

Working Paper 121

UNDERSTANDING RANGELAND BIODIVERSITY

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Acronyms

CBD	Convention on Biological Diversity
COP	Conference of the Parties
DADIS	Domestic Animal Diversity Information System
FAO	United Nations Food and Agriculture Organisation
IPRs	Intellectual Property Rights
LPPB	Linking Policy and Practice in Biodiversity
PCR	Polymetase chain reaction
UNEP	United Nations Environment Programme

Summary

- Rangelands are geographical regions dominated by grass and grass-like species with or without scattered woody plants, occupying between 18–23% of world land area excluding Antarctica. Rangelands are home both to significant concentrations of large mammals and plants with a high value in both leisure and scientific terms and to human populations that have historically been excluded and marginalised, pastoralists and hunter-gatherers. However, rangelands present a paradox for the conservation ethic, however; most are definitely not ‘natural’ and very often prove to be recent formations.
- The literature commonly tries to distinguish ‘natural’ grasslands (i.e. edaphic grasslands) from anthropic grasslands (typically tropical savannas resulting from deforestation). Grasslands are usually divided into four major types: tropical grasslands, prairie/steppe, temperate grasslands and tundra. However, recent research has tended to question any rigid distinction between the two categories. Human impact on rangelands, biodiversity loss and consequent degradation are often thought to be recent phenomena, brought about by overstocking etc. But this distinction is artificial and partly results from the time-scale over which a landscape is viewed. Grazing by herbivores changes the composition of landscape over time even without human interference and evidence for human manipulation of vegetation is of great antiquity.
- Despite their economic and social importance and the biodiversity they harbour, rangelands have never garnered the scientific and media attention their conservation merits. This is partly because they are simply less photogenic than tropical forests, but more significantly because they are widely perceived as degraded land for grazing.
- Many of the world’s rangelands in areas where pastoralism was traditionally practised are anthropic and therefore their biodiversity is about ‘natural’ as the qualities attributed to some brands of shampoo. Given this, restoration to some imagined primordial state makes no sense. However, this should not be seen as an argument for laissez-faire management; rather that a decision has to be made as their overall use and a functional biodiversity encouraged in line with those objectives.
- The economic importance of rangelands world-wide is extremely variable according to the socio-economic system in which they are embedded. In developed economies, such as Australia and America, rangelands are essentially marginal terrain suitable for low-intensity stock-rearing and hunting. In pluralistic economies such as Brazil, high-density vegetation such as rainforest, of crucial importance to hunter-gatherers and smallholder farmers, can be all too easily converted to low-fertility savanna of interest only to wealthy ranchers. In Africa and Central Asia, rangelands are essential to the subsistence of pastoralists, foragers and farmers dependent on rainfed crops, who usually constitute the most vulnerable groups in the ecozone.
- To set priorities for rangeland biodiversity conservation is simultaneously to establish priorities for specific socio-economic matrices. Experience from rangeland conservation in developed economies may have technical significance for pastoral areas, but because of the economic context, the resultant development strategy may well be quite different.

- Population pressure in many semi-arid regions is tending to drive arable farming into more and more marginal areas, especially with new irrigation techniques. This in turn places further pressure on pastoralists and foragers and thus on rangeland vegetation. Although there have been serious doubts about the long-term impact of 'overgrazing', the impact of intensive pressure on rangelands over the shorter term can mean that they may be poor producers of biomass for both livestock and wildlife over many years.
- Arguments for the conservation of biodiversity in rangelands are a subset of those for biodiversity in general. However, the strongly anthropic character of most rangelands makes these arguments problematic; if rangelands are human creations there is no 'original' state that can be conserved, maintained or restored. Indeed the argument must be turned on its head; there is a strong case, on both economic and ecological grounds, for thinking that rangelands should be biodiverse to fulfil their intended function over the longer term.
- A distinctive pattern of management of rangelands worldwide is the short-term perspective of users, whether they be Brazilian ranchers or African pastoralists. Rangelands can be used sustainably *if* their ecosystems are maintained intact. They are most productive when most biodiverse, assuming they are put to a variety of uses. But the tendency has been both to turn individual ranges to single uses (e.g. one livestock species) and to try and extract the maximum value over a short period (for example by burning off the grass cover). Because individuals are not liable for long-term damage to the ecosystem, nor are they responsible for the costs of their actions, patterns of intensive short-term exploitation may be both economic and socially acceptable.
- A clear strategy for maintaining biodiversity is simply to put rangelands in developing countries to diverse uses, such as large wild herbivore production. This would:
 - a) increase potential export income
 - b) provide diversified products that could not easily be produced intensively and therefore would be less subject to external competition.
 - c) make more effective use of diverse vegetation than any anthropic system

but would require users to encourage and maintain rangelands biodiversity.

1. Introduction

But lo! men have become the tools of their tools. the man who independently plucked the fruits when he was hungry is become a farmer; and he who stood under a tree for shelter, a housekeeper. We now no longer camp as for a night, but have settled down on earth and forgotten heaven.

Henry David Thoreau,
Walden 1847.

1.1 Rangelands, biodiversity and livelihoods

Rangelands are geographical regions dominated by grass and grass-like species with or without scattered woody plants, occupying between 18–23% of world land area excluding Antarctica. Rangelands are home both to significant concentrations of large mammals and plants with a high value in both leisure and scientific terms and to human populations that have historically been excluded and marginalised, pastoralists and hunter-gatherers. However, rangelands present a paradox for the conservation ethic, however; most are definitely not ‘natural’ and very often prove to be recent formations. The great majority of the world’s rangelands are largely anthropic creations and this is particularly true where the dominant subsistence strategy is pastoralism. As such, they do not have a ‘natural’ biodiversity, making problematic the argument that they should either be preserved as they are, or somehow returned to their ‘original’ state. For this reason, it is essential to engage with history in understanding rangelands; without a narrative of the process whereby a given ecosystem reached its present state it is impossible to proceed with rational policy formulation. Where large mammals are involved, emotion has frequently triumphed over science in terms of management and investment strategies. Similarly, where the powerful economic interests of large-scale ranching predominate, biodiversity is generally ignored.

The other side of the coin is that the typical inhabitants of anthropic rangelands are pastoralists, hunter-gatherers and increasingly subsistence farmers depending on uncertain rainfed crops or irrigating semi-arid land from non-rechargeable water sources. Historically, when demographic pressure was substantially lower, these groups could interact with only limited conflict. Now, throughout the world’s rangelands, these groups are competing for a shrinking land resource, and the more marginal groups, the hunter-gatherers and pastoralists, are being increasingly displaced by farmers. A key aspect of this is that there is a clinal relationship between subsistence strategy and biodiversity. Hunter-gatherers, low density populations depending on a wide range of protein sources, inevitably have an interest in maintaining the broad genetic base of animals and plants. Generally speaking, the more different animal species that exploit grassy vegetation, the more plant species colonise the region and biodiversity is correspondingly high. Pastoralists bring in a small number of species of domestic stock and displace large herbivores, although not herbivorous insects. This will reduce the number of plant species through preferential grazing. Once farmers begin to convert the habitat to arable land they eliminate both animals (‘pests’) and numerous plants (‘weeds’) reducing biodiversity still further. This suggests a direct trade-off between the area required to feed a human population and biodiversity.

The conservation of rangeland biodiversity then becomes more about political choices and less about its uniqueness or otherwise as a biota. In countries where farming interests dominate political structures, for example in the West African Sahel or SE Asia or Jordan, the colonisation of rangelands has proceeded almost unchecked and the flexibility and fluid tenurial systems of pastoralists has acted against their interests as farmers increasingly claim land by cropping. The

unfortunate aspect of this is that the type of farming that is possible in such marginal areas is rarely sustainable and depends, for example on boreholes exploiting non-rechargeable water sources. Very often, as in West Africa, as soon as there is a dip in rainfall, these regions become disaster zones and all the machinery of crisis swings into action. Where pastoral (or at least livestock) interests are influential with government as in Central Asia, Australia and parts of the New World, powerful administrative structures are established to prevent encroachment on ranches, for example. Nowhere in the world do foraging peoples have the power to prevent their land being alienated (Blench, 1999); if they have survived until now it is only because of their remoteness. Nonetheless, under rather specialised circumstances, the desire to conserve the habitats of large mammals, especially in eastern and southern Africa for science or tourism has led to the indirect conservation of grasslands.

None of these groups act as they do from a desire to conserve biodiversity, nor do they generally consider it when adopting a livelihood strategy. Even when reductions in biodiversity affect livelihoods this is an external conceptualisation; a pastoralist noting the absence of palatable grasses does not frame this as a consequence of an overall decline in biodiversity. Nonetheless, these activities all affect the biodiversity of rangelands and therefore to frame policy effectively it is essential to understand:

- a) the definition and distribution of rangelands
- b) the historical origin of a given rangeland area and thus the validity of a given conservationist argument
- c) the competing uses to which rangelands are put
- d) the political and economic forces that determine which use predominates

This paper is intended to describe these issues in some detail with a view to clarifying the background to the policy process.

1.2 Where are the World's Rangelands?

The literature uses several terms for the main world's rangelands: African savanna, Eurasian steppe, South American savanna, North American prairies, Indian savanna, and Australian grasslands (Moore, 1970; Groombridge, 1992: 285; Solbrig, 1996). Estimates of their importance vary according to the regions included, but as figures given in the literature suggest, rangelands occupy between 18–23% of world land area, excluding Antarctica (Table 1).

Rangelands is a broader term than grasslands, including regions where woody vegetation is dominant; moreover, it is a term common in texts looking at land from the viewpoint of livestock production. Grasslands are just that, and the term has a more biological emphasis¹. Some of the ecological literature attempts to distinguish 'rangelands' and 'natural' grasslands (for example, the

¹ There are two parallel series of international congresses, the International Rangelands Congress and the International Grasslands Society whose meetings alternate, but which are attended by largely the same constituency. So similar are these meetings that it has recently been proposed to merge the two societies, although this proposal remains controversial.

Table 1 Estimates of the area of the world's rangelands

	Whittaker and Likens (1975)	Atlay, Dugvigneaud (1979)	Kettner, Olson, Watts and Allison (1983)
Savanna (million km ²)	15.0	22.5	24.6
Temperate grassland (million km ²)	9.0	12.5	6.7
Total (million km ²)	24.0	35.0	31.3
	%	%	%
Rangeland as % of world land area	16.1	23.7	20.7
Rangeland as % of world land area (excluding Antarctica)	17.9	26.5	23.1

Source: Groombridge (1992: 281)

Elsevier 'Ecosystems of the World' premises different volumes on this dichotomy – see Bourlière (1983) and Coupland (1993a). But closer examination of the descriptions suggests that either the origin of many grasslands is contentious or else grasslands become 'natural' if they are ancient human creations (see, for example, Gillson (1993a) on the grasslands of New Guinea). One of the themes of this paper is that such distinctions are of limited use compared with information about the nature of documented management and use systems. Apart from this, especially in tropical ecosystems, woody and grassy vegetation can show long-term alternations and the dominance of a specific type at a particular time reflects a node in the pattern of vegetation replacement. This document will use rangelands in the discussion of human management and grasslands to discuss the more biological aspects, keeping the terminology in harmony with the published materials.

In the grassland literature, they are usually divided into four major types: tropical grasslands, prairie/steppe, temperate grasslands and tundra. These can be treated as determined either by the underlying soils or by climatic conditions. Table 2 shows the main categories of grasslands and their major zones of concentration:

Table 2 Classes of grasslands

Category	Where
tropical grasslands	Africa, South America, northern Australia, India
prairie/steppe	North America, Central Eurasia, South Africa
temperate grasslands	Europe, North America, Australia, New Zealand, Asia
tundra	all subarctic grasslands

The main floral component of rangelands, grass, exists to be grazed, and over time co-adapts to both the intensity and quality of grazing. The long-term evolutionary history of a grassland ecosystem as well as the history of the last few centuries are therefore essential to understanding its response both to management and to new pressures on it. The discussion outlines some of these long time-depth perspectives with a view to illuminating present policy options.

1.3 Two views of rangelands

The literature on biodiversity in the world's rangelands manifests an intriguing dichotomy. Some authors consider the main function of rangelands as pasture, and biodiversity a 'tool' to be manipulated like any other, for the sustainable management of livestock. A good example of this is Walker (1995), who defines rangelands negatively, as 'semi-arid regions where reliance on rain-fed cropping, on its own, is not a viable form of land use'. He notes that the 'primary use of rangelands is for livestock production' and that 'the most common and significant manifestation of biodiversity loss in rangelands is a change in the proportional mix of species...this aspect of biodiversity loss...is central to the issue of rangeland management' (Walker 1995: 69).

