figures for Wales			Totals adjusted to allow for urban streets (minus 16.8%)		493,762	199,819.2

The total areas in both Tables 2 and 3 have been reduced by 16.8% to allow for urban streets which have no grass verges. This figure is that used by Way (1973) being at that time the percentage of the total road mileage found within the Greater London Council, and in County Boroughs. This figure has not been up-dated, as with the demise of County Boroughs no similar figure is available. However, it would be fair to assume that since the earlier estimates were prepared there has been more road development in rural areas than within towns, so that the figure of 16.8% could be considered as high, and the consequent reduction in the total area unrealistically large.

MAINTENANCE AUTHORITIES AND THEIR FINANCE

The Department of Transport appoints agents to maintain trunk roads and motorways on their behalf, these normally being County, or Metropolitan Highway Authorities. The Department seeks annual estimates from the agent Authorities for the work necessary, and allocates funds at the beginning of the financial year. The funds allocated may fall short of those sought by the agent Authority. The Department of Transport may consider its agents' estimates inflated, or that some of the work proposed was unnecessary. Additionally the Government, through its Ministers, exercises financial control according to its policies, and may well place a ceiling on expenditure far below the estimate of the Department's agents. With the present constraints on public expenditure priority is given to funding the maintenance of the structure of highways to the detriment of routine maintenance operations, such as grass cutting which may not be considered cost effective. On county roads the local Highway Authorities can, in theory, maintain to whatever standard they wish. However, in practice, they tend to follow the pattern set by the Department of Transport for trunk roads and motorways, and with the present financial constraints on Local Government expenditure they would find it difficult to justify higher maintenance standards than those attained by a Central Government Department.

MANAGEMENT OBJECTIVES

All highway management operations must be primarily designed to ensure the proper functioning of the road, and the safety of those using it; but when dealing with roadside vegetation directly, other considerations may have to be taken into account. Disregarding these for the present, one can define the objectives of verge management as follows:—

i To provide full visibility for the drivers of vehicles, particularly at junctions, and across left-hand bends. While the height of the driver's line of sight is regarded as 1.05m, he may be required to see across a left hand bend to the rear light of a vehicle ahead at a height of 0.26m.

ii To prevent the obstruction of signs. While the majority of these are carried at such a height that they are unlikely to be obscured except by overgrown hedges, or the lower branches of trees, tall weed growth could restrict the visibility of signs from a distance when on a curving vertical alignment. It may be necessary to cut the herbage on motorways so that the kilometre marker posts remain visible.

iii To prevent the herbage falling or flopping on to the running surface of the road, thus reducing its effective width.

iv To allow the free passage of pedestrians. Where there are no footpaths it may be necessary to maintain the verge vegetation so that long grass does not encourage pedestrians to walk on the metalled surface of the road.

v To control vegetation in discharge ditches, and on the granular fill of french drains so that their efficiency is not impaired.

While these are the main objectives of herbage management on roadsides, there are others which are not vital for the proper functioning of the road but, nevertheless, are of great importance. In the first place a landlord must behave in a neighbourly manner and consider the interests of adjoining land owners. In this context he will need to control injurious weeds to prevent them from spreading on to his neighbour's land. The Department of Transport requires its agent Authorities to prevent the seeding of the injurious weeds listed in the Weeds Act (1959) should adjoining landowners complain. The weeds proscribed are spear thistle (*Cirsium vulgare*), creeping or field thistle (*Cirsium arvense*), curled dock (*Rumex crispus*), broad-leaved dock (*Rumex obtusifolius*) and ragwort (*Senecio jacobaea*). Additionally, it must be necessary to control weeds such as wild oat (*Avena fatua*) and weed beet (an annual variety of sugar beet) where they are likely to be detrimental to adjoining crops. Roadside vegetation cannot be permitted to harbour diseases which may be of economic importance to adjoining crops – for example, fire blight (*Erwinia amylovora*) on hawthorn (*Crataegus monogyna*) and other rosaceous trees and shrubs where these adjoin orchards, and bacterial canker (*Pseudomonas morsprunorum*) on *Prunus avium* in cherry growing areas. Similarly, vegetation may have to be controlled when it is found to be harbouring rabbits or other vermin which may damage adjoining crops.

While unmown grass may be acceptable in rural areas, in urban and semi-urban situations some regular management is necessary for reasons of visual amenity. Normally an acceptable appearance can be achieved with 8–12 cuts/year, depending on rainfall and the length of the growing season.

The Department of Transport accepts the need to carry out special maintenance programmes on roadside verges of particular botanical interest. In these instances the Department looks to the appropriate County Naturalist Trust to identify such sites and to put forward their recommendations for management. It has always been accepted that a diverse flora on roadsides is desirable; and to encourage this the Department of Transport and its predecessors has strictly controlled the use of selective weedkillers and other chemical sprays. Similarly,

it has always been opposed to excessive grass cutting which favours few broad-leaved plants. The benefits of this policy are obvious to the observant road traveller who cannot fail to miss the large stands of cowslips (*Primula veris*), primroses (*Primula vulgaris*), vetches (*Vicia spp*), cow parsley (*Anthriscus sylvestris*), ox-eye daisy (*Chrysanthemum leucanthemum*), dandelions (*Taraxacum officinalis*) and other showy plants.

MANAGEMENT STANDARDS

Prior to 1975 the Department of Transport set out in some detail the standards to which grass areas on trunk roads and motorways were to be managed. These were not restricted to fulfilling the objectives set out above, but additionally related the standard of management to the type of landscape through which the road was passing. In areas of grazed meadow land regular cutting of grass areas would be encouraged, whereas, where roads passed through woodland, only weed control should be practiced so that the regeneration of woody species would be encouraged. Between these two extremes there were varying standards to cope with differing types of landscape and the demands of visual amenity.

In terms of visual amenity these standards could be regarded as ideal, but in practice they were wasteful in resources. There is no doubt that, with a wide range of grass cutting machinery to hand, many of the Department's agents were maintaining to "produce a neat and tidy appearance" – a standard that cannot be justified. Not only does neatly mown grass appear incongruous in the countryside, but regular mowing severely restricts the number of broad-leaved plant species which can establish themselves in the sward.

In 1975 the Department of Transport issued a new instruction which restricted grass cutting to that necessary for the proper functioning of the road, on the lines set out above. While this was primarily designed to eliminate unnecessary expenditure it also restricted the activities of the tidy minded and was to some extent welcomed by conservationists.

METHODS AND COST OF MANAGEMENT

On roadsides the methods of herbage management are limited to mechanical and hand cutting, and the use of herbicides and other chemicals. While herbage may be taken as hay, and tethered goats and ponies may occasionally be seen on roadsides, grazing is not a practical form of management. For obvious reasons burning cannot be considered as an alternative for cutting.

In rural areas cutting is carried out by the use of flail mowers of one type or another depending on the size of the area involved. As these machines can manage herbage of almost any height, and pulverise the cut material so overcoming the problem of clippings blowing on to the carriageway, they have

virtually replaced other forms of mechanical cutting. Occasionally adjoining landowners may cut verges for hay using the traditional cutter bar, but the presence of litter and other extraneous material likely to affect the palatability of the hay, and even damage the cutting equipment, generally makes roadside hay-making unattractive.

