Global Issues of Rangeland Management

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SUMMARY

Rangelands occupy about 50% of the world's land area. They are ecologically and economically as important as rain forests and in even greater danger of degradation and disappearance. This paper reviews the definitions and distribution of rangelands and describes their global environmental importance in terms of erosion control, carbon storage and methane emission. Condition and degradation of rangelands are defined and discussed and it is argued that soil protection and carbon storage can be increased and methane emission per animal decreased by conservative use and improvement of rangelands, whilst at the same time alleviating hunger and malnutrition in developing countries. It is concluded that policies should be adopted by national governments and international development programs to conserve and improve rangelands.

INTRODUCTION

Rangelands occupy about 50% of the world's land area (Friedel et al., 2000). The importance of rangelands is far greater than rangeland managers generally appreciate. Rangeland managers are mostly concerned with only one of the functions of rangelands: animal production. However, rangelands, together with rain forests are also of great ecological significance, because both vegetation types protect often fragile soil profiles, harness large amounts of carbon dioxide (CO_2), are a habitat for wild fauna and flora and act as watersheds for large river systems. Economically, rain forests and rangelands provide mankind with essential goods and services. Both vegetation types contain medicinal plants, timber, germplasm for new and wild relatives of existing crop and pasture plants and recreational opportunities. In addition, rangelands are the main feed resource for traditional livestock rearing systems in many parts of the developing world. This is of great economic and social importance, because it offers a livelihood to millions of people. Traditional animal production provides people in developing countries with food (milk, meat and blood), manure (for fuel and fertiliser), wool, hides, draft power, transportation, added security and the possibility to accumulate capital. Livestock is also important in association with arable agriculture, because livestock provides the power for cultivation and manure for increased fertility, whilst livestock consumes crop residues, which often has no or little other value, except that straw can be used as roofing material or made into baskets. Furthermore, rangelands provide designated reserves for wildlife, plants and indigenous peoples, for recreation and for military training grounds.

Rain forests have become front-page news, but rangelands have not yet drawn public concern. Rain forests and rangelands are the last land resources of the world and they are in danger of degradation and disappearance through unwise use, over-exploitation and destruction and they are equally as deserving of the attention of politicians, administrators, scientists as well as the general public. In fact, it can be argued that rangelands are in even greater danger than rain forests, because they occur in drier regions which are often very densely populated and over-exploited by cropping and overgrazing, leading to degradation and desertification. Therefore, there is a great need for the conservation of rangelands, meaning their sustainable use for the benefit of mankind now and in perpetuity.

This paper will briefly describe the importance of rangelands and their management from an environmental and economic point of view, but first rangelands need to be defined and their world distribution indicated.

DEFINITIONS AND DISTRIBUTION OF RANGELAND

The term rangeland covers a great variety of vegetation types, which already follows from the often quoted varying estimates that it occupies from 30 to 50% of the earth's land surface, depending on the definition of what rangeland constitutes.

According to the concise Oxford dictionary range is a "stretch of grazing or hunting ground". This may well have been the original meaning as British settlers used the land when they first settled in America. Rangelands occur on all continents and particularly in Africa, Australia and the United States much research has been carried out on rangelands and in each continent a different definition has been coined. Pratt et al. (1966) defined rangelands in Africa as "land carrying natural or semi-natural vegetation, which provides a habitat for wild or domestic ungulates". Harrington et al. (1984) defined Australian rangelands as "ecosystems in which man seeks to obtain a productive output by simply adding domestic livestock to a natural landscape". In the United States of America, Heady (1975), who has done much of the early work on rangelands in the USA as well as in Africa, stated that "rangeland vegetation includes shrublands, grasslands and open forests, where dry, saline or wet soils, steep topography and rocks preclude the growing of commercial farm and forest crops". On the occasion of the First International Rangeland Congress, held in Denver, Colorado, USA, McGuire (1978) quoted the definition of rangeland as proposed by the American Society for Range Management as: "land on which the native vegetation is predominantly grasses, grass-like plants, forbs, or shrubs suitable for grazing or browsing use (which) includes lands revegetated naturally or artificially to provide a forage cover that is managed like native vegetation". A general definition was given by Van Gils (1984) as: "a tract of land currently used for grazing by domestic livestock and/or wildlife, where no mineral fertilisers are applied; semi-natural vegetation is the main forage resource and the stocking density is lower than 1 Animal Unit (= 250 kg live weight) per ha per year".

All these definitions have much in common, but I would like to propose a general, globally applicable, definition as follows: "rangelands are ecosystems which carry a vegetation consisting of native and/or naturalised species of grasses and dicotyledonous herbs, trees and shrubs, used for grazing or browsing by wild and domestic animals, on which management is restricted to grazing, burning and control of woody plants". Rangeland is unimproved grassland in the sense that grasslands are vegetation types in which the woody plant canopy cover does not exceed 40%. This includes open woodlands (savannas), shrublands, heathlands, tundras and pure (i.e. treeless) grasslands. The main difference between this definition and Heady's is that he excludes land which would also be capable of growing crops and that he includes as management options agronomic practices such as seeding of grasses and legumes and fertilisation. My definition excludes management options such as fertilisation, introduction of selected plant species, irrigation, etc., which Heady (1975) does not explicitly exclude and part of which McGuire (1978) implicitly includes. In my terminology such management transforms rangeland into improved grasslands or pastures.