This type of anthropocentric paradigm, although still common in the literature, albeit in a less explicit form, has an archaic feel to it. Few writers about tropical forests would assume that the only value of their biodiversity was the role they play in human food production systems. Even if the human-centred approach is retained, it now seems off to exclude other types of human users of rangelands, such as hunter-gatherers, or the possibility of game reserves and other leisure or scientifically-oriented uses. The opposite pole, which might be ascribed to IUCN and similar bodies, is that rangeland is a biome like any other, with its own characteristics, which we have a responsibility to inventory, maintain and conserve while remaining in constant dialogue with characteristic human productive activities.

Table 3 represents the differences between these two approaches:

Table 3 Contrastive paradigms of rangelands biodiversity

	Anthropic	Ecosystem
Definition of rangeland	land unsuitable for rainfed cropping	open land defined by predominance of graminaceous species
Purpose of rangeland	livestock production	biomes do not have a 'purpose'
Biodiversity	principally focused on plant species	considers, vegetation, herbivores, predators, invertebrates, micro-organisms as interlinked
Management	Good management improves livestock productivity	Good management balances conserving overall biodiversity against human needs
Degradation	provides poor livestock feeds	low overall biodiversity
Restoration	encourages palatable species to spread	restores overall biodiversity

Except perhaps at the poles, almost all environments in the world are more or less human artefacts. The concept of 'climax' vegetation, some state which a biome would naturally attain if left untouched by human activity, has been replaced by a more dynamic view, stressing rather cyclical change and the interlinking of all environments. Forests may be preserved from human interference in reserves but they are still surrounded by anthropic environments that affect them chemically, in terms of water supply and in restricting mechanisms for seed dispersal. Rangelands, however, are rather more obviously artefacts of human activity. Especially in Africa, Europe and India, the majority of rangelands are anthropogenic, derived from forests burnt down by herders. The concept of their having any 'natural' biodiversity to conserve makes no sense since their composition always reflects the pattern of pasture use.

This contrast, between rangelands conceptualised as essentially for human use, as opposed to an ecosystem with an independent existence, relates very directly to the issues of livelihoods. The literature has been dominated by a very specific interest group, representing the rangelands of North America and Australia and their production systems. There is a relative abundance of material on biodiversity in rangelands managed for ruminant livestock in extensive high-capital systems and very little on indigenous pastoral² or foraging systems. This is not for lack of material on pastoralism in general; pastoralist research is dominated by social anthropologists who have by and large eschewed studies of its ecological impact in favour of advocacy. However, declining biodiversity in tropical rangelands has paradoxical effects; anthropic savannas may create pasture where none existed previously thereby improving the livelihoods of pastoralists while threatening those of forest users. However, when biodiversity declines in rangelands it initially favours some types of pastoralists against others, for example browsing species as opposed to grazing species. Figure 1 represents a model illustrating the linkages between environment, research investment and the potential conflict between approaches.

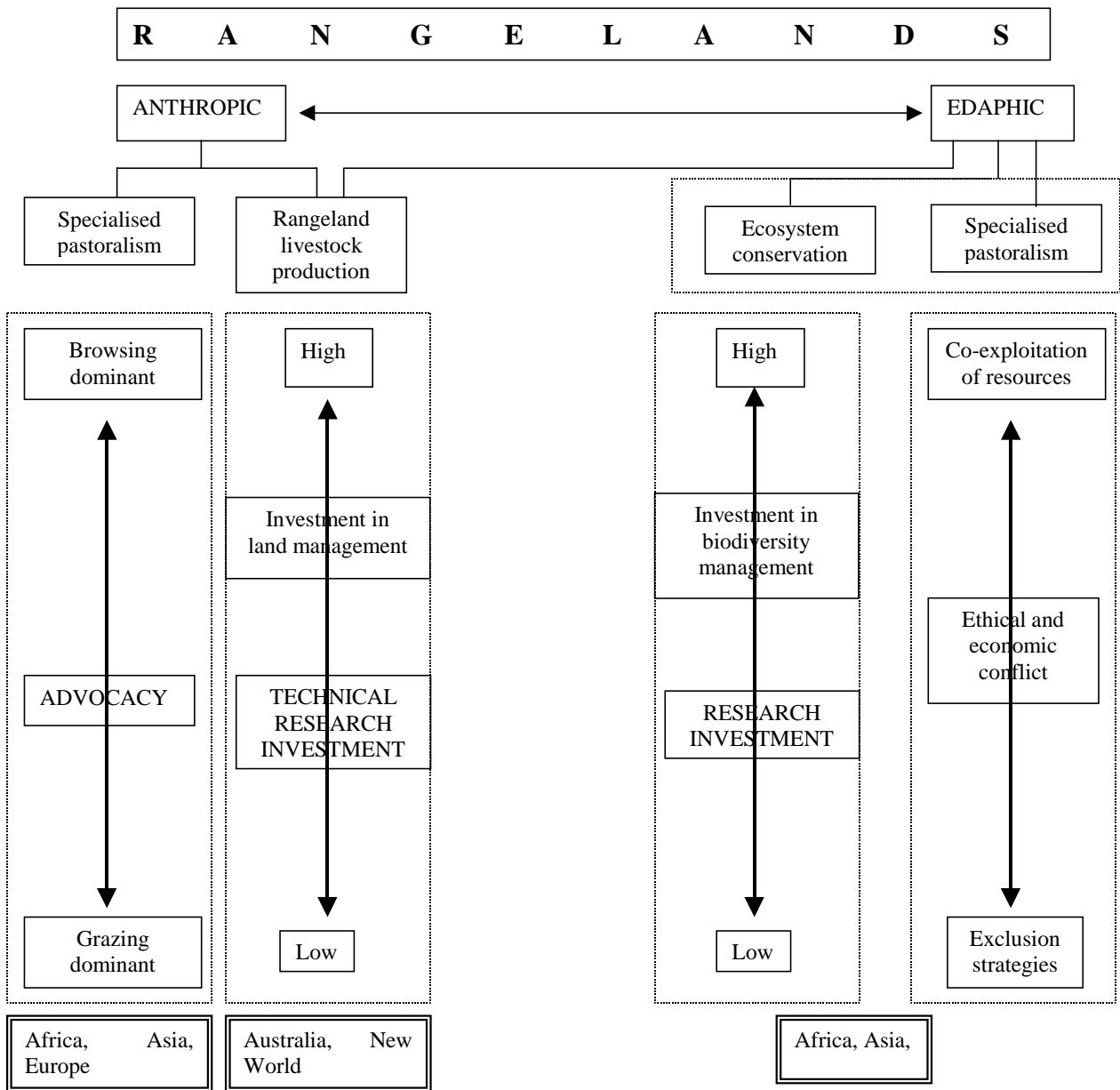
It is no accident that the high-capital land management approaches common in Australia and the New World are in areas where hunting-gathering populations lived prior to colonial intrusions. Historically, forager cultures have proved the most vulnerable to aggression from agricultural and technology-based cultures; ‘guns, germs and steel’ against dispersed low-technology populations (Diamond, 1997). The decline of the Australian and Amerindian peoples following European intrusion is a familiar story, outright violence replaced by degradation and cultural assimilation. Although foraging peoples do use fire to manipulate animal and plant populations, the absence of traditional pastoralism in these areas and the rapid and complete dispossession of the indigenous peoples meant that a wholly new and exotic production system was rapidly introduced into the rangelands. The impact on biodiversity was thus quite different from the long-term co-adaptation between livestock and range characteristic of traditional pastoralism.

1.4 Rangeland biodiversity

Biodiversity is often taken to refer mainly to the diversity of species, especially where conservation is under discussion. Species diversity still receives more attention and is better understood than genetic or ecosystem diversity (West, 1993). But species both exist within a larger matrix of ecosystem and landscape and are themselves composed of genetic elements that may vary in patterns distinct from the species itself. Biodiversity must then encompass the variety of living organisms, the genetic differences among them and the ecological processes and landscapes in which they occur.

² ‘Pastoral’ in development literature is usually applied to traditional pastoralists such as the Maasai or the Mongols. However, in Australia, it is applied to virtually any management system where cattle are kept outside for some part of the year, which creates a fruitful source of confusion at conferences where the two interest groups meet.

Figure 1 Model illustrating the interlocking of different approaches to rangeland biodiversity



The literature on rangelands alternates between two poles, focusing either on their use as pasture for livestock or as a habitat for large mammals, especially in Africa. However, the biodiversity of rangelands in ecosystem terms is poorly described in relation to their overall importance. This is reflected by the amount of literature that has been published on rangelands in comparison to forests. Subject word searches in bibliographic databases turn up references on biodiversity/forest with eight times greater frequency than biodiversity/grassland, rangeland, savanna or steppe

Why have policymakers, researchers and the public found rangeland biodiversity so much less alluring? Rangelands are certainly no less economically important than forests. Rangelands provide fodder for about 360 million cattle and over 600 million sheep and goats, some 9% of the world's beef and 30% of the sheep and goat meat. For an estimated 100 million people in arid areas, and probably a similar number in other zones, livestock production is the only possible source of livelihood (De Haan et al., 1997: 17).

Genetic diversity: the genetic building blocks occurring among individual representatives of a species.

Species diversity: the living organisms occurring in a particular site.

Ecosystem diversity: the species and ecological processes, both their kind and their number, that occur in different physical settings.

Landscape diversity: the geography of different ecosystems across a large area and the connections between them.

Source: Szaro (1996: xxvi)

Media hold a key role in shaping public opinions and forests are visually more attractive than rangelands. Plants are bigger, and particularly tropical forests appear to be more exotic or mysterious. Degraded rangelands are visually much less shocking than burnt-down or heavily-logged forest; indeed it often takes specialist knowledge to interpret an image of rangeland. Tropical forests are the focus of campaigns of environmental NGOs such as Greenpeace or WWF. The only exceptions to this are campaigns focussing on large mammals in rangelands, but even there the emphasis is not on the grass over which the elephants tread.

However, the fate of rangelands should not be determined by images nor by the economic interests of a relatively small number of livestock producers. Although recent research has suggested that Sahelian grasslands are more resilient than once thought, this should not obscure the fact that the overall biodiversity of the world's rangelands is declining alarmingly, either through mismanagement or inappropriate habitat conversion. Apart from the biological aspects, this has significant implications for food security. Many populations in tropical regions living outside rangelands already depend for protein on livestock produced within them. As arable land comes under greater pressure the potential for keeping anything but backyard stock inevitably declines. Solbrig (1996: 17) points out that no complete inventory of any of the main tropical rangelands (savannas) exists. Best known are vascular plants, birds, and mammals; least known are invertebrates, in particular arthropods, fungi, and protists. This illustrates well the selectivity of research; it is easy to demonstrate that insects consume more grass than large herbivores and the diversity of insects is probably a better sign of the health of the biome than the presence or absence of headline species (Speight, Blench and Bourn, 1999). But insects are poor public relations and generate only limited research funds.

1.5 Structure of the review

This review explores current understanding of biodiversity in rangelands, first by presenting a general picture of the types of rangeland in the world and the background to their formation. This is followed by social and institutional factors responsible for monitoring and conserving biodiversity and obligations of national governments under the CBD. A descriptive section outlines the major rangeland categories found in different geographical regions. The second part of the review begins with the arguments for conserving rangelands and the factors that must be taken into account when making strategic policy decisions. Policy options for conserving biodiversity in rangelands are considered within the context both of a livelihoods framework and of competition between stakeholders. The conclusions explore potential topics both for action and for further research.

2. Institutional structures

2.1 Existing structures

Rangelands are a good example of a biome that falls between conventional categories and so does not fall under the remit of any one international agency co-ordinating research, management and conservation. 'Range management' has typically been the preserve of livestock production experts and consisted of experiments with water, fertiliser and productive species to increase the productivity of both enclosed and external range. Such institutions regard rangeland strictly from the perspective of livestock. Wildlife institutions on the other hand, regard the conservation of grasslands as incidental to their main task, the protection of fauna.

The consequence is that international bodies, such as those exist for agriculture, livestock and forestry have not been created for rangelands; indeed, rangelands seem everywhere to be regarded as a sort of scrap category, the land left over when other types of land use have been categorised. Added to this is the technical problem of deciding what biodiversity conservation might mean in relation to rangelands and the result is a recipe for inaction.

2.2 Claims on rangelands

The economic importance of rangelands world-wide is extremely variable according to the socio-economic system in which they are embedded. In developed economies, such as Australia and America, rangelands are essentially marginal terrain suitable for low-intensity stock-rearing and hunting. In pluralistic economies such as Brazil, high-density vegetation such as rainforest, of crucial importance to hunter-gatherers and smallholder farmers, can be all too easily converted to low-fertility savanna of interest to wealthy ranchers. In Africa and Central Asia, rangelands are essential to the subsistence of pastoralists, foragers and farmers dependent on rainfed crops. Such groups are generally the most vulnerable groups in the region, both because they depend on a variable climate to support a necessarily patchy resource, and because tenurial regimes tend to be more ambiguous in regions often regarded as a common pool resource.