In urban areas Highway Authorities invariably delegate their responsibility for verge maintenance to the local parks department who have a full range of cylinder, rotary and flail mowers suitable for all the site conditions they are likely to encounter.

The chemicals used in the control of herbage are generally grass growth retardants and herbicides. The former are commonly based on maleic hydrazide and when applied early in the growing season will inhibit grass growth for 10–12 weeks depending on the formulation and the amount of active ingredient applied. This material is useful in areas where high quality turf of lawn standard is not required, and yet a short sward is needed. The manufacturers of this chemical have equated the cost of the spray treatment as roughly equal to the cost of cutting grass twice. Where grass only has to be cut to preserve full visibility, and a height of 300mm can be accepted, there would be no financial saving in the use of chemical retardants as this standard can be achieved with two cuts. However, on the central reserves of dual carriageway roads, where lanes have to be closed so that cutting equipment can be operated safely, spraying may have an advantage over cutting. The main disadvantages of this material are the short application period if greatest efficiency is to be achieved, and the amount of water required on motorways and rural roads where no ready supply is available.

The range of selective herbicides available for broadleaved weeds – such as 2,4-D and MCPA with various additives – have an important part to play in verge maintenance. In many areas, once the tall-growing herbaceous weeds have been removed, the grass species can be left uncut as their ultimate height is unlikely to affect the proper functioning of the road. Non-selective herbicides may be used along french drains, beneath guard rails, around the base of lighting columns, signs and other street furniture.

Comparative costs of the different types of management are not readily available; the Department of Transports' agents are required to maintain grass areas to the minimum standard laid down, and the Department exercises financial control through their allocation of monies. It is not possible to isolate the cost of grass cutting as this expenditure is included with other verge maintenance operations under the heading "Grass Cutting, Siding, Hedges and Trees". Siding is the operation of cutting back grass edges to prevent their encroachment on to carriageways or footpaths. On trunk roads the highway boundary, and the hedge – where one exists – is the responsibility of the adjoining owners and the Department of Transport should not incur expenditure on the management of trunk road hedges. Where hedges have to be cut back as they are obstructing the highway, the costs should be recovered from the owner. On motorways the Highway Authority owns the boundary and is

responsible for its management, and hedges were planted on the early motorways (M1 St Albans – Crick; M6 Preston and Lancaster By-passes; M5 Strensham – Lydiate Ash; and M50 Ross Spur). At that time it was proposed that hedges would form the permanent bounday of the motorways – the fences being allowed to fall into disrepair. However, the difficulty of getting really stock-proof hedges in some areas, and the heavy maintenance costs, led the Department to abandon hedges and to rely on fences as the permanent motorway boundary. The management of trees, the final item under this Grass Cutting, Siding, Hedges and Trees heading refers to the management of mature trees. Generally, the maintenance of young trees planted as part of the landscape treatment of new roads is financed from a different source.

Grass cutting and siding probably account for 90% of the expenditure under Grass Cutting, Siding, Hedges and Trees, and the other items all form part of the management costs of the marginal land associated with highways. The national cost of this work for 1979/80 is set out below in Table 4.

Table 4
Roads in England: expenditure on grass cutting, siding, hedges and trees 1979/80.

Class of road	Total (£)	£/mile	£/km	£/acre	£/ha
Motorways	485,888	364	226	29	71
Trunk roads	1,462,634	300	186	46	114
County roads	28,311,000	176	114	58	154

CONCLUSION

The standards to which roadside marginal land is managed – and particularly that on trunk roads and motorways – have since 1975, been reduced to the absolute minimum necessary. The figures shown in Table 4 are for 1979/80 – the last financial year for which full details are available. It is likely that the amount spent in 1980/81 will be considerably less in real terms.

While initially there was some criticism when the amount of grass cutting was reduced, there was not the outcry that many anticipated, and the problems forecast have not yet proved to be so great as to indicate that the current policy is ill-advised. In some areas there has been an increase in the population of injurious weeds, but there has also been an increase in the range of broad-leaved plants generally which can only be advantageous to the aims of conservationists.

The fear that uncut areas will become colonised with scrub and eventually trees, to the detriment of herbaceous species, is a real one, but it is only on motorways and major trunk roads that substantial areas can be left unmown. Reference to Table 2 indicates that the areas of verges and marginal land associated with motorways only represents 3.33% of the total and that on motorways and trunk roads 8.88%. It could be argued that, while there will be a decrease in herbaceous plants, habitats for nesting birds and other wildlife

will be increased. The rate at which hardwood species will colonise is extremely variable and depends on climate, soil types and the presence of propagules. Observations on roadsides indicate that even in favoured situations extensive shrubby growth will only occur after a 10 year period.

It can be argued that a Highway Authority has a duty to manage the marginal land associated with roadsides, so that the original landscape objectives are achieved, and that the relationship between areas of grass, shrubs, and trees should be maintained, and the contrast between enclosure and open views preserved. However, it is doubtful if a Highway Authority is justified in incurring expenditure on the management of land purely to favour herbaceous plants, and to prevent the development of woody species.

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DISCUSSION FOR MR DUNBALL

Mrs S E Wright I am concerned that there seems to be a rejection of the idea of leaving some areas of new motorway and roadside verges free of topsoil, so as to allow natural regeneration of local species of plants to take place. Could not other nearby areas receive compensatory larger amounts (and so a greater depth) of topsoil, since carting surplus topsoil any distance from the construction site is costly. I know that vegetation takes a long time to re-establish, and that we do not seem to be prepared to wait. We ought perhaps to learn to be more patient.

Is the general policy for management of herbaceous vegetation on highway verges to maintain a herbaceous cover, or is natural succession to scrub and woodland being allowed?

Mr Dunball (Speaker) On the question of using less, or no, topsoil. We have done this particularly on the chalk, sometimes at the request of the Nature Conservancy Council, and in other places where the slope is too steep to stick the topsoil on. We do also use varying depths of topsoil: we specify 12 in (30 cm) for areas that are to be planted with trees and shrubs, and 6 in (15 cm) elsewhere. In fact there is a lot of variation because the manner in which the soil is spread does not guarantee an exact depth. However, one cannot spread more than 12 in, because where there is more than that the surface becomes unstable. The

problem is largely one of cost, and of disposal of topsoil from the area of the construction of the carriageway. Nevertheless, I feel that it is an odd concept to do away with topsoil and grow plants on subsoil, even if it is supposed to get a more diverse flora.

I agree that we shall get diversity as a consequence of the progression to scrub that you mentioned. I have accepted in my paper that there are going to be problems with a lot of scrub on certain roads, where the verges have not been mown since the day they were constructed. On the Stevenage by-pass for instance, we are now clearing trees and scrub. We wouldn't want a situation where one travelled all the way from London to Carlisle enclosed by woodland.