The consequence of this is that there is a sort of gradient of competition for access to rangelands. In developed economies, rangelands are given over to low-intensity grazing or protected areas. Conflicts that arise, such as the desire of governments to increase the area of national parks, assert claims for mineral rights or predation from protected species on livestock, are relatively minor and easily settled. However, in the South American case, where rangeland can be created at the expense of the livelihoods of the occupants of the forest, conflict has been prolonged and violent. Unfortunately, the principal means of habitat conversion, burning, is, for practical purposes, irreversible. Once cleared, neotropical rainforest takes centuries to regenerate.

In Sahelian Africa, India and west-central Asia, competition for rangelands is intense, but, by and large, it is not usually a case of the wealthy and powerful versus the poor and dispossessed. Increasing population pressure is tending to push arable farming into more and more marginal areas, especially as new low-cost irrigation techniques develop. This in turn places further pressure

on pastoralists and foragers and thus on rangeland vegetation. Although there have been serious doubts about the long-term impact of ‘overgrazing’ on resilience, continuing intensive pressure on rangelands must mean that they will be poor producers of biomass for both livestock and wildlife over many years.

The consequence is very often that the poorest groups are competing with one another for a limited resource. Across semi-arid Africa and in parts of India, conflict between expanding farmers and pastoralists is an everyday occurrence; the numbers and political power of the farmers, as well as tenurial regimes more supportive of agriculture than livestock, ensure that the farmers are generally dominant. At the same time, foragers and livestock producers may come into conflict, especially in southern Africa. The consequence is often to drive pastoralists into zones so arid that farmers cannot follow them – placing more pressure on these fragile environments and exposing the herders to greater risks of climatic uncertainty.

Foragers and pastoralists often live in overlapping territories, especially in Africa and Siberia. Prior to the twentieth century, land competition was not of major significance and these two interlocking subsistence strategies could effectively co-exist. However, as human population densities have increased and pastoral habitats converted, pastoralists are under pressure to define their territories. In Siberia, the system of simply managing wild reindeer, was transformed under the Soviet regime into a system of herding within bounded and fenced territories, thereby excluding such hunting peoples as the Nenets. The Nenets were supposedly settled, although it has recently emerged that many fled into extremely remote areas. In Botswana and Namibia, cattle-keepers such as the Kgalagadi, Herero and Ovimbundu have themselves faced exclusion from white-owned fenced ranches and have been pushed into further incursions on the hunting territories of the Khoisan. At the same time, the establishment of game fences, intended to exclude migratory herds of wild animals and thereby keep livestock disease-free, reduced the ability of hunters to follow game, especially across national boundaries.

One of the options that foragers often take when faced with pressure from outside forces to cease hunting is to work with livestock. The Navajo have become well-known sheep-herders and native Australians frequently work as stockmen. The Khoikhoi of southern Africa were partly herders at first European contact, but also engaged in extensive foraging. The impact of European settlement was grim and one of the few locations where their society survived in altered form was in Namaqualand, in the arid regions in the extreme northwest of South Africa and adjacent Namibia. Reserves were created and managed on a communal tenure system. However, in the early 1970s, a new proposal was made to create the Richtersveld National Park, effectively sequestering 80,000 hectares from the Nama (Boonzaier et al., 1996). This reflected as much the extreme political marginalisation of the Nama as any protection of the minimal wildlife resources of the region. However, in a reversal of the usual course of events, advocacy groups joined with the Nama to protest the proposed exclusion. The effect was to halt the park creation until the end of the 1980s when grazing and foraging rights were conceded (or else compensation for their loss) and employment as rangers was offered as a priority to Nama.

Hunting and tourism in these regions remains a special case and of variable importance. The rangelands of west-central Africa, for example, are virtually devoid of large herbivores and infrastructure so unattractive as to make hunting and tourism insignificant. In eastern and southern Africa, however, wildlife constitutes a significant element of national income, notably in Kenya, Tanzania, Zimbabwe and South Africa. The system of national parks and a highly organised infrastructure means that the greatest proportion of income accrues directly to the state, rather than to nearby communities. As a result, poaching is rife and an adversarial relationship between park

authorities and villagers is the norm. Although revenue-sharing systems have been put in place in some areas and heavily promoted by aid and development agencies, their contribution to livelihoods in these regions remains extremely small.

At the same time, as the income from tourism and hunting increases, so does the desire to control resources with greater precision. Animals are now regularly translocated between protected areas both to control population and to ensure that tourists see a particular range of species that have been advertised. Similarly, veterinary services to 'wild' animals are now an accepted method of ensuring their presence for visitors. With these levels of investment, the trend will be both to ensure that tenurial rights are enshrined in legal documents and to adopt ever more powerful policing methods to exclude local populations. Since powerful interests in national governments depend heavily on the revenues accruing from such enterprises, it seems most unlikely that any type of revenue-sharing initiatives will be allowed to make more than a limited impact.

In Central Asia, the situation is somewhat different, since until recently, all protected areas were reserved by decree and certainly did not benefit from consultation with the local populations. The paradoxical consequence was an almost unparalleled level of habitat conservation. Similarly the system of collective farms was kept going with subsidised inputs, sometimes brought in at uneconomic costs. This had the effect of reducing pressure on the natural rangelands, as did the central control of animal numbers and relatively high levels of offtake. Tourism remains a nascent industry, and any income from it extremely volatile, reflecting the unstable politics of the region. However, the implosion of the collective farms has resulted in the regeneration of pre-Soviet patterns of pastoralism and grazing, increasing pressure on the rangelands and bringing herders into potential conflict with the management of poorly-resourced parks and protected areas. The lack of market infrastructure and the limited range of inputs means that Central Asian pastoralists are generally much poorer and more vulnerable than those in Africa.

2.3 Obligations under the CBD

Under the international Convention on Biodiversity (1992), signatories were required to take action in a number of areas affecting rangelands (Box 2).

In the case of rangelands, little has so far been achieved. The biodiversity of rangelands (Articles 7b, 7d of the CBD) is poorly documented and what evidence there is relates largely to developed world economies, notably Australia and North America. Solbrig (1996) notes that no complete floral and faunal inventory exists for any tropical rangelands. The pressures on rangeland biodiversity (Article 7c) are better understood: intensified use of rangelands, fragmentation and loss of habitat. However, the pressure for habitat conversion usually comes from dominant or influential groups within a particular nation-state and government often finds it hard to resist these. So outsiders are often better placed to analyse the causes of biodiversity decline, but less in a position to take preventive action. Ground-based monitoring of habitat conversion is slow, expensive and often seems to be of limited or even negative value to national governments. However, the advent of remote-sensing, and the potential for example, to estimate the amount of tropical forest burnt down each year has changed the situation. Governments can no longer shelter behind professions of ignorance. Even so, progress towards archiving and maintaining such data (Article 7d) remains slow and unconvincing.

Similarly, although many developing countries, under pressure from external donors, have developed national environmental strategies, few of these include any very specific provisions for rangeland protection (Article 6a) nor are these integrated with other sectoral programmes (Article 6b). Where the state has taken an interest in the management and conservation rangelands, notably in Australia, the socio-economic conditions are so distinctive as to hold few lessons for the developing world.

Box 2 Action required by signatories of the CBD (1992)

- identify the components of biodiversity important for conservation and sustainable use (article 7a)
- monitor the components of biological diversity (article 7b)
- identify and monitor processes and categories of activities having or likely to have significant adverse impacts on the conservation and sustainable use of biodiversity (article 7c)
- maintain and organise the data derived from identification and monitoring activities (article 7d)
- develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity or adapt existing strategies, plans or programmes for this purpose (article 6a)
- integrate, as far as possible and as appropriate, the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies (article 6b).

Source: IUCN (1994: 29–26)

3. The formation of rangelands

3.1 Biotic factors

The determinants of natural rangeland vegetation are minimum temperature, plant available moisture (PAM), plant available nutrients (PAN), fire, and herbivores. The combination of these factors prevents the establishment and the growth of trees and other woody plants in high densities (Solbrig, 1996; Barbier et al., 1994), although their significance varies in different parts of the world. The South African and northern South American rangelands are good examples of soil and climate favouring the production of grass and herbaceous species, rather than trees. Elsewhere, the evolution of large herbivores is related to the creation and extension of grasslands. Rangelands that have co-evolved with grazing species include: the savannas of Africa (antelopes and zebras), the steppes of Asia and Eastern Europe (gazelles, goats, camels, bison and wild horses), and the prairies of North America (deer and bison). Large herbivores are complemented by numerous small mammals, such as marmots, pikas, ground squirrels, gerbils and voles. In addition, in Africa, Australia and South America termites are extremely important, consuming up to one-third of the total annual production of dead wood, leaves and grass.

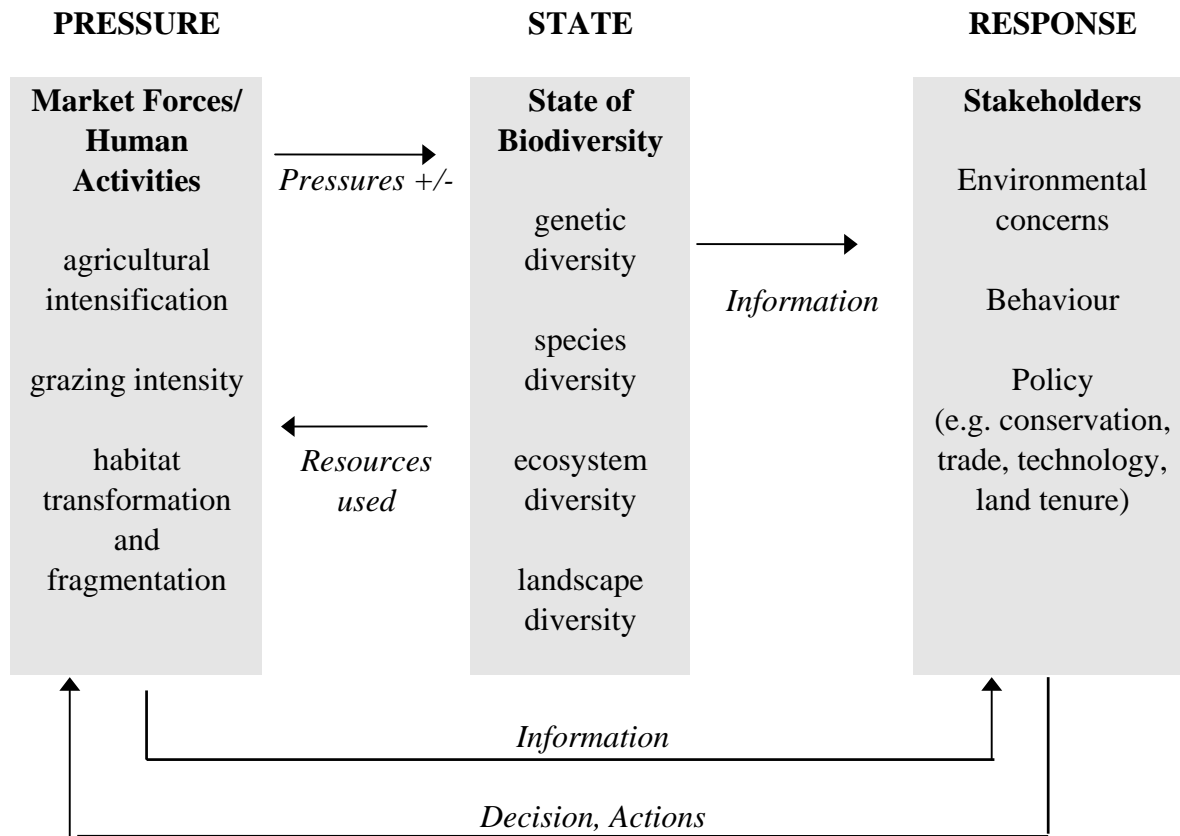
Today, the world's rangelands are used primarily for livestock production. All other forms of land use, such as foraging, recreation or military activity, are of minor importance (Solbrig, 1993). In most continents, livestock production has been intensified through the application of new technologies and practices, such as the use of fertiliser, the seeding of high-yielding grass and legume species, modifications to the natural water regime, and heavy grazing through high stocking rates. The principal problem of intensive ranching is to provide enough high quality fodder during the dry season. For that reason, natural pastures are replaced partially or totally by planted pastures with a high proportion of cultivated legumes. Such pastures cannot be maintained without fertilisation and may also require irrigation during the dry season (see Solbrig, 1996: 24). These practices have transformed the rangelands ecosystems generally in the direction of reducing biodiversity, which allows the producer to focus biomass production towards the needs of a particular species.

Generally, market forces are the underlying cause of transformation and intensified use of rangeland. If only economic costs and benefits are considered in decision-making rapid loss of biodiversity will not be halted. The short term negative effects of converting rangelands into artificial (species poor) pastures or agricultural fields are low, and the benefits in increased productivity sufficiently high as to outweigh the negative effects (Solbrig, 1996: 219).

Human activities are also shaping the extent and location of rangelands. On one hand, the original extent of natural grasslands has been extended by human activities. Rangelands are now found throughout much of the region once occupied by the world's temperate and tropical forests. On the other hand, humans have converted large areas of rangeland to crop production. Overall, the total area of rangelands has been declining rapidly over the past few centuries. It is estimated that grasslands once covered up to 40% of the world's land area but habitat fragmentation presently gives rangelands a much more discontinuous aspect (Groombridge, 1992).

In short, biodiversity in rangelands has declined due both to the intensification of the use of rangelands; and secondly, due to fragmentation and loss of habitat. The ‘Pressure–State–Response’ framework (Figure 2) illustrates the relationships between pressures from human activities, the state of biodiversity, and activities initiated by stakeholders to conserve and maintain biodiversity in

Figure 2. Pressure-State-Response framework for biodiversity in rangelands



Source: adapted from De Haan et al. (1997)

rangelands:

3.2 The world-wide pattern of large herbivores and the theory of ‘Pleistocene overkill’

Rangelands have been altered by human activities for a very long time. Foraging peoples have almost certainly been setting fire to grasslands to flush out game for as much as 100,000 years. Selective hunting of species of large herbivores would have changed the natural balance between predators and prey as well as contributing to evolving grazing pressure on different plant species. Palaeontological evidence clearly shows that there were once a wide variety of herbivores in many of the world’s grasslands, and that these died out almost everywhere except in Africa and to a lesser extent, the Eurasian steppe. Controversially, these ‘megafaunal extinctions’ have been associated with human colonisation (e.g. Martin, 1973, 1984; Diamond, 1989). This is seen very clearly in the New World, where the first colonising movement of human populations across the Bering Strait may have been as recent as 20,000 BP. Slow-moving large herbivores with no natural predators

would have been ill-equipped to defend themselves against bands of well-armed and well-organised human beings. Similar processes are thought to have occurred in Australia and Eurasia, leaving Africa as the exception. The likely explanation is that modern humans evolved in Africa, and thus would have co-evolved with their potential prey, forcing it to become more effective in avoiding hunters.

The effect of exterminating large herbivores is also to eliminate specialised predators and to open niches for small species, which presumably multiply and speciate. In some parts of the world, pastoralism came to fill these niches but elsewhere, the rangelands remained empty until European expansion a few hundred years ago. Table 4 compares the impact of these two major anthropic effects for different regions:

Table 4 Pastoralism and megafaunal extinctions in different regions of the world

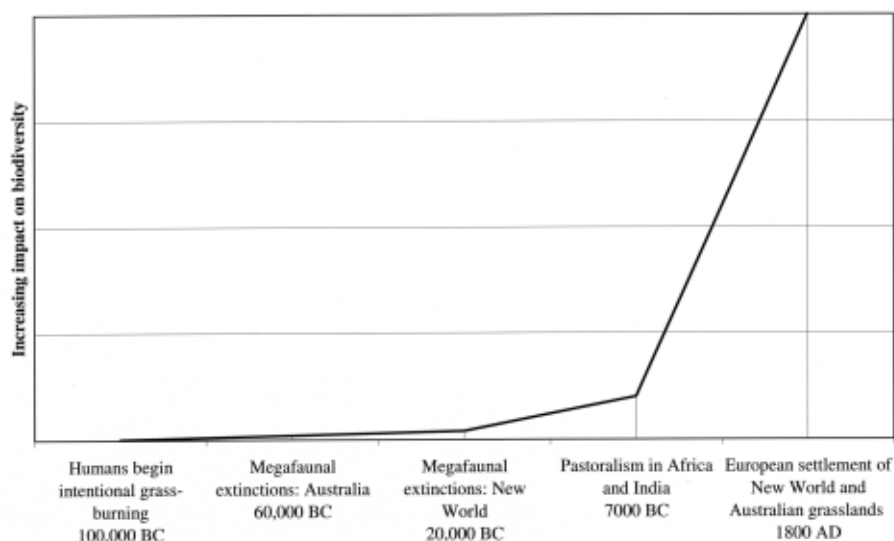
Region	Megafaunal extinction	Pastoralism
North America	Yes	With advent of Europeans
South America	Yes	With advent of Europeans except for small-scale llama/vicuña herding
Australia	Yes	With advent of Europeans
Europe/ Near East	Yes	ca. 10,000 years ago
North Africa	Yes	ca. 7000 years ago
Central Asia	Partial	ca. 7000 years ago
India	Yes	ca. 5000 years ago
Africa	No	ca. 6000 years ago
Oceania	No	With advent of Europeans

The last significant megafaunal extinction was the elimination of large mammals from the littoral of North Africa. Unlike other extinctions, this was not caused by subsistence hunting, but by the demand for spectacular animals to display at the Roman games.

Nonetheless, the last 10,000 years has seen a major acceleration in anthropic impacts and many of the processes set in motion are still continuing today. Figure 3 presents a highly schematic view of the history of the increasing impact on rangeland biodiversity of human activity, beginning with the hypothetical initial burning of grasslands to flush out game.

The most significant changes came about through the evolution of pastoralism. The occupationally specialised herding of herbivores has a very different history in the different continents, accounting in part for some of the differences in their biotas. Pastoralism begins in the Near East perhaps as much as ten thousand years ago. In Africa, Central Asia and India pastoralism is at least 8000 years old. The main domesticates, cattle, yaks, sheep, goats, horses, reindeer and Bactrian camels all derive from Central Asia, and from the earliest period, pastoral herds would have competed with their wild relatives for range space.

Figure 3 Historical evolution of increasing human impact on rangelands



3.3 Species richness distribution

The floristic diversity of rangelands varies markedly by geographical region. Some locations in Africa or South America approach the diversity of tropical forests, others, such as those in Australia seem to be depauperate (Groombridge, 1992). The reasons for this are still disputed, but factors such as plant available moisture (PAM), plant available nutrients (PAN), minimum temperature, occurrence of fire, and influence of herbivores all influence the evolutionary process. Species composition and distribution is dynamic and constantly changing (Szaro, 1996: xxvi). Some changes are more subtle, such as alterations in the genetic composition of populations, while others, such as plant succession after fires and floods, are more obvious.

Species in any ecosystem are differentiated by their morphological and physiological characteristics. Baruch et al. (1996: 179) argue that species differentiation may be more marked in high-stress (resource poor or severely and/or frequently disturbed) ecosystems and more subtle in resource-rich, low-stress ecosystems. Rates of speciation and extinction are higher in semiarid ecosystems than in temperate ones, because a highly stressed system will limit numbers of co-occurring species with similar ecological requirements. Greater availability of resources in low-stress ecosystems permit more species with similar ecological requirements to inhabit a particular niche. As a result, semiarid ecosystems tend to support lower species diversity than mesic ones (Baruch et al., 1996).

The key factors in determining floristic diversity are thus likely to be the morphology of grazing impact, the density of micro-habitats and the degree of habitat conversion. Changes in the pattern of grazing, for example through the introduction of domestic stock, can affect grassland biodiversity both directly through pressure on plants, and indirectly, by trampling from large hoofed animals. Box 3 contrasts the impact of grazing history on different rangeland ecosystems. Heavy grazing tends to cause palatable species to decline and the subsequent dominance by other, less palatable, herbaceous plants or bushes (De Haan et al., 1997; Adams, 1996; James et al., 1998). De Haan et al. (1997) note that the regeneration after such a change can take between 30 and 100 years.

In arid and semi-arid rangelands, extensive vegetation change can be a cyclical process responding to climatic variability. The extent of vegetation change that can be attributed to livestock versus

climate is debatable (Adams, 1996; De Queiroz, 1993a,b; Doughill and Cox, 1995; Hiernaux, 1996; Homewood and Rogers, 1987; Perevolotsky, 1995 and West, 1993). Ungulate grazing is an important process in many rangeland ecosystems. If grazing is excluded, biodiversity may increase in the short term, but may decline long term because the system itself changes and in the future may be less able to withstand external disturbances such as drought and fire (West, 1993: 9). Figure 4 illustrates how moderate grazing can enhance diversity.

3.4 Biogeochemical cycles

Archer et al. (1996: 207) suggest that the functioning of ecosystems can be interpreted in two ways: either as flow of energy and nutrients through an ecosystem, or as the persistence of species populations and their properties, i.e. the relative stability. The analysis of biogeochemical cycles provide one tool for monitoring biodiversity. Biogeochemical cycling incorporates primary production, water-uptake and organic matter decomposition as primary variables, as well as biomass-allocation patterns, herbivory, and interactions between these processes (Table 5).

Changes in biodiversity can modify the pattern of biogeochemical cycles in a given ecosystem both quantitatively and qualitatively. Baruch et al. (1996: 176) note that the mechanisms of biogeochemical cycles, such as organic matter production, water and nutrient cycling, and decomposition, are well understood, but their quantitative aspects have not been worked out satisfactorily.

This can perhaps be best understood by considering the complex of elements that go into the maintenance of soil fertility. The fertility of soils is essential for crop growth and for the biomass production upon which pastoralists depend. Soils themselves are complex ecosystems which contain a rich flora and fauna (Ehrlich and Ehrlich, 1992: 223). Earthworms loosen soil and allow oxygen and water to penetrate it. Insects, mites, and millipedes give soil its texture and fertility. Micro-organisms convert nitrogen, phosphorus, and sulphur into forms usable by the higher plants on which livestock depend (Ehrlich and Ehrlich op. cit.). Bacteria decompose organic matter,

Box 3 Differential effects of grazing histories

The effect of similar grazing pressures on biodiversity vary in different regions. West (1993: 8) argues that the effects of grazing on biodiversity depends on grazing intensity, evolutionary history of the site, and climatic regimes. In semiarid rangelands with a lengthy evolutionary history of grazing, herbivory appears to have a relative small effect on species diversity (e.g. short grass plains of the US). On the other hand, climatically similar grasslands, which have a shorter evolutionary history of large mammal grazing, lose diversity at much lower grazing intensities, for example, the Argentine pampas.

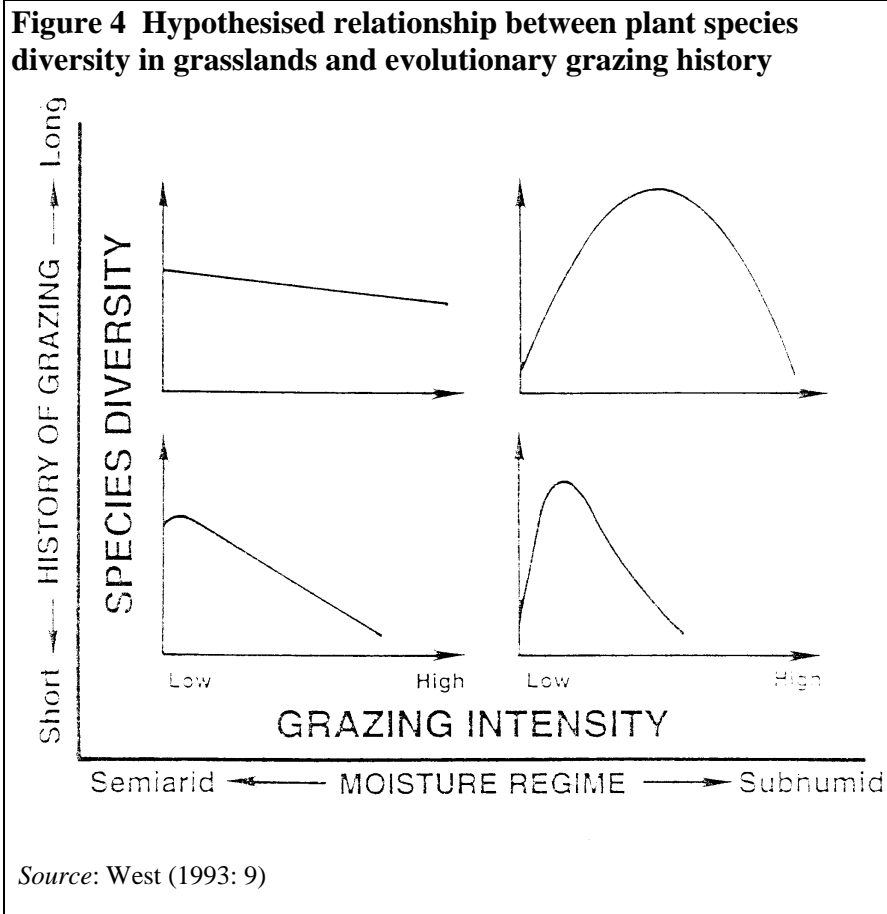


Table 5 Biogeochemical processes in savanna ecosystems

Biogeochemical cycle	Processes involved
Energy and carbon fixation	Photosynthesis
Water cycling	Allocation of biomass for leaf area development Water uptake and transpiration by primary producers
Nutrient cycling	Allocation for: leaf area development, root biomass and area Nutrient uptake by primary producers roots, symbiosis and mutualism Nutrient transfer and redistribution living plant matter consumption (herbivores) dead plant matter consumption (detritivores) secondary consumers Nutrient release decomposition processes (soil micro-organisms) mineralisation Soil formation organic matter conditioning and humification
Interactions	Organic matter production requires nutrient and water uptake, whilst the water cycle in the system introduces nutrients into, and leaches nutrients out of, the system.