Mr Spencer-Jones Should motorway verges be managed as areas for rare or indigenous plants? They cannot be seen by the speeding motorist, who is also prevented by law from stopping. It seems to me that motorway verges are the wrong sort of place in which to try and preserve areas of wild plants.

Mr Dunball (Speaker) The percentage of land tied up in motorway verges, as against that associated with the rest of the road system, is not very great, but there is a great deal of emotive talk about motorways in particular, because people use them a great deal. Nevertheless, if we have got the land, and it is a resource, we should use it in the best way we can. Only one person in the vehicle is driving, and the other one-and-a-half (said to be the average) are likely to be pretty bored. So that if there are interesting plants, and variation between woodland and open fields, so much the better. But again there is the problem of whether an authority responsible for roads and traffic should spend money on creating a diverse flora, or of managing the roads for reasons of amenity, rather than for getting traffic moving.

Mr Lucas (Chairman) We have talked about the flora. Is there a possibility of animal life coming in to such an extent that it becomes a hazard on the motorways?

Mr Dunball (Speaker) No. There is no evidence of that.

Mr Smart It is important to keep in perspective broad considerations other than conservation which should weigh heavily in coming to a general strategy for roadside management. There is a need for policies based on regional characters as the framework for more detailed solutions.

There is also the loaded question of steering, or of educating, public taste. Some problems stem from decisions related to different sets of objectives. Steep, glazed, unstable engineering earth slopes create problems of sward establishment, and produce visually unrelated physical forms, which a more comprehensive solution would avoid by allowing regraded slopes to merge with, and support, the husbandry of neighbouring farms. Pressure to produce instant landscape compresses natural processes and produces less than totally satisfactory results, whilst the motorway speed of travel requires a breadth of treatment which is meaningful against the scale of the motorway.

The Management of Herbaceous Vegetation for Wildlife Conservation

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INTRODUCTION

Herbaceous vegetation mostly created and maintained in the past by the unenclosed pasturing of stock is a resource of considerable importance for the conservation of wildlife and landscape as well as for the provision of informal recreation in the countryside. Such vegetation embraces a wide range of plant communities. They vary from species rich downland and other limestone grasslands over calcareous rendzina soils to species poor heathlands over acidic podsols and meadow grasslands over waterlogged gleys. Gimingham (1972), Duffey *et al.* (1974) and Smith (1981) have described them in detail. All are typified by consisting mainly of short or tall swards of grasses and accompanying forbs, though heathland which is not very heavily grazed or trampled is commonly dominated by bracken (*Pteridium aquilinum*), or by dwarf shrubs, particularly the commoner heathers (*Calluna vulgaris, Erica cinerea, E. tetralix*) and smaller gorses (*Ulex minor* and *U. gallii*).

Although most such grasslands and heathlands are not strictly natural communities, being on land cleared from forest by man and maintained by his stock, they are nonetheless of very considerable ecological interest and importance for wildlife conservation. It is probable that they are close analogues of quite natural ecosystems maintained before the advent of agriculture to Britain by wild cattle (*Bos taurus*), wild horses (*Equus* spp.) and other native herbivores; domestic stock have merely taken over from the wild grazers which are now scarce or extinct. Forest clearance may have greatly expanded the extent of these ecosystems, but they are mostly unsown and justifiably regarded as semi-natural, even though now maintained by human agency. They are the nearest approach found in the British Isles to the steppe and Mediterranean ecosystems of the continental land mass. Many species of limestone grasslands and heathlands are from these continental ecosystems, most, like the early spider orchid (*Ophrys sphegodes*) and Dartford Warbler (*Sylvia undata*), being rarities which only gain a slender foothold in the British Isles.

These ecosystems are also attractive for informal recreation. Large numbers of people use them for picnicking, rambling and many other unorganised activities. A number of factors make them so attractive for these purposes. Limestone grasslands and heathlands are open and dry, their plant communities are aesthetically pleasing, and in areas of predominantly enclosed and ploughed agricultural land they afford rare and welcome access to large tracts of open country. In addition, much of their remaining extent is on hills and escarpments too steep to plough and these positions usually command fine views.

Before the development of modern intensive agriculture after the 1947 Agriculture Act, extensively managed grassland and heathland was a much more important part of the rural economy than it is over most of the country today. Huge tracts of heath, moor and hill grassland were grazed by sheep under systems of traditional pastoral husbandry which were not only important for producing wool and mutton, but for transferring fertility to the arable by folding and manuring. Large areas still survive in the north and west, but, because of their infertility and unprofitability by modern standards, only with the help of hill farming subsidies. Here and elsewhere the great grazing lands of down and dune, moor and marsh are rapidly giving way to improved enclosed pasture or to arable cropland. The loss of these habitats has been documented by Goode (1981). Downland in Hampshire and Sussex has, for example, declined by 20% since 1966 and heathland even more. This loss of habitat leads directly to loss of species, and the fragmentation and isolation of habitats threatens others which require specific habitat features or large areas. In 1930 the snakeshead fritillary (*Fritillaria meleagris*) occurred in 116 10km squares; with loss of meadows it now occurs in only 17. In the last ten years sand lizard (*Lacerta agilis*) localities on southern heathlands have fallen from 159 to 42.

Those areas of herbaceous vegetation which remain, mostly outside the modern agricultural system, are thus of considerable wildlife importance. Amenity grassland, defined as all grassland which has recreational, functional or aesthetic value, but which is not used primarily for agricultural production, has been estimated to cover some 4% of the land surface of the British Isles (NERC, 1977). This includes intensively managed grassland in playing fields, urban parks and domestic lawns, but well over half is extensively managed semi-natural grassland in nature reserves, country parks, commons and other public open spaces, road and rail verges, airfields and golf course roughs. Despite its extent this semi-natural grassland accounted for less than 10% of the total expenditure on amenity grassland management in 1973. This is, of course, in a large part because it requires less management than more heavily used amenity grassland; but this also reflects its lack of proper management. It is one of the great embarrassments of the conservation and amenity movements that many protected areas are scrubbing over fast, losing their open, herbaceous swards and characteristic species under an ever advancing front of rank grass and thorn.

OBJECTIVES OF MANAGEMENT

The functions of herbaceous vegetation in different situations may dictate different management objectives. Relatively short swards may be desirable in golf course roughs to facilitate the finding of balls and to expedite play; rather longer swards may be desirable on airfields to discourage bird flocks and minimise the risk of air strikes. On road verges even taller swards may be tolerated provided they do not threaten sight lines and road safety. In rural country parks, commons and other public open spaces even bracken and some scrub and trees, with the herbaceous vegetation confined to glades, may be thought desirable for informal recreation; though in some more urban situations where assault is considered a hazard, the less cover, the happier the land manager. Likewise on river and sea flood protection walls and berms water engineers are primarily concerned with preventing the ingress of woody species whose roots eventually die and create holes and weak points in the flood defences. In all these situations the protection of wildlife is very much an incidental, albeit important, byproduct, or at least secondary objective, of the land management policy.

In nature reserves, Country Parks, National Parks and other protected areas it is a primary objective. Here the intention will usually be to maintain particular assemblages of plants and animals. These are usually characteristic of herbaceous swards of differing structure. Thus most of the desired plants and many animals of downland are most abundant in a short springy turf, but some butterflies and other insects require areas of taller and ranker vegetation. In heathland managed for wildlife, however, it is usually regarded as desirable to hold the succession at the dwarf shrub stage, for it is an old heather sward which seems to be a critical requirement of rare and characteristic species of heathland like sand lizards and Dartford warblers.

The ecological goals of management are often constrained by a number of factors, particularly cost and feasibility. For these reasons, herbaceous vegetation is often managed at less intensity than desired. Fortunately many species favoured by more intensive management and shorter swards are able to survive, but not flourish, under less intensive regimes. But very few can survive under thick scrub and, once a closed canopy has developed, herbaceous swards can be very difficult to recover. In all cases the minimum objective of management of herbaceous vegetation must therefore be to prevent the development of a closed scrub canopy.

ECOLOGICAL PRINCIPLES UNDERLYING MANAGEMENT

Grasslands and heathlands in Britain are plagioclimax communities only maintained by external agencies such as grazing, mowing, trampling and burning from process of natural succession to scrub and then, finally, woodland. An

understanding of the processes driving these changes and of the mechanisms by which they can be manipulated is essential if one is to control succession in order to maintain open herbaceous ecosystems.

All these agencies arrest succession by two quite different mechanisms. First they act physically by damaging and excluding colonising species more than the species of open swards. Thus woody species such as shrubs and trees with their growing points in exposed apical buds are constantly cut back by grazing, mowing or fire, whereas grasses and rosette herbs with growing points at, or below, ground level can more readily and continuously repair the losses of tissue. Rhizomatous species, such as tor grass (*Brachypodium pinnatum*) and bracken which are, respectively, common colonisers of downland and heathland are susceptible to trampling; but fine leaved grasses like sheeps fescue (*Festuca ovina*) and rosette herbs like daisies (*Bellis perennis*) and ribwort plantain (*Plantago lanceolata*) are more resilient. Some competitive grasses like tor depend upon the build up of a thick litter of dead leaves to suppress other species. Grazing, cutting or fire prevent, or consume, this accumulation.

The second main way by which these agencies favour the species of open swards rather than the colonisers is by maintaining low fertility. The vegetation and soils of limestone grasslands and heathlands are very impoverished, particularly of the major nutrient elements nitrogen and phosphorus. It is this infertility which is largely responsible both for the characteristic species richness of limestone grassland and species poorness of heathlands. More vigorous nutrient-demanding species are constrained, or excluded, by it, allowing a wide range of the typical slower growing and less demanding grasses and herbs to flourish. Heathlands are species poor because not many of these species are adapted to tolerate the toxic concentrations of iron and aluminium which come into the soil solution under acid conditions. Nutrients commonly accumulate with succession, particularly during the shrub stages when nitrogen-fixing legumes like gorse (*Ulex* spp.) invade. If the scrub cover is removed species-rich, herbaceous swards are difficult to restore for the accumulated nutrients favour weedy competitive species like rosebay (*Chamaenerion angustifolium*) and nettles (*Urtica dioica*) (Green, 1972).

Grazing, mowing and fire can all remove nutrients and thus help control the succession by penalising the bigger and more demanding shrubs and trees. Traditional extensive grazing systems were designed as much to pump nutrients to the arable as raise stock. The downland sheep '. . . was held in the highest esteem for its folding quality, for its propensity to leave its droppings on the arable at night, and for its ability as a walking dung cart, robbing the downs for the sake of the tillage, ... ' (Kerridge, quoted in Smith, 1980). Mowing likewise removes nutrients if the cuttings are taken away as hay. So does burning, as much as 95% of the nitrogen and 25% of the phosphorus in the standing crop being lost in the smoke (Chapman, 1967).

Since modern agriculture is concerned with maximising production, and therefore also fertility, its objectives are quite the opposite to those of the amenity land manager, who will want to maximise diversity, or maintain

characteristic species of heathland, both of which mean low fertility. Agricultural grassland management which aims for fertile, high production low diversity swards, usually means ryegrass (*Lolium* spp.) monocultures. Where herbaceous vegetation survives outside the system of intensive agriculture, in hedge and road banks or elsewhere, it may still be subject to fertiliser drift. And it is likely to be no longer managed under extractive systems of rabbit grazing, burning or hay cutting, but swiped with flail or gang mowers which leave the cut material and its damaging nutrient load. This is why swards which were once a mass of primroses and other small wildflowers are now rank with tall herbs, particularly cow parsley (*Anthriscus sylvestris*), hogweed (*Heracleum sphondylium*) and nettles.

METHODS OF MANAGEMENT

There is a good deal of information now available on the management of herbaceous vegetation for wildlife. The more important work is described in Gimingham (1972), Duffey *et al.* (1974), Hunt & Rorison (1980) and Green (1981). Most of the work has been concerned with establishing the effects of different management techniques on the botanical composition of the sward. Apart from the work of Morris and one or two others on invertebrates (Morris, 1971), much less is known about effects on animals. Our knowledge as to how management systems found effective in trials on nature reserves might be more widely employed in a countryside where the rural economy no longer contains either the stock, manpower or markets appropriate to the traditional systems of management is even more fragmentary. It is this development of effective systems of management for wildlife and amenity which is the most urgent need if we are to maintain examples of herbaceous ecosystems (Green, 1973; Thiele-Wittig, 1974; Lowday & Wells, 1977; Large & King, 1978; Lefeuvre, 1980).

This discussion of management techniques therefore concentrates on these aspects, limiting the information to the more obvious practical advantages and difficulties of the different techniques and then illustrating them with my own experience in managing grassland on Wye Downs. Details of how different kinds of animals, different kinds of mower, or times or season of cutting produce different swards are available in the literature cited above. The one important distinction that always needs to be made is between the reclamation of swards which have been under-managed to a desired earlier seral stage, and the maintenance management of swards which are already at the desired seral stage. Some techniques are much better for reclamation than maintenance and others *vice-versa*.

Grazing

Most conservationists would regard grazing as the best means of maintaining most kinds of herbaceous swards. Unfortunately, the types of unenclosed grazing systems which maintained them in the past were very different in their ecological effects to the fenced and paddocked systems which amenity land managers are commonly forced to adopt on protected areas of limited size today. Grazing is therefore not always the best means of management.

Horses and cattle are better than sheep at reclaiming rank swards and scrub, but sheep are best at maintaining short swards. Rabbits, deer and other feral species once maintained large areas of herbaceous vegetation, but fencing costs and problems with adjacent landowners make them difficult to operate today.

Advantages	*Difficulties*
The most 'natural' method of management, stock simulate wild herbivores.	Fencing, water and shepherding costs high.
Impact on invertebrates and other animals minimal?	Tough stock suitable for rough swards difficult to buy and sell.
Remove nutrients if folding or zoning system used.	Effete modern stock breeds may need supplementary feed and its damaging nutrient input.
	Paddocked systems can increase fertility and reduce diversity.
	Stock needs override those of the sward.
	People and dogs disturb stock.