Source: Baruch (1996: 177)

releasing carbon dioxide and water into the soil and leaving humus, a residue of tiny organic particles, which is resistant to further decomposition and a key component of soils. Humus particles maintain soil texture, retain water and play a critical role in soil chemistry, permitting the retention of nutrients essential for plant growth. Disrupting any specific element in this complex can result in the collapse of the soil ecosystem and a consequent decline in the biodiversity of soil fauna.

3.5 Functional diversity

Functional diversity in a savanna ecosystem tends to minimise the loss of resources such as energy, water and nutrients (Baruch et al., 1996: 189). Functional groups are aggregated species which have similar effects on ecosystem processes. If there is more than one species per functional group, the species within that group may be equivalent or redundant in their impact on ecosystem processes and that the ecosystem could function equally well with fewer species (West, 1993: 9). But if a functional group is totally eliminated from the system, some resources will not be captured and then their flux within the system will decrease. For instance, if trees are eliminated from a savanna, total leaf area will decrease, resulting in less energy entering the system and total root length similarly decreases, reducing both the water transpired and the mineral elements absorbed. Thus, change in functional diversity will decrease the amount of resources used, leaving some resources unutilised; eventually these may be lost from the system.

Changes and loss of species from ecosystems tends to affect the availability of resources (e.g. nutrients, energy) for the remaining species, even where resources are not lost. Baruch et al. (1996: 188) report that the replacement of native species by African species in South America as a result of post-Columbian transfers initiated a new and progressive loss of species from the community. Changes in the biodiversity of primary producers that result in variations of system structure (biomass allocation, leaf area amount and distribution, etc.) affect water, nutrient, and energy flow. Rates of water, nutrient, and energy cycling through ecosystems depend on the horizontal and vertical structural features of their primary producers (e.g. leaf area, extension and area of the root system, and vertical stratification of the above-ground biomass). Changes in structure usually follow from variations in the proportions of functional groups within primary producers; for instance, if the balance between species with extensive as opposed to intensive root systems (i.e. trees against grasses and sedges) changes the whole ecosystem alters. These alterations in the structure of the ecosystem tend to affect its function more than changes in species richness alone (Baruch et al., 1996: 190).

The elimination of a species in species-rich habitats has a very different effect from the same occurrence in less diverse systems. Baruch et al. (1996: 189) found that the removal of dominant species tends to affect ecosystem function more strongly in less diverse communities. In diverse communities, other species in the community may increase in size or frequency and thereby capture the resources released by the elimination. But, in less diverse communities, there will be fewer similar species and perhaps none that are able to control the resources the same way.

The introduction of alien species of a certain functional group (e.g. grasses, trees) causes changes in biogeochemical cycling. Exotic species appear in rangeland through human agency, either introduced intentionally to improve the forage value of range or as escapes from cultivation or ornamentals. The introduction of highly productive grasses affects productivity, temporal distribution of biomass production and reproduction (phenology), flammability of the above-ground biomass, and quality of biomass for herbivores. The history of vegetation is strewn with unfortunate examples of both adventives and intentional introductions causing collapses in biodiversity. Box 4 shows a typical example from the Great Basin of the United States.

Box 4 Invasive species and permanent changes in ecosystem structure

The invasion of the Great Basin of the United States by *Bromus tectorum* illustrates the irreversible changes wrought by a single species. It has replaced many native herbaceous species, primarily by reducing the amount of water available to these species. As a result, the frequency of fires has increased, causing further loss of native species. Species turnover and fire tend to be accompanied by the losses in soil fauna and micro-organisms, preventing recolonisation. Dominance of a single introduced species, *Bromus tectorum*, has irreversibly altered the ecosystem.

Source: Mack, 1981

However, not all exotic (alien) species are a threat to biodiversity. West (1993: 11) argues that, as open systems, wildland communities continuously receive new arrivals and adjustments do not necessarily result in a net loss of species. For instance, the plant species richness of the Californian annual grasslands is probably higher today than in pre-European times, although there may have been a reduction in perennials. Calls for the removal of all alien species are probably impractical as well as arising from a faulty conception of some original mythical status quo.

3.6 Biodiversity and ecosystem stability

Biodiversity also plays a crucial role in ecosystem stability. Stability can be measured by various ecosystem properties, such as floristic composition, demographic behaviour and vegetation cover. Archer et al. (1996: 214) argue that the more species overlap in their functional characteristics, the greater the probability that an ecosystem will be capable to cope with extreme disturbances (e.g. fire, drought). Therefore there is a significant relationship between patterns of species richness and degree of stability. For instance, if trees are totally eliminated from a dry tree savanna, seedling establishment will be reduced and the savanna will take longer to recover from the fire, or will not recover at all, changing into grasslands. In the context of drought, where greater levels of biodiversity have been conserved, post drought recovery of the ecosystem was much more rapid than in less diverse areas (Tilman and Downing, 1994).

The overall extent of a habitat area is also related to the stability of an ecosystem. Archer et al. (1996: 212) found that relationships between stability and diversity are sensitive to spatial scale. Rangelands ecosystems can be very diverse in their structure (e.g. areas of pure grasslands, or with patches of trees or shrubs, etc.). Stability is promoted by functional complementary among different spatial components of the ecosystem, and interchange of functionality between those components. This means that ecosystems covering a large surface area tend to be more stable than fragmented systems. Smaller areas of rangeland are more likely to be modified as a result of a disturbance and habitat fragmentation is thus associated with instability.

4. Regional rangelands systems

Given the importance of regional systems and the historical specificity of different continents, this section provides a brief overview of the situation by region.

4.1 North America

The North American rangelands, the prairies, may have been affected by Amerindian hunting practices, but were certainly highly biodiverse at the point of the European irruption into the region. Their decline has two main sources, transformation into agricultural land and the creation of secondary pasture. Continuing application of agrochemicals may also be detrimental to aquatic plants and wildlife species as well as to human health. Besides habitat destruction, farming has had indirect effects on biodiversity. Waterways, railways, and roads have fragmented and disturbed natural habits so that these can no longer support many native animal species, as the example of Iowa illustrates (Box 5) (Bultena et al. 1996).

An aspect of North America that is striking in global perspective is the speed at which the habitat has disappeared. A combination of good human health, violent elimination of indigenous peoples and high resource investment were responsible for spectacular levels of habitat conversion in less than a century and a half. Prior to the 19th century, Canada had an estimated 360,000–400,000 km² of prairie; only 80,000 km² remained by 1982. Today most of Canada's rangelands (325,000 km²) is secondary with correspondingly low levels of biological diversity. The change to arable land continues at a rate of approximately 500 km² per year (Mondor and Kun, 1982 cited in Groombridge, 1992: 289).

Box 5 The decline of the Iowa grasslands

Iowa was once covered by prairies. It is estimated that in pre-Columbian times 30 of Iowa's 36 million acres were covered with rangelands or wetlands. Iowa's rangelands have been modified more extensively than anywhere else in the United States and the prairie ecosystem essentially eliminated. Recent inventories indicate that only about 30,000 acres remain; 93% of Iowa's total area is now farmland. Numerous plant and animal species have disappeared; of 250 higher plant species that once grew in the native tallgrass prairie, only fifty to sixty remain. More than thirty species of vertebrate have disappeared from Iowa over the same period.

Source: Bultena et al. (1996: 92)

4.2 South America

South America encompasses both tropical (savanna) and temperate (pampas) rangelands. Tropical rangelands constitute the majority of the vegetation cover exceeding 2 million km². The two rangeland ecosystems with the greatest extension are the Brazilian *cerrados* and the *llanos* in Colombia and Venezuela. In other areas, such as Amazonia or Central America, rangelands occur as more or less isolated xerophilous patches of open vegetation amid the rain forests (Sarmiento, 1983:245). The temperate rangelands are further south and cover major parts of Argentina and Uruguay (Adamoli et al., 1991). Generally, South American rangelands contain high levels of biodiversity.

Figure 5 show levels of species richness estimated for the different savannas in South America.

Table 6 Floristic richness of South American rangeland types

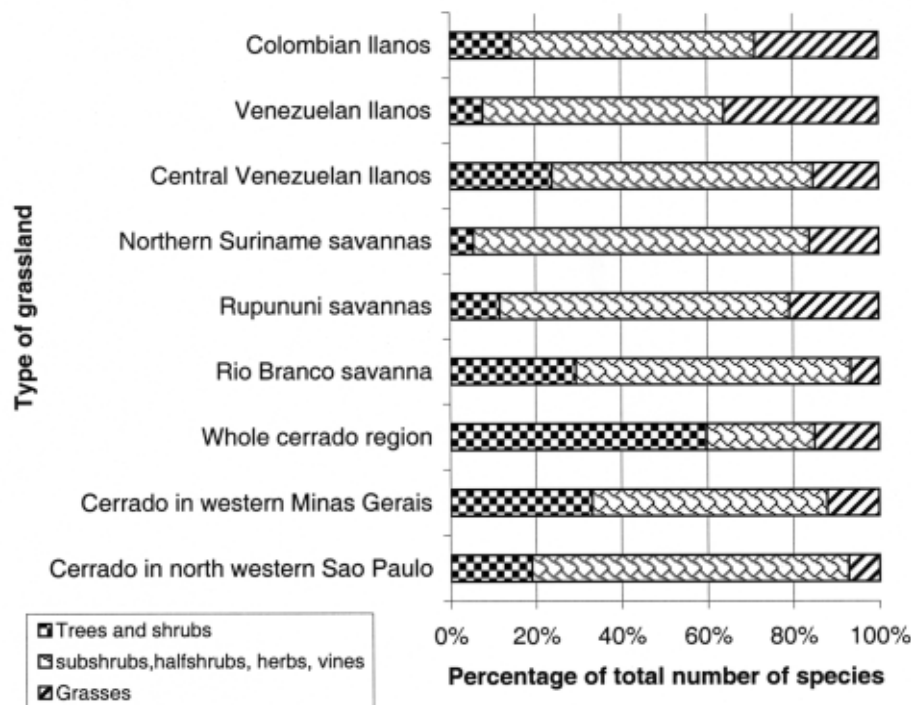
Formation	Area (in 1000km ²)	No. of recorded species			Total Species
		Trees and shrubs	Subshrubs, halfshrubs, herbs, vines	Grasses	
Cerrado in north western Sao Paulo	50	45	175	17	237
<i>Cerrado</i> in western Minas Gerais	15,000	c. 200	c. 330	73	c. 600
Whole <i>cerrado</i> region	2,000,000	429	181	108	718
Rio Branco savana	40,000	40	87	9	136
Rupununi savannas	12,000	c. 50	291	90	431
Northern Surinam savannas	c. 3000	15	213	44	272
Central Venezuelan <i>llanos</i>	3	69	175	44	288
Venezuelan <i>llanos</i>	250,000	43	312	200	555
Colombian <i>llanos</i>	150,000	44	174	88	306

Source: Groombridge, 1992: 282

Some of these figures vary markedly from source to source. The number of species given for the Cerrado region (718) in Table 6 contrasts sharply with Solbrig et al. (1996: 218) which states that the Cerrado is the richest rangeland area of the world with up to 10,000 species of trees and shrubs and several thousand species of herbs. The temperate grasslands of Argentina and Uruguay support over 400 grass species, which is very rich in comparison to comparable areas in other continents (Groombridge 1992: 281).

Generally, the agricultural productivity of tropical rangelands is low on account of their poor soils and seasonal climate; agriculture is usually practised in areas with better soils and rainfall over 700mm. However, such natural disadvantages can be increasingly counterbalanced by the application of technology (investments in land preparation, irrigation, fertilisation and pesticides). Increasingly large areas have been converted to capital intensive agriculture (e.g. growing of soybeans in the Brazilian *cerrado*). The constant use of fertiliser and pesticides has negatively affected local ecosystems and thus biodiversity (Solbrig, 1996).

Extensive commercial ranching is the preferred use of rangelands in both tropical and temperate grasslands. The capital investment required by extensive commercial ranching is relatively low compared to agriculture (Adamoli, 1991). In savannas, fire is set to 'improve' the quality of the grass cover, i.e. to produce short-term gains through stimulating new shoots. Solbrig (1996: 24) points out that this technique of land management reduces woody cover and leads to land degradation if livestock numbers are too high, which is usually the case. In Argentina, although the earliest use of the pampa was for livestock, conversion to cropland was under way by the 1850s

Figure 5 Composition of different types of South American grassland

(Ghersa & Leon, 1999). Unusual extensive documentation makes it possible to recover the changing levels of biodiversity corresponding to these changes in land use.