Mowing

Tall herb meadow swards and road verges were commonly cut for hay in the past and the aftermath grazed. Golf courses, airfields and other areas where mowing is still employed illustrate that it can produce swards suitable for wildlife. Mowing is most useful as a maintenance, rather than as a reclamation technique.

Advantages	*Difficulties*
One or two cuts per year may be quite adequate to maintain desired sward.	Only possible where terrain not too steep or uneven.
Season and height of cuts can be readily controlled to favour species in relation to their phenology.	Cuttings must be removed on all but most infertile areas and this is time consuming and expensive.
	Levels microtopography, anthills, etc. which are important for species regeneration.

Burning

Firing vegetation in the autumn or spring to provide a flush of new growth for stock was an integral part of the traditional systems of unenclosed grazing, as it still is where they survive in the North and West. It is also an important natural factor, caused mainly by lightning, in maintaining plagioclimax ecosystems throughout the world. Conservationists have largely disregarded it as a management tool, tragically, for it is arguably the most formidable and useful one available. Although fire is most effective as a reclamation technique, or maintenance technique in conjunction with grazing, it can alone maintain herbaceous vegetation.

Advantages	*Difficulties*
A natural feature in plagioclimax ecosystems.	Prejudice against fire as destructive agency.
Part of traditional pastoral husbandry.	Skill needed to control safely fire and delimit burn.
Only necessary on one occasion at infrequent intervals, perhaps 3–15 years?	Used too extensively or frequently may reduce invertebrate and other animal populations.
Removes nutrients in smoke.	
Prevents disastrous accidental summer fires.	
Easily and inexpensively undertaken.	

Chemicals

Herbicides and growth retardants have not been widely used to manage herbaceous swards for wildlife conservation. Where they have been employed it has usually been as accessories to the use of selective uprooting or cutting of trees and bushes as a reclamation technique to recover open grassland from scrub. Here brushwood killers have been widely and successfully used to prevent regrowth from stumps. Herbicides have also been tried to selectively control rank species such as tor grass. Chemicals like dalapon, which have a degree of specificity for monocotyledons, and asulam, which has been used specifically against bracken, have been successful in small trials. There are indications also that even total herbicides like paraquat can surprisingly selectively penalise the ranker, undesirable species and favour the smaller herbs. Growth retardants such as maleic hydrazide can certainly do this and serve as maintenance rather than reclamation tools.

Advantages	*Difficulties*
Only necessary at infrequent intervals.	Prejudice of conservationists against chemicals.
Easily undertaken and delimited.	Fears of side effects on animal life and non-target species.
	Expensive.

All these management techniques are ideally employed on a rotational basis so that there are always some areas being managed and some being rested and recovering. This ensures that there are always places where species can shelter from management, or flower and set seed to provide colonists which can re-stock any areas from which they may have been lost. This is particularly important with the more potentially destructive management agencies like fire and chemicals, but may be equally important with grazing or mowing which, if continuous, can preclude both flowering and the development of longer swards necessary for many invertebrates. Such rotational systems most nearly resemble both the natural perturbations now thought to be important in maintaining the diversity of many ecosystems (Connell & Slatyer, 1977; Whitmore, 1982) and the traditional systems of management where areas were regularly overgrazed then abandoned to recover. Some species such as juniper (*Juniperus communis*), may be absolutely dependent on such sporadicity of management for their regeneration. Juniper seems to need the bare soil created by over-grazing or fire for germination, but then needs several years free of grazing or fire, to which it is very vulnerable, before it is big enough to tolerate them (Ward, 1981; Miles & Kinnaird, 1979; Gilbert, 1980). Rotational grazing systems are difficult to implement because of higher fencing and watering costs and increased localisation of eutrophication in smaller paddocks. Management by mowing, fire or chemicals is, however, much easier to employ on a rotational basis.

A CASE HISTORY: BURNING AND GRAZING ON WYE DOWNS

Wye Downs have long been renowned for the richness of the plant and animal communities of the escarpment grasslands. Seventeen species of orchid, including the rare early and late spider orchids (*Ophrys sphegodes* and *O. fuciflora*) are recorded. The grassland is dominated by tor grass. This species forms continuous swards in the least disturbed areas and invasive patches in other areas which have been ploughed or otherwise agriculturally improved at various times and reverted to rough grassland. Much of the area is being colonised by scrub. This has evidently been progressing for a considerable time since most of the woodland on the escarpment is not present on old maps and thus has evidently developed secondarily from abandoned grassland in the last two hundred years. Management of the grassland in both Wye Downs National Nature Reserve, and the nearby Crownfield Down owned by Wye College, has concentrated on controlling scrub invasion and maintaining mixed short and longer sward grasslands suitable for maintaining their floristic and entomological richness.

On the Broad Downs area of the National Nature Reserve management for the last 20 years has been mainly by winter grazing with sheep under a grazing tenancy. This has been inadequate to maintain open swards and control scrub invasion for three main reasons. First, stocking densities have reflected the

needs of the sheep and the tenant, not those of the sward. More sheep would likely have better controlled the rank grass but at the expense of the condition of the sheep. Second, the grazing areas contain some relatively fertile and productive plateau grassland as well as the rough escarpment swards and sheep naturally prefer the former. Third, a winter grazing season has been used in deference to disturbance from people and dogs on what is a popular recreation area in the summer, and for fear that summer grazing would deflower and prevent seeding of the grassland plants. But there is little fresh grass on the area in winter and the impact of grazing is thus minimised. Under these conditions the tor grass develops a tall rank sward with thick litter and most of the grassland forbs are suppressed. More open swards with abundant wild flowers were briefly reclaimed by two periods of more intensive management in the early seventies. Summer grazing by cattle and spring burning were both, independently, shown to be very effective in controlling the tor grass and scrub invasion. Neither has been repeated and the sward continues its inexorable decline.

Management on the Crownfield Down was similar until 1979 and the sward had deteriorated in the same way. It had been laxly grazed with sheep throughout the year and occasionally burned. When it came into the full control of Wye College in 1979 the entire field was dominated by tall grasses, mainly tor grass, but also a small amount of tall fescue (*Festuca arundinacea*) and meadow and hairy oats (*Helictotrichon pratense* and *H. pubescens*). The sward was 35–50 cm tall and the ground covered by a thick deposit of undecomposed grass leaf litter. The standing crop of above ground vegetation plus litter harvested between the 26th August and 2nd September 1980 varied, in three replicates, between 773 and 1,330g m^2 dry weight, mean 1022g m^2. Few associated species survived under the tor grass, those doing so most commonly were sheep's and red fescue (*Festuca ovina* and *F. rubra*), salad burnet (*Poterium sanguisorba*), rockrose (*Helianthemum chamaecistus*), burnet saxifrage (*Pimpinella saxifraga*), hairy violet (*Viola hirta*) and yarrow (*Achillea millefolium*). In total 24 species were recorded in three, one m^2 quadrats surveyed for rooted frequency in 100 x 10 cm^2 subdivisions. The maximum number of species in any one quadrat was 17, the minimum 13 and mean 15 (Fig. 1, – *Poa pratensis* and *Rosa* spp. are the two species not recorded there for want of space).