4.3 Australia

Australian arid and semi-arid rangelands occupy nearly 70% of the continental land mass, much of it used for extensive livestock production (Groves, 1981). Australia's rangelands have been transformed subsequent to European settlement through action to support the pastoral industry by:

- the provision of artificial sources of water
- the introduction of cattle, sheep and rabbits
- the introduction of exotic forage species (e.g. buffel grass, *Stylosanthes*)
- changes to traditional burning patterns
- the elimination of the dingo from most sheep areas
- and the clearing of overstorey trees

(James et al., in press)

Such interventions in the ecosystem had a negative impact on biodiversity. James et al., (in press) point out that one third of the marsupials (12) and 78 plant species that formerly occurred in rangelands are now extinct. Today more than half of Australia's endangered mammal species, more than a third of threatened bird species, about 10% of threatened reptile species, and about half of threatened plant species occur in rangelands (CSIRO, 1998).

In the higher rainfall areas, agriculture has been a major cause of loss of biodiversity. Native rangeland habitats in Victoria originally covered more than 30% of its area. Today grass and grassy

woodlands constitute the most threatened ecosystem and 31% of the endangered plant species are confined to these habitats. Of the 152 vertebrates species which are extinct, endangered or threatened, 40% are associated with rangelands and grassy woodlands while 26 vertebrate species have become extinct (Groombridge, 1992: 291).

In many arid or semi-arid rangelands in Australia and in North America artificial sources of water are so widespread that lack of rainfall results in localised feed shortages (Bennet, 1997). Large herbivorous mammals are able to continue grazing in areas which they would usually have had to abandon (James et al., 1996). Native wild animal populations, which previously relied on drinking from natural sources, increase because they are able to persist in areas that were previously most of the time not habitable. Such 'artificial' increases in some species may have negative effects on others. The effects on native fauna are: the displacement of ground-dwelling bird species; changes to the distribution and abundance of invertebrates (e.g. grasshoppers, ants and collembolans); possible recent extinction of some medium-sized native mammals; and indirect effect on wildlife populations through changing activities of predators (James et al., 1998: 1). Another effect of artificial water sources is to maintain constant high levels of grazing pressure. Many native plant species are naturally not adapted to constant grazing and will tend to be eliminated in favour of exotics (Austin and Williams, 1988).

4.4 Europe

Agricultural intensification and transformation of grassland habitat have been near-universal in Europe. The most extreme examples of human landscape shaping are the entirely sown and intensively managed short-term rye-grass leys of western Europe. These secondary rangelands have almost no significance for biological diversity. Today only fragments of European grasslands remain. Table 8 shows the remaining areas of dry, semi-natural rangelands (grasslands) in comparison to secondary rangelands (grasslands).

The 'dry semi-natural rangelands' correspond to the English meadow, no more than an area of grassland that has never been cropped. It is instructive to remember that the real destruction of meadows only occurred after World War Two. There are thought to have been something like forty thousand meadows in England in 1945 and today there are ten. Similar losses of habitat have occurred in the European wet grasslands documented by Joyce and Wade (1998).

4.5 Near East and North Africa

The pastoral culture of the Arabs grew out of a belt of arid rangelands stretching from the Straits of Gibraltar to the deserts of Baluchistan. Although now associated with camels, archaeological evidence suggests that sheep production was the original pastoral system allowing the colonisation of this vast, if harsh, resource. The absence of artificial water points limited the extent of grazing in these subdeserts until the introduction of the camel around 0 AD. Even with grazing pressure, large herbivores persisted throughout much of the region until the spread of rifles. The practice of carrying water in trucks to herds in remote waterless zones has developed since the 1950s, creating the same sort of pressure on indigenous plants as in Australia. However, the extreme aridity has made much of the vegetation extremely hardy and surveys have typically shown only restricted loss of endemic flora. However, another factor is the relative wealth of many governments in this region and their willingness to subsidise the pastoral sector. For example, throughout the Arabian peninsular, few Bedouin herds depend on pasture; the main diet of livestock is now trucked-in feeds (Blench 1995a; 1998c).

Table 8 Secondary rangelands and dry semi-natural rangelands in Europe

Country	Secondary rangelands '000 ha	Dry semi-natural rangelands '000 ha
Belgium	632	0,5
Czechoslovakia	1,600	?
Denmark	214	?
France	12,000	250
Germany	5,700	100
Great Britain	4,800	200
Greece	1,789	?
Hungary	1,350	200
Ireland	5,800	700
Italy	5,000	200
Netherlands	1,100	10
Poland	4,040	?
Portugal	761	?
Romania	4,400	?
Spain	6,645	1,452
Sweden	480	?
Yugoslavia (former)	6,400	?

Source: Groombridge (1992: 286)

4.6 Central Asia

The Asian steppes reach from Manchuria westwards to Bulgaria and Hungary, between the taiga in the north and deserts or mountains in the south. The eastern steppes represent today the most extensive area of rangelands in the world. In Mongolia, land use practices, mainly semi-nomadic pastoralism with low intensity grazing, have been very stable over centuries. Agricultural intensification has been very low and fertiliser and pesticides have rarely been used. The likely explanation is that the extremely cold winters (falling to -60 C.) make any form of cultivation unsustainable. Although Soviet scientists documented species richness and distribution in immense detail, this literature remains largely inaccessible and untranslated. Rangelands in Mongolia appear to be very rich with up to 80 higher plant species per m^2 (Groombridge, 1992). Mongolia is also notable for the variety of large mammals still extant, including wild Bactrian camels, bears, argali and wild asses as well as predators such as wolves and snow leopards. Indeed, these animals are only now threatened by unregulated hunting by outsiders. Grasslands in China are similar to those in Mongolia, although temperature falls are less dramatic and the higher human population has meant similarly higher levels of habitat conversion (see CSC, 1992).

In contrast, in the higher temperature steppes of the former USSR, large regions have been transformed into agricultural land through huge irrigation projects, especially in the hinterland of the Aral Sea. Many of these schemes have now collapsed due to the cessation of centralised input supply, and progressive salination. The land is left polluted and can neither produce crops nor revert to grassland, while crucial water sources are so reduced in size and have become so saline that they cannot be used to revive the grasslands. The task of reversing this vast transformation is so daunting that investment is unlikely to be forthcoming in the immediate future.

4.7 SE Asia

SE Asia is not usually thought of as having savannas, but as Stott (1990) points out, they constitute the single largest vegetation formation in many countries. These savannas are dominated by six species of deciduous dipterocarp and thus have the appearance of open forest. This ecosystem stretches from extreme northeast India (Manipur) across Burma, Thailand, Laos and Vietnam. Although there are more limited open savannas in Thailand, Cambodia and Vietnam but these have become extremely fragmented. The exact history of these forests remains poorly known and although they are clearly fire-adapted at least part of the core areas may be edaphic. Stott (1990: 381) argues that the poor public image of these lands, often classified as wasteland or degraded land by SE Asian governments, combined with an absence of major internationally traded timber species, has allowed these savannas to be passed over for conservation measures.

These savannas have long been used for grazing and gathering of forest products, notably fungi, but agricultural expansion has cut into them in many countries, notably Thailand. The patches of remaining savanna are now often too restricted to support significant populations of wild herbivores or indeed birds and have been described as faunal ‘deserts’. A typical victim of this process is the kouprey (*Bos sauveli*), a bovid thought to be one ancestor of modern domestic cattle. Chronic war combined with industrialisation throughout the SE Asian region has been responsible for much of the deforestation of the humid forests but has also led to extensive cutting of dipterocarp forests.

4.8 India

With minor exceptions, the grasslands of India and Sri Lanka are considered to be anthropic, the early consequence of habitat conversion (Misra, 1983; Yadava, 1990). It is thought that the whole of the subcontinent was formerly wooded; in reality, up to half the land classified as ‘forest’ may be grasslands (Pemadasa, 1990). The *patanas*, or montane grasslands of Sri Lanka may well be edaphic (Holmes, 1951). Repeated cycles of grazing and burning have led to a variety of systems reflecting different levels of biotic disturbance. The savannas of NE India are notable for the persistence of large herbivores, including rhinoceroses, elephants, buffalo and barking deer. This is in contrast to those elsewhere in the continent, where grazing species other than domestic animals have been all but eliminated. It is generally considered the Indian rangelands are relatively stable, if of poor biomass productivity, as they have adapted to the regime of grazing and burning over a long period.

4.9 Africa

Although commonly used for nomadic and transhumant pastoralism, African rangelands contain by far the widest variety of extant large and medium-sized herbivores. If the 'Pleistocene overkill' theory is correct, then their persistence is the exception in global terms. Large mammals play an important role in the ecology of African rangelands. Today, the greatest concentration of large mammals in the world is found on the savanna of northern Tanzania, but this is largely an accident of colonial history. To judge by the distribution maps in Kingdon (1997), the rangelands of eastern and southern Africa do shelter the greatest diversity of large mammals found anywhere, although Madagascar and Ethiopia are notable for their high degree of endemism.

The floral diversity of Africa's rangelands is relatively high. Areal richness is conventionally measured by the number of species per 10,000 km². The average areal richness of savanna (c. 1750 species) is not far below that of rain forest (c. 2020 species) (Menaut, 1983).

Table 9 and Figure 7 give an overview of species richness by chorological zone:

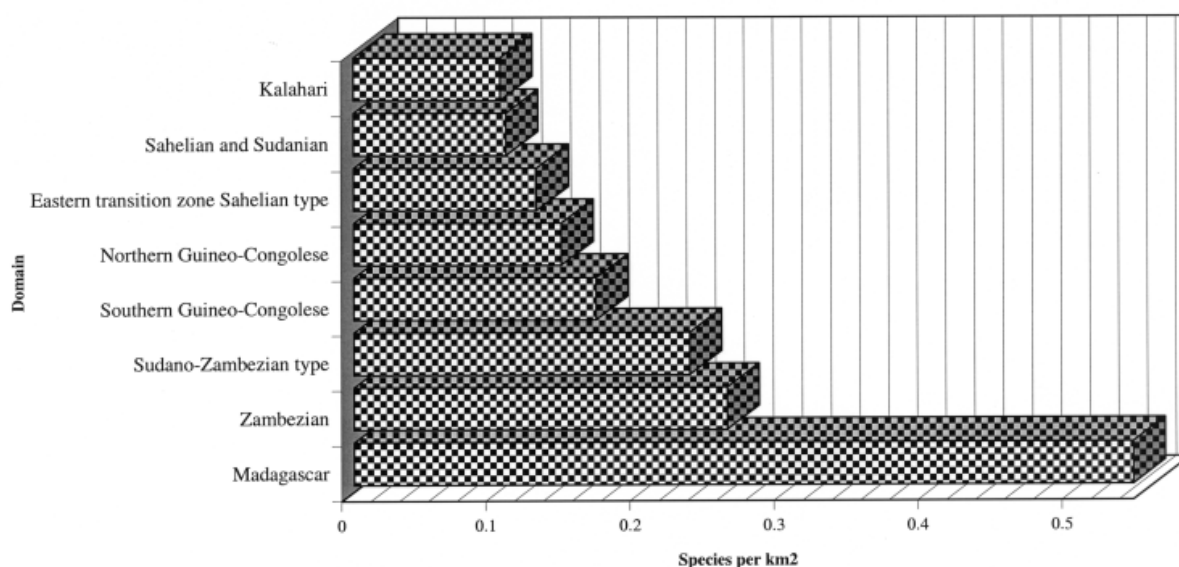
Table 9 Zones of species diversity in Africa

Region	Species per 10,000 km ²
Guineo-Congolese region, peripheral domain	
Northern district	1,440
Southern district	1,680
Sudano-Zambezian region	
Sahelian and Sudanian domains	1,060
Zambezian domain	2,590
Eastern transition zone Sahelian type	1,270
Sudano-Zambezian type	2,330
Kalahari domain	1,020
Madagascar	5,410

Source: Menaut (1983: 113)

The figures should be treated with some caution as a high proportion of the plant species listed are associated with forest, wetland or other habitats. These high levels of biological diversity flow in part from the fact that Africa's rangelands merge gradually into other large habitat formations, notably forest and semi-desert, rather than being confined by mountains, the sea or intensive agriculture (Groombridge 1992: 282).

Figure 7 Species richness of African savannas



After Menaut (1983)

Although natural fires affect huge areas, limiting the build-up of dry organic matter and favouring the survival of some species at the expense of others, human beings have been burning Africa's rangelands for a minimum of 50,000 years and probably much longer (Herlocker et al., 1993; James, 1993). Fires bring game out in the open, but the flush of grass that appears shortly after burning also attracts grazing animals, making them easier to hunt.

Pastoralism may begin in Africa as early as 7000 BC, but its major impact is probably felt by about 3000 BC in both East and West Africa. Cattle and sheep do not reach the rangelands of southern Africa until about 300 AD. The widespread presence of tsetse would have constituted a major constraint to livestock in many regions, at least until trypanotolerant breeds were developed. Destroying tsetse habitat in woody vegetation and gallery forest would have provided an additional incentive for pastoralists to burn off forest cover. The twentieth century brought trypanocides, enhanced veterinary care and eliminated much tsetse habitat, providing an incentive to substantially increase herd sizes and thus grazing pressure (Blench, 1995b). Hence the growth of a large and often problematic literature on range degradation and overgrazing.

Other literature has focused on range degradation and vegetation change due to overgrazing or to climatic variability (Adams, 1996; Behnke, 1994; Doughill and Cox 1995; Blench and Marriage, 1999). Nonetheless, heavy grazing does change the composition of the vegetation (Hiernaux, 1996). The density of palatable perennial species falls as they are replaced by less palatable ones, because their competitive ability declines.

Another consequence of heavy grazing can be the spread of woody vegetation and the eradication of grassy areas (Arntzen, 1990). Adams (1996: 6), discussing the Kalahari in Botswana, reports that in 'low tree and shrub savanna' the combination of heavy grazing and the absence of hot grassfires causes the spread of dense, woody vegetation (bush encroachment). The spread of pure and persistent stands of species – such as blackthorn – means long-lasting and irreversible decline in species diversity (De Queiroz, 1993b; Dougill and Cox, 1995). This kind of bush encroachment

means a decline in the productivity of the grazing for both cattle and goats, as well as wild herbivores. Adams (op. cit.) points out that bush encroachment in the Kalahari is distinct from other forms of vegetation change, both in terms of persistence and its exclusion of other species.

Apart from the semi-arid and subhumid savannas, Africa has a smaller number of high-altitude grasslands. The Ethiopian Plateau constitutes the most extended area, but the highlands of Uganda and Rwanda represent a similar ecology. In West Africa, the Fouta Djallon in Guinea and the Adamawa grasslands in Cameroun and Nigeria are comparable grasslands. Unlike the Sahel, the West African grasslands have historically had relatively low grazing pressure from wild herbivores and none from domestic animals because the foothills around these plateaux are humid forest that acted until recently to exclude cattle. The colonisation of these grasslands by pastoralists took place in the mid-to-late nineteenth century when the expansion of population cleared sufficient areas of tsetse to make it possible to reach them without unacceptable levels of mortality from trypanosomoses. They represented almost ideal conditions for pastoralists, with lush grass, little competition with farmers and reduced disease problems. As a result, cattle herds came in increasing numbers, gradually changing the pattern of vegetation until they became almost unusable as a habitat for livestock (Blench 1998b). The Mambila Plateau in SE Nigeria represents a good case history of this type of cycle (See Box 7).

4.10 Oceania

Oceania is not thought of having grasslands in the same way as the large land masses. Nonetheless, both the Pacific Islands, New Zealand and the sub-Antarctic islands have limited edaphic grasslands. Gillison (1993a) notes that these grasslands have been little studied, with the exception of New Zealand. New Zealand and New Caledonia are the principal islands where these grasslands are extensively exploited for grazing. The principal references on these regions are:

Oceania	Gillison (1993a)
New Zealand	Mark (1993)
Other Pacific islands	Gillison (1993a)
Sub-Antarctic islands	Hnatiuk (1993)

Box 6 The overgrazing controversy: more heat than light?

It is impossible to research the literature on rangelands without encountering numerous impassioned polemics on the subject of overgrazing. Stereotypically, it divides into 'old' literature which is characterised as saying that grasslands are being irreversibly degraded – the usual causes of this are feckless pastoralists with their oversized herds. Revisionists however observe that Sahelian rangelands have a much greater ability to recover than has previously been recognised and that pastoralists are in fact sound environmental managers and their large herds represent rational economic decision-making. Both views probably say more about the internal politics and changing ideologies of Western researchers than they do about the world's rangelands. Rangelands are so biotically diverse and so heavily influenced by a variety of anthropic factors in different regions of the world, that almost any position can be supported through appropriate case studies. Pastoralists are so socio-culturally diverse that it seems extraordinary to argue they are all following comparable underlying management strategies unless the argument takes as axiomatic the posit that every society is economically rational in the same way. The overgrazing controversy is worn down to the thin soil it grew in and only a greater accumulation of careful descriptions of individual cases are likely to produce innovative generalisations.

The debate about the ‘naturalness’ of these grasslands is full of uncertainties and much of the literature concludes that the firing of woody vegetation from about 40,000 BP is responsible for much of today’s grasslands. In New Zealand, the grasslands may be much more recent still, with evidence that they were created by firing to increase the productivity of the edible fern *Pteridium esculentum* by the Maori over the last thousand years (Gillison, 1993a). The grasslands of Rapa Nui (Easter Island) are certainly the result of overexploitation of woody vegetation by early Polynesian settlers as recent palynological studies have shown.

The grasslands of the sub-Antarctic islands are rarely mentioned in inventories of rangelands and their composition is highly variable from one island to another. Composition and biodiversity is relatively simple, but the interest of these grasslands is that they have had virtually no human interference except in very recent times and many have been declared Protected Areas, conserving both flora and fauna in that pristine state rarely encountered elsewhere (Hnatiuk, 1993).

Box 7 Overgrazing in Africa’s high-altitude grasslands

The Mambila Plateau in SE Nigeria is a typical high-altitude grassland of Adamawa. It was first colonised by Ful^oe pastoralists in the 1890s in the immediate pre-colonial era (Blench 1991a). From then, waves of herds appeared from all parts of West Africa, until by the 1930s, colonial officers began to complain that overstocking would lead to environmental degradation. These were followed by a series of reports on the management of the Plateau. None of these recommendations had any effect on policy and by the time of the first aerial survey of numbers in 1984, the cattle population was in the region of 400,000. The signs of degradation were beginning to be highly visible, but even so, numbers continued to increase during the 1980s, until a second survey in 1990 estimated there were some 600,000 cattle. A decade later, in 1999, numbers have undergone a major crash, and the ubiquitous bracken and tussocks of inedible grass suggest that ecological collapse has finally drive away the vast herds. High-altitude grasslands are not resilient in the same way as Sahelian rangelands because they do not have a history of responding to climatic variability and have not co-evolved with a limited range of herbivores. In this way, overgrazing can occur and a potentially rich resource that might be managed sustainably becomes a barren wasteland.

Source: Author’s observations

5. Why conserve biodiversity in rangelands?

Arguments for the conservation of biodiversity in rangelands are a subset of those for biodiversity in general (see Blench, 1998a). However, the strongly anthropic character of most rangelands makes these arguments problematic; if rangelands are human creations there is no 'original' state that can be conserved, maintained or restored. Indeed the argument must be turned on its head; there is a strong case, on both economic and ecological grounds, for thinking that rangelands should be biodiverse.

A distinctive pattern of management that emerges from observations of rangelands world-wide is the short-term perspective of users, whether they be Brazilian ranchers or African pastoralists. Rangelands can be used sustainably if their ecosystems are maintained intact and they are most productive when most biodiverse, assuming they are put to a variety of uses. But the tendency has been both to turn individual ranges to single uses (e.g. one livestock species) and to try and extract the maximum value over a short period (for example by burning off the grass cover). Because individuals are not liable for long-term damage to the ecosystem, these patterns of intensive short-term exploitation may be both economic and socially acceptable.

5.1 Ethical and aesthetic arguments

Apart from ecological and economic arguments based on the notion that biodiversity should be conserved for reasons of self-interest, ethical and aesthetic arguments are also commonly put forward. Aesthetic arguments say diversity has a value in itself, that organisms are attractive in their own right. This is linked to the 'stewardship' argument, that we have an ethical responsibility to preserve biodiversity for future generations, partly because the function of so much biodiversity remains unknown and it would be irresponsible to destroy a resource whose potential has remained unexplored.

These arguments only really work with those who are already converted to this line of reasoning and are not very helpful in practical decision-making. Aesthetic and quasi-religious priorities have a habit of shifting ground over time, making an argument that was valid for one generation irrelevant for the next. They are determined by personal and cultural preferences, which may be widespread, important and indeed the focus of political action by advocacy groups. But without a scientific grounding they are likely to remain ephemeral. This has a particular relevance to rangelands since aesthetic priorities will result primarily in the conservation of attractive, large and visible species, as the present situation of African rangelands suggests. There is pressure to conserve tropical savannahs where they provide an environment for large mammals, for example in East Africa, whereas in West Africa, where such 'headline' species have disappeared, they are at the bottom of the list of biome conservation priorities.

A problematic subset of aesthetic arguments concerns the focus on biodiversity hotspots. Madagascar exhibits some of the highest species diversity per unit area of any country in the world. It is threatened, however, by the same processes, overgrazing and burning as well as habitat conversion. Scientists have generally concluded that since many endemic species are at risk and cannot be recovered if they disappear, Madagascar should therefore be considered a priority. Similar arguments have been advanced for other islands, for example Soqotra, where similar rates

of endemism prevail. However, the plight of smallholder farmers is roughly comparable to many other semi-arid regions and it is unclear that their presence in a landscape of exceptional biodiversity should allow them to be favoured against poor communities elsewhere.

5.2 Economic arguments

Rangelands, with their use-based definition, can be valued more directly than forests. Economic arguments for biodiversity conservation in rangelands may be said to have direct and indirect elements; loss of large mammals or indiscriminate burning can result in reduced tourism revenue while replacement of grass species can reduce soil fertility and quality, contributing less to ecosystem services. In most cases, however, the arrow in the equation is not unidirectional. Habitat conversion can lead to loss of livelihood for one producer (a pastoralist) and corresponding gain for the arable farmer, a procedure paradoxically reversed when rainforest is converted to pasture.

Such arguments cannot be considered outside the specific socio-economic context of a particular landscape. For example, an Australian rancher may mismanage pasture, thereby reducing its capacity to support livestock. The preferred solution may not be to manage the pasture better, but to spray fertiliser and leguminous seeds from a plane, thereby decreasing overall biodiversity but increasing, albeit temporarily, the biomass of palatable species. Such responses usually have support of range management scientists and may be subsidised by government. Moreover, they may be economic in the short term because the rancher controls livestock access.

Such an option would not be open to pastoralists depending on open-access pasture, and indeed the infrastructure would not be available to deliver such a solution in most parts of the world. A comparable situation, when pasture suddenly becomes accessible (for example when a lake dries up) results in increased movement towards a particular location, rapidly eliminating the pasture resource and causing further damage through trampling etc³.

Economists argue that some loss of biodiversity is an inevitable and justifiable cost of economic development (Flint, 1992; Panayotou, 1992; Turner et al. 1994). Conventional economic approaches to assess how much biodiversity should be conserved are hampered by inadequate scientific information and the nature of biodiversity. Markets give no signals of rapidly declining biodiversity, because they do not capture its value. Defining a critical threshold (precautionary principle) under which biodiversity should not be depleted is nearly impossible with current scientific knowledge. Current policies and market forces will result in further loss of biodiversity, thereby transferring an accumulation of risk to future generations (Flint, 1992).

The economic perspective on biodiversity decline is not limited to the direct costs of species extinction. Changes in the mix of species modifies the ecosystem over the long term. For instance, a shift in the vegetation composition from palatable grasses to unpalatable grasses and woody plants reduces the availability of fodder for livestock. Woody vegetation can sometimes become so thick as to prevent livestock access completely, but in more open landscapes, it tends to attract pastoralists specialised in browse species. Low income groups whose livelihoods depend heavily on rangeland production are particularly affected (see Barbier et al., 1994: 149; Perrings and Walker, 1995).

³ In Sahelian Africa, the dessication of Lake Chad (Blench 1991b) and the fall in levels of water in the Inland Delta in Mali provide useful case histories of this problem.

5.3 Ecological arguments

Rangeland ecosystems provide ‘natural’ services such as fertility of soils, water cycling, biomass production, cycling of nutrients, evolution or natural control of pathogenic and parasitic organisms. The evidence suggests that various types of interference with the balance of organisms leads to long-term declines in biodiversity and lowered capacity to respond to extreme events such as fire and drought. As so often, ecological arguments for biodiversity conservation reflect the time-scales under consideration. Seeding a natural grassland with high-input exotics will change the biomass output and forage value over a short period and the short-term economic calculations prevalent in development this would seem to be a logical option. But the evidence is that in the long term, these ‘simplified’ systems are much less resilient in the face of drought, and ultimately reduce forage quality and yield due to lower mineralisation rates of humic material (Holmes and Mott, 1993; Tilman and Downing, 1994).