This dense rank grassland was regarded as a summer fire risk. For this reason a large part of the Crownfield Down was burned by College estate staff in March 1980 as a precautionary measure to remove the fuel accumulation. The grassland rapidly recovered after the burn and the whole area was grazed for part of the summer by 20 sheep. Observation indicated that the sheep mainly grazed the more fertile grassland over the superficial deposits at the top of the slope and there was little indication on the sward of grazing where the recording was undertaken. There was, nonetheless, a marked difference between the burned and unburned areas when some vegetation recording was undertaken in late August. Three sample stands were recorded, each within 3–5 m of the corresponding unburned stands described in the previous paragraph. The

burned swards bore only a quarter of the standing crop of the unburned, varying between 240 and 343g m^2 dry weight, mean 300g m^2. Much of this difference is attributable to the almost complete consumption of the dead leaf litter by the fire, for in derelict tor stands the litter commonly accounts for about two thirds of the above ground standing crop. Some of the difference is, however, attributable to less vigorous growth of the tor grass after burning. This was reflected in the height of the burned swards (10–20 cm) being less than half that of the unburned.

The removal of the smothering litter and suppression of the tor grass allows those species such as salad burnet and rock rose which persist in thick tor infestations to flourish and greatly increase their rooted frequency, and a whole suite of species not evident in thick infestations re-colonise the sward (Fig. 1). In total the three sample stands in the burned area contained nearly twice as many species (40) as the unburned; in each individually 31–33 species (mean 32) were recorded. *Carex flacca*, both *Helictotrichon* species, *Thymus pulegiodes* and *Cirsium acaule* made particularly notable increases. Some of the colonising species clearly germinated in the bare soil left by the removal of the leaf litter and were seen as seedlings, presumably from seed already in the soil. Others seem to have spread rapidly by vegetative means. The one species which does not seem to have been able to take much immediate advantage of the control of the tor grass is *Festuca ovina*. The apparent vulnerability of this species to fire, and its replacement by *Helictotrichon* has been noted by Lloyd (1968).

The three sample sites were chosen to represent the natural range of vigour in the tor grass on the Crownfield Down; which seems, broadly, to be related to soil depth. When the performance of the tor grass at these sites, burned and unburned, is plotted against the number of species in the sward the negative relationship between its dominance and species number is quite clear (Fig. 2). The performance of the tor grass was crudely measured as both the total standing crop and the proportion of total species records it accounts for. The suppression of the tor grass is not so evident in the records of rooted frequency where it hardly declines from 100% even in the burned plots. Its decline is, however, more evident in cover records obtained with a pin frame. Cover sampling undertaken in 1981 shows it to have declined from 100% cover in unburned areas to as low as 50% in areas burned and grazed even though its rooted frequency was still 100%.

Subsequent management of Crownfield Down in 1981 has included further controlled burning, both alone and in conjunction with cattle grazing. In addition an enclosure has been set up within which the effects of fire, mowing and herbicides are being monitored in a series of replicate plots. The remarkable recovery of the sward by burning has been consolidated under the new grazing regime and in 1982 the sward has once again come to resemble a typical downland turf. Green-winged, fragrant and bee orchids not seen for many years have reappeared and butterflies have once again become noticeable as their food plants like horseshoe vetch (*Hippocrepis comosa*) and bird's foot trefoil (*Lotus corniculatus*) have increased in abundance.

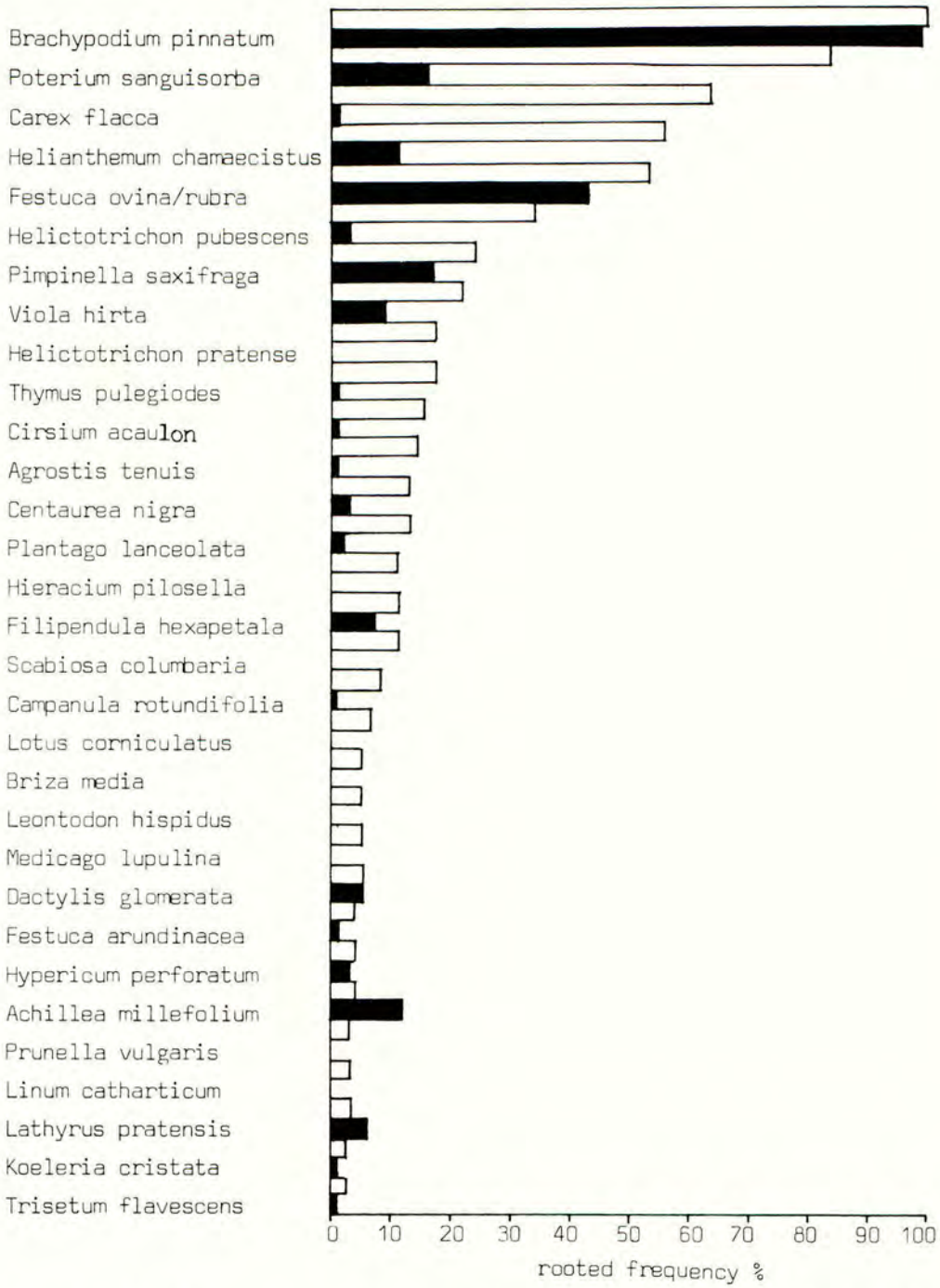

Figure 1. Grassland species composition on the Crownfield Down, Wye, without (black columns) and after (white columns) fire management.