Genetic diversity also provides a natural barrier against the evolution and spread of pathogens that can result in large-scale forage or food deficits. As a rule, the more genetically uniform a population is, the more vulnerable it is to pathogens. Plants and animals constantly adapt to counter such assaults. The more diverse a population is, the greater the chance of developing strategies against these pathogens (Blench, 1998a).

5.4 ‘Artificial curiosities’: arguments for a focus on rangelands

From all that has been said above it should be clear that rangelands are generally about as ‘natural’ as a shampoo infiltrated with herbs. So no process of restoration can occur without defined goals grounded in a socio-economic analysis of the pattern of use. In other words, biodiversity is to be maintained or encouraged for a specific purpose. If that purpose is to secure the livelihood of camel-herders, then one type of vegetation is appropriate; if the use is supporting a diversity of large herbivores for recreational viewing, then quite another should be adopted.

It is also clear, however, that in many regions the status quo cannot be maintained and that rangelands are a ‘resource under siege’. Innovative strategies are required to simultaneously secure livelihoods and encourage biodiversity. In many regions these are revolving around the interlocking use of wildlife and domestic stock. This can be the combination of cattle and large mammals for hunting or recreational viewing or the production of ‘wild’ species for meat. In many ways this is an attractive solution, since diversity among grazing species brings with it diversity among species grazed (Bourn and Blench 1999). Using rangelands for diverse large herbivore production would:

- a) increase export income from regions previously regarded as low-potential
- b) provide diversified products that could not easily be produced intensively and therefore would be less subject to external competition
- c) make more effective use of diverse vegetation than any anthropic system

but would simultaneously require users to encourage and maintain rangelands biodiversity.

6. How can rangelands biodiversity be conserved?

6.1 Establishing Protected Areas

The establishment of Protected Areas is a primary strategy to conserve biodiversity, although reserves alone cannot guarantee that biodiversity will be maintained. In the large national parks of the western US, 0–43% of the original large mammal fauna have been lost since the parks were established (West 1993: 10). Similar or more extreme figures are likely to be the case in Africa. In Kenya, where figures have been collected on a regular basis to a much greater extent than other African countries, almost all species including livestock have undergone a decline in numbers between the 1970s and 1990s. Table 10, compiled from Bourn and Blench (1999) shows estimates for each species during that period.

Such changes are almost certainly a result of enclaving; poor management outside affects processes inside (Reid, 1998). At the simplest level, protected areas provide a reserve of large mammals that are a positive lure to hunters, who may be from adjacent communities. Those after rarer and more valuable species such as rhino or tiger may either have come from further away or be funded by entrepreneurs linked to international markets. Although this effect can be mitigated by complementing reserves with buffer zones where ecological principles are implemented in land use and management of natural resources (Szaro, 1996). This has been tried in several reserves in Tanzania and monitoring data suggests that it is only useful if the buffer zones can be effectively monitored.

6.2 Habitat restoration

Habitat conversion and the resulting fragmentation is probably the most severe cause of declining biodiversity in rangelands; the most immediate response has been restoration. Habitat restoration is analogous to the recovery of threatened and endangered species but at a broader ecosystem or landscape level. Techniques such as the reconnection of hydrological connections within wetlands, the reintroduction of lost species, the burning of invasive vegetation, the introduction of livestock grazing systems compatible with wildlife, fencing to exclude cattle, vegetation planting to control erosion, fertilisation of existing vegetation to encourage growth, control of exotics and others, can be used to restore ecosystems. Such strategies are costly and can only be practised on a limited scale, even in the developed world. Moreover, they depend on the assumption of a value-free model of the pre-existing ecology and an argument about why this should be restored

6.3 ‘Keystone’ species and the assignation of priorities

Biodiversity conservation usually focuses on threatened and endangered species. They are the most fragile and potentially vulnerable members of biological communities and may be indicators of environmental disturbance (Szaro, 1996: 738). However, not all threatened and endangered species

can or should be conserved. Extinction is a part of the evolutionary process, and policies which place equal emphasis on every species are both ecologically unsound and tactically unachievable (West, 1993).

Table 10 Kenya Rangeland Livestock and Wildlife Population Estimates: 1970–1990s

	Est 70s	SE 70s	Est 90s	SE90s	70s-90s	%70-90	Stat. Sig. (p=0.9)
Buffalo	35,453	6,060	30,187	4,197	-5,266	-15%	
Camels	551,462	24,636	651,254	33,209	99,792	18%	+ve
Cattle All	3,319,749	157,958	2,911,496	83,333	-408,254	-12%	-ve
Donkey	95,059	10,884	85,350	5,021	-9,710	-10%	
Eland	25,775	3,376	19,123	1,242	-6,652	-26%	-ve
Elephant	39,108	6,008	14,923	1,808	-24,185	-62%	-ve
Gazelle Grant's	247,491	12,407	103,208	3,915	-144,283	-58%	-ve
Gazelle Thomson's	87,086	14,766	31,259	4,269	-55,827	-64%	-ve
Gerenuk	42,918	1,820	21,418	1,282	-21,500	-50%	-ve
Giraffe	62,255	2,808	50,080	2,337	-12,175	-20%	-ve
Greater Kudu	233	99	45	25	-188	-81%	-ve
Impala	116,177	8,930	67,934	3,194	-48,243	-42%	-ve
Kongoni	29,606	2,533	18,521	1,054	-11,085	-37%	-ve
Lesser Kudu	17,468	1,214	7,751	710	-9,716	-56%	-ve
Oryx	53,653	3,571	25,824	1,950	-27,829	-52%	-ve
Ostrich	25,716	1,772	33,871	2,798	8,154	32%	+ve
Topi	93,822	10,977	92,934	18,139	-888	-1%	
Sheep & Goats	6,473,519	263,793	5,696,021	173,426	-777,498	-12%	-ve
Waterbuck	12,309	1,476	5,260	733	-7,049	-57%	-ve
Wildebeest	224,404	49,582	173,354	38,918	-51,050	-23%	
Zebra Burchell	138,448	12,643	146,093	9,549	7,645	6%	
Zebra Grevy	10,364	1,355	4,868	871	-5,496	-53%	-ve
Total Wildlife	1,262,227		846,652		-415,634	-33%	-ve
Total Livestock	10,439,789		9,344,121		-1,095,600	-10%	-ve

Including: Baringo, Garissa, Isiolo, Kajiado, Kilifi, Ktui, Kwale, Laikipia, Lamu, Mandera, Marsabit, Narok, Samburu, Taita Taveta, Tana River Turkana and Wajir Districts (Source: GoK, 1996).

Although priorities must be assigned to different species, conservation programmes tend to focus on those which are large, generally easily observable or aesthetically pleasing. Media and organisations, such as the World Wide Fund for Nature (WWF) and Greenpeace, tend to use these images in their literature even where their background documentation is more sophisticated. Conservation (emergency) programmes of the type 'save the elephants in western Kongo' are often uncoupled from scientific understanding and focused on satisfying the opinions of those who watch National Geographic channel. Commonly, such programmes tend to address symptoms rather than underlying causes, although priorities should not be based on constructed public images, but on scientific understanding.

In determining priorities, one point to consider is their value in maintaining essential ecosystem functions. Key species are defined in terms of their greater influence on the functioning of ecosystems. For West (1993: 10), 'keystone' species as those whose direct or indirect effects on the survival of other species or on ecosystem function are disproportionately large in relation to their abundance. One example of such a species is mycorrhizal fungi. These organisms exchange carbon fixed by green plants for enhanced uptake of phosphorus and their absence may severely inhibit recovery of about 90% of the green plants that interact with them. Repeated fires promoted by cheatgrass in former sagebrush steppe (US) can lead to extinction of mycorrhizae and impede re-

establishment of shrubs and perennial grasses over large areas. Keystone species can also be small mammals. An experiment at the Chihuahuan-Sonoran desert in Arizona showed that without kangaroo rats a shrub steppe quickly changed to grassland as the digging of these rodents favours establishment of shrub seedlings. Without them, grass competitively squeezes out shrubs.

6.4 Controlling grazing pressure

Artificial water sources are now widespread in many arid and semi-arid rangelands. For example, in pastoral areas of Australia today there is at least one artificial waterpoint every 10km (Bennet, 1997: 11). Originally, establishing closely spaced water sources was intended to avoid the localised degradation that follows the concentration of many animals at few sites. Creating this dense network induced similar grazing patterns over large areas. The impact on biodiversity was negative because native species in Australia's arid and semi-arid rangelands are adapted to very light or no grazing pressure. Once biodiversity becomes a consideration, management should promote grazing patterns that are spatially heterogeneous rather than uniform. Fencing tends to be expensive for extensive areas, whereas water is a powerful and cheap tool for this purpose. If artificial water points were shut down in areas with a high conservation priority, grazing pressure would be reduced. Obviously, such a strategy is only applicable where artificial water sources are numerous and would not apply in Africa or much of South America.

7. Conclusions

7.1 Research

All discussions of biodiversity customarily call for more research, and it might seem initially that rangelands were not a primary candidate in view of the vast literature on grasslands associated with ruminant production. However, this body of literature, whose primary function is economic, has in many ways acted to obscure the biodiversity issues. The anthropic paradigm (Table 3) tends to ask how rangelands can best be managed for the benefit of capital-intensive livestock producers. Increasing interest in game ranching is expanding the field of enquiry (at least in Africa) to 'livestock and commercialisable wild species' but this remains a narrow focus. Research on the relationship between livelihoods and rangeland biodiversity is clearly only beginning, especially in relation marginalised pastoral and forager communities.

Given the immense energy that has been applied to understanding tropical forest ecosystems, it seems reasonable to redirect some part of that to rangelands. Limited studies suggest that their potential biodiversity is only slightly less than forests, and that the low levels of diversity currently recorded in many of the world's rangelands are a recent human artefact. With an increased emphasis on vulnerable groups and poverty alleviation, rangelands should be assigned higher priority, since encouraging greater biodiversity would bring with it greater food security for populations dependent on the range (Little, 1996; Paroda and Bhag, 1995; Scholes and Walker, 1993).

The priorities for research are thus:

- Continuing inventory and monitoring of genetic, species, ecosystem and landscape diversity; development of biodiversity indicators
- Analysis of human impact on rangelands ecosystems, both global and local
- Comparative stakeholder analysis to develop priorities for regional action
- Economic valuation of biodiversity, both in terms of local users and in relation to ecosystems services
- Devising mechanisms to provide incentives to maintain biodiversity at the local level within a variety of socio-economic matrices
- Evaluating the cost-effectiveness of different conservation approaches

7.2 Priorities for international action

Improved scientific understanding of biodiversity, notably its role in ecosystem functioning, is a precondition for increased concern and thus action to conserve it. The more stakeholders are aware of the importance of biodiversity, the higher the value they will assign to it in decision-making.

Rangelands, rather like the oceans, depend on setting priorities on a regional basis; grasslands do not stop at national borders, nor do the animals that exploit them recognise political boundaries. Conservation of biodiversity in rangelands involves the co-operation of different stakeholders,

including foragers, pastoralists, ranchers, arable farmers, local and national governments and international bodies. Conservation approaches must recognise that rangelands are physically and institutionally fragmented. As populations increase the numbers and types of claim on these lands expand, cross-cutting and interlocking with one another. Institutional environments differ extremely not only from continent to continent, but also within single countries. Conservation has tended to focus on threatened and endangered species rather than landscape. However, it is the land owner and land user who have the closest contact with conservation of biodiversity, and economically they are likely to be most affected by international programmes. If they see economic losses for themselves as a result of such programmes, it can be expected that they try to prevent, or sabotage conservation efforts. Even local governments may lack the will to enforce conservation rules and laws in such circumstances (Tisdell, 1995: 218).

At the local level, the incentive to conserve biodiversity is often limited, as the benefits are very broadly distributed. The global community benefits more from the maintenance of genetic diversity than individual smallholders, at least over the time-period of concern to individual households. Nevertheless, maintenance or restoration of habitats should be of equal or greater concern, because the best way to minimise species loss is to maintain the integrity of ecosystem function, and determination of status of each species and design of conservation measures to meet its needs can be largely avoided. Therefore it is important to create incentives at the local level to conserve biodiversity. Land owners and users will have to be awarded a larger share of the total gains from conserving biodiversity. Mechanisms which can be used for this purpose are: (a) subsidies for conserving biodiversity; (b) payment of royalties on the use of genetic material conserved; (c) utilisation of conserved areas for tourism with income transfer (Tisdell, 1995).

Rangelands are more perplexing environments than most when it comes to conserving or recreating their biodiversity. They are not visibly lost in the way of forests, nor do many shelter the headline species that attract funds and research. Some are characteristic of highly developed economies and have been managed in ways that do not necessarily elicit sympathy. Yet the role they play in the supporting subsistence households around the world, and the evident problems that arise when biodiversity is undermined and the range can no longer respond to extreme conditions argues that greater importance needs to be attached to rangelands.

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