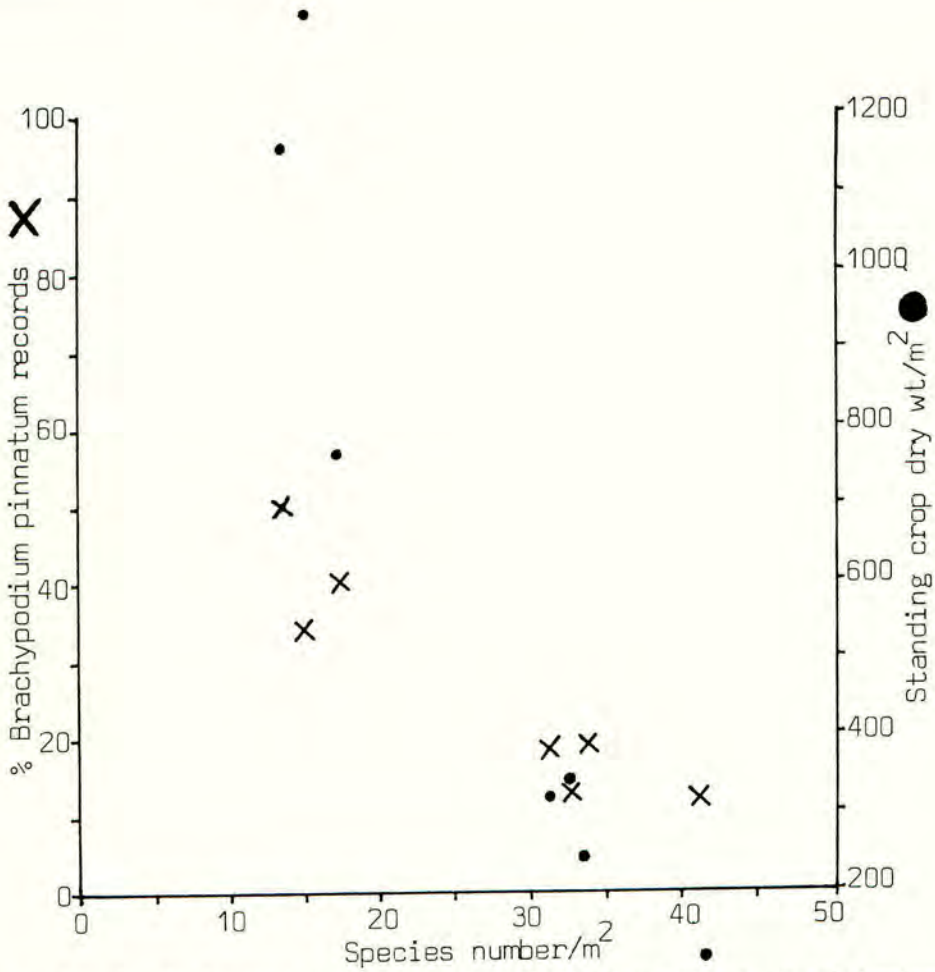

Figure 2. Grassland species number and tor grass (*Brachypodium pinnatum*) dominance on the Crownfield Down, Wye.

CONCLUSION: A PLEA FOR THE WIDER USE OF FIRE MANAGEMENT

Fire is a willing servant, but a hard master. There is no doubt that if not very carefully undertaken burns can quickly get out of control. Fires which are progressing nicely one minute can be raging infernos the next if the wind suddenly changes. The effects of fire are also very different under different conditions. Downwind, or headfires, are, for example, much faster over the ground than backfires into the wind. For this reason they are more difficult to control. But their speed means that temperatures reached in any one spot are lower than in slower and more intensive backfires, and some areas are usually skipped altogether. These facts may mean that headfires allow more plants and animals to survive than backfires.

The season of burning can also make big differences in the effects of the fire. Controlled management burns undertaken within the statutory burning season of 1st November to 31st March (The Heather and Grass Burning (England and Wales) Regulations, 1949) are usually made in early November or late February and March when the vegetation is dry, but the ground still damp. The underground parts of plants, and seeds and animals which are then in the soil are relatively unaffected by such burns. Heather, for example, rapidly regenerates from its roots and seed in the soil. But accidental summer fires when the ground is dry commonly burn off the surface layers of soil, killing roots, seed and soil animals. The bare mineral ground may then be colonised by purple moor grass (*Molinia caerulea*), bracken (*Pteridium aquilinum*), or birch (*Betula* spp.), or alternatively disastrous erosion may ensue (Maltby, 1980).

Fire frequency is another important factor in determining the effects of fire. Artificial fires which take place more frequently than natural fire episodes can prevent species obtaining dominance which would otherwise do so (Moll *et al.* 1980). We are only just beginning to understand the role of fire in natural ecosystems and it is clear that there is still much to learn of the responses of individual species and how these determine the composition of the vegetation (Walker, 1982).

It is not surprising that this lack of knowledge and the unpredictability of fire, coupled with safety considerations, has led many conservation land managers in Britain to reject it as a management tool. But others have abjured it on much more suspect grounds, based on well-meaning, but naively misguided ideas of minimum disturbance in protected ecosystems which fail completely to appreciate recent advances in knowledge on the ecological and historical factors which created and maintained them (see, for example, Walker, 1982). Concern is continually expressed for the fate of animals in fires yet there is very little evidence that they do not, in time, recolonise burnt areas. Indeed there is every reason to suppose that they must have survived in plagioclimaxes because of fire, not despite it. Fire is a perfectly natural occurrence in British ecosystems. Twenty-three fires due to lightning were recorded in Galloway on two days in June 1970 (Thompson, 1972). Effective fire control and, more importantly, the small size and isolation of inflammable ecosystems, now unfortunately prevents the spread of such natural fires. Fire return intervals at any one spot are thus much longer than they would naturally be.

This reduction of fire episodes leads to the build up of dead litter fuel in the ecosystem so that when fires do occur they are far more intense and damaging. The disastrous accidental fires of the hot summer of 1976 which devastated heathlands and grasslands in Britain, many of them nature reserves, would not have been anything like as damaging if sites had been managed on a rotational system of controlled winter burning. If, in the light of this experience, conservation organisations fail to implement fire management, any recurrence of fires like those of 1976 would represent culpable negligence on their part. The National Park Service in the USA has learned this lesson and recently changed

its policy from one of fire control to one of fire management. North American experience in fire management has recently been comprehensively reviewed by Heinselman (1978).

The way in which herbaceous vegetation in nature reserves, Country Parks and other public open spaces is being lost almost everywhere to an advancing tide of scrub and woodland testifies to the lack of success of many grazing, mowing or scrub-clearance policies and systems of management. Greensand heathlands in Kent, which were described and photographed in early ecological studies as open heather communities are now very ordinary secondary birch/oak woodlands in which heather survives only in rides or heathy glades. Conservation land managers who persist with present management methods must ask themselves whether they want grasslands and heathlands to continue to change inexorably in this direction, with the prospect of a few rare insects, sand lizards or Dartford warblers hanging on in woodland glades only by assiduous 'gardening'; or whether they want to maintain open grassland and heathland ecosystems, even if without their more vulnerable species. If the latter objective is favoured then there is no really practicable alternative to using fire much more widely as a management technique.

Lloyd (1968)	*'In the absence of grazing periodic spring fires in grassland communities have the effect of maintaining the floristic diversity of the communities and checking scrub invasion. Only rarely do fires appear to be detrimental to the communities in which they occur.'*
Vogl (1974)	*'Grassland managers, from private ranchers to agency directors, should be "encouraged" to experiment with fire and learn to use it as an effective tool. It is time that we realise that "playing with fire" will not necessarily lead to getting burned and just might help us to relearn a lost art and gain a powerful and natural tool.'*
Webb (1980)	*'Burning still remains the simplest and most effective way of maintaining heathland.'*

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DISCUSSION FOR DR GREEN

Mr Gilmour Is it true that farmers burn straw to increase fertility, because if so, it seems odd that you were saying that you burn to reduce nutrients in the soil?

Dr Green (Speaker) Studies on burning on heathland have shown that something like 80–90% of the nitrogen in the standing crop, and as much as 25% of phosphorus, go up in the smoke. Many people think that because potash is left on the soil fertility is increased, but potash is rapidly leached, certainly from porous soils. So burning removes nutrients from 'natural' ecosystems in one way or another, and this must be the case for agriculture as well.

If a farmer were to plough in straw, the process of microbial decay of the straw seems to take nutrients out of the soil in the first part of the breakdown process, so that it is perhaps to a farmer's advantage in this case to lose the nutrients locked up in the straw by burning. If he ploughs in the straw he may not get any direct benefits from the nutrients in it, and it is much easier for him to replace them with inorganic fertilisers.

Mr Carter Burning straw does result in loss of nitrogen and phosphorus but not potash. Ploughed-in straw, whether long or chopped, has other detrimental effects on the following crop. Work at the Agricultural Research Council's Letcombe Laboratory has shown that over a number of years yields of crops following the ploughing-in of straw may be reduced by 10–20%, compared to crops where the straw had been burned-off or carted. This has been attributed to products from the straw that inhibit germination.

Mr Peters The paper indicates that some habitats can be reconstituted. If this is possible, then how important in terms of priorities for conservation are such habitats? Can you comment upon the need for islands of the original habitat type, their size and number, and management to maintain them as adequate resources?

If such an approach to reproducing habitats is possible, how are priorities to be reached in nature conservation terms? Should we not concentrate on habitats that cannot be reproduced?

Dr Green (Speaker) On the first part of the question, it is indeed relevent to ask whether, if a habitat can be reclaimed, we need to manage it in the first place? But with grassland you can only allow natural succession to go on for relatively few years, because once scrub becomes established, nutrient accumulation takes place, and these nutrients once in the soil are very difficult to get rid of. This build-up also takes place on heathland under gorse and broom, on sand dunes under sea buckthorn, on peat bogs with bog myrtle, and in fens with alder; all of which fix nitrogen. Even on downland where you haven't got nitrogen fixing species, scrub acts as a sieve taking nitrogen out of the air in dust and in rain, and brings nutrients up from the lower soil horizons with its roots. In addition, birds perching in the bushes contribute significant quantities of nutrients. Thus, once scrub is established there can be an increasing pattern of nutrient enrichment, so that management is required to prevent scrub establishment proceeding too far.

Questions of island biogeography and of the sizes of habitats required for survival are more important for woodlands, and for animal populations than for grasslands. It has been

shown that you need a wood of about 100 ha in order to have a reasonable probability of finding all 50 species of lowland, woodland birds common in this country. The general relationship is that for every tenfold reduction in area of an isolated, island, habitat, the number of species is halved. Whilst this seems to work for animals, and especially birds, it is not so critical for plants. The main size consideration which is important for plants is the viability of the management unit. If there are many small areas, it is much more difficult for example to set up grazing systems to make the whole thing worthwhile.

Mr Burdekin How far do the measures taken to conserve vegetation in downlands and heaths, at the same time act as management techniques for landscape and recreation? I wonder whether in this case you are in the very fortunate position of being able to conserve the vegetation, but at the same time satisfying some of the other demands which the general public is making on these areas.

Dr Green (Speaker) We first used burning for the management of downland at Wye as a result of advice that I had from a Nature Conservancy Council warden at the time when I was the NC Regional Officer. He persuaded me that burning was, firstly, part of the traditional management system, and that, secondly, if the vegetation in an area with such recreational pressures was not burnt deliberately in the winter, it would be burned accidentally by the public in the summer. Winter burns which take place in February or March interfere little with recreational use.

The one possibly unacceptable aspect of burning is the danger it poses to small animals, for which reason most amenity land managers are very reluctant to use it. Against this one can argue that one only burns limited areas, in a mosaic pattern, so leaving populations of insects and other animals in the unburnt parts to recolonise. To some extent these animals have to take their chance – they have survived in the past because of burning and not despite it; they are much more likely to be severely affected by uncontrolled summer fires. If the grassland is not burnt it will be invaded by scrub, so that the species characteristic of open ecosystems will disappear, and much of the recreational and landscape value will be lost as well. Fires in grassland and in woodland are a natural feature of wild ecosystems, and are a way (along with floods, avalanches, pests and diseases) by which diversity is introduced into areas that would otherwise be entirely dominated by very few 'most successful' species. With controlled burning, one can limit the extent of any particular episode, and prevent the build-up of plant litter which provides the fuel for very disastrous accidental hot fires, rather than light ground fires which occur when fuel is limited.

The problem with conservation in Britain is that management has almost been a dirty word – at one time there was an idea that if you had a protected area, you put a fence round it and left it. This has of course changed now, but it is still prevalent in some parts of the continent. But even now conservation managers in Britain are far too timorous. There is still too much concern for "gardening" for sand lizards, or Dartford warblers, or particular orchids, when it would be much better if there was more ruthless management, even to the extent of really devastating some ecosystems on a rotational basis. That would do more good for plants and animals than just sitting back or pussy footing around.

Mr Barber This last point about timorousness in land management. During my association with the Royal Society for the Protection of Birds (RSPB) as Chairman over the last five years until quite recently, the thing that I am most proud of is the way that the RSPB has developed this dynamic habitat manipulation on its reserves of about 120,000 acres. I have

been trying to persuade other organisations to adopt the same sophisticated techniques. I believe that this is an incredibly important aspect of the whole thing that we have been discussing, that is to introduce dynamism into land management. We need to persuade as many public and private, and voluntary, landowning bodies as possible to go along that route.