Rangelands are found on all continents and in all climates: in the tropics in Australia, Africa, South America and Asia; in temperate regions in Australia, South and North America, Europe and Eurasia. Also in arctic regions rangelands occur (tundra and taiga). Rangelands are not only natural vegetation types, occurring in climates that are too dry or too cold for dense tree growth. They also originated as a result of grazing and burning of abandoned croplands and of land after forest clearing in humid and sub-humid regions, in which case they form a sub-climax vegetation, maintained by grazing, cutting or burning.

At the moment, most natural rangelands occupy land that is not suitable for cropping because the climate may be too dry or too cold or because the land is not cultivable as a result of steep topography, rocks or stones or because the top soil layer is too thin. However, the great cropping regions of the world have been created by ploughing up natural pure grassland areas (rangelands) in relatively dry regions and often on fertile soils (e.g. Steppe in Russia; Prairie in North America; Pampa in Argentina; Veld in southern Africa; Downs in Australia and Pusta in Eastern Europe). Wherever the rainfall and soil fertility in these regions are adequate and where economic crop production is possible, these areas have been converted to cropland, particularly for cereal production. However, not everywhere have such lands been converted to croplands and particularly in Australia there are large areas still under extensive grazing, which would physically be cultivable, but for which an economic basis for cropping is lacking.

RANGELANDS AND THE GLOBAL ENVIRONMENT

Rangelands have many functions, but environmentally the most important one is that it provides a vegetation cover and thus protection for the soil, which also ensures sustainable economic production of feed for animals, firewood and other indirect benefits.

Rangelands are a product of environmental factors (rainfall, temperature, soil type, fire and management), but they also contribute to the local and global environment.

Locally, rangelands act as watersheds and as habitats for wild fauna and flora. They may contribute to pollution after burning and as a result of nitrogen (N) emissions to the atmosphere (NH_3 volatilisation from animal excreta) and to the ground water (NO_3 leaching from urine and dung spots). However, since the size of N flows in extensively grazed rangelands will be small, rangelands can be taken as not to contribute significantly to adverse local environmental conditions.

Globally, rangelands are usually not considered significant in terms of environmental issues. This is an attitude of ignorance, because rangelands play a major role in the so called greenhouse effect, which may lead to an increase in global temperature with possible far reaching consequences for the height of the sea level, the environment and agriculture. The greenhouse gases are carbon dioxide (CO_2), which contributes 49%, methane (CH_4) 18%, CFC's 14%, nitrous oxides 6% and others 13%. Three of the greenhouse gases, CO_2, CH_4 and nitrous oxides (mainly N_2O) have relevance to rangelands. Rangelands play a positive, i.e. beneficial, role in the storage of C, but a negative role because of the emission of CH_4, whilst its role in relation to the release of N_2O is negligible, because of the low levels of N in the rangelands ecosystems. The role of rangelands in the storage of C and in the emission of CH_4 will be briefly discussed.

CARBON

The global carbon (C) balance is being disturbed, because there is a rapid increase in accumulation of CO_2 in the atmosphere as a result of burning of fossil fuels and removal and burning of vegetation. The process that counteracts this accumulation is photosynthesis, by which green terrestrial and aqueous plants assimilate CO_2 from the atmosphere. The atmosphere is estimated to contain 730 gigatonnes (10^9, Gt) C and the annual assimilation by photosynthesis was estimated at 120 Gt C. The earth's plant cover contains 563 Gt C and the soil 1515 Gt. In addition, the ocean holds 39000 Gt C, of which 725 Gt in surface layers (De Groot, 1990). The main stores of C on earth are the ocean, forests, grasslands and rangelands, with little difference between forests on the one hand and grasslands plus rangelands on the other (Goudriaan, 1990; Minami et al., 1993). Long and Jones (1992) estimated that tropical grasslands alone store 26% of the total terrestrial carbon, tropical forest 19%.

The importance of rangelands as a C sink can be illustrated by a simple calculation. One metric ton of grass dry matter (DM) contains about 400 kg C based on the C % of DM of 40-44% (Sheehy et al., 1979). Assuming that the mean standing crop of rangeland ranges between 2 and 10 tons DM/ha, to which should be added about an equal amount of stubble, rhizomes, litter and roots, the total amount of C in above and below ground vegetation would be between 1600 and 8000 kg/ha. To this has to be added the accumulated organic matter below ground, which varies between soil and vegetation types, but a low estimate would be 50 tons/ha organic C (Jenkinson, 1988). The total amount of C would than range from 52 to 58 (say 55) tons/ha of rangeland. Using a global estimate of 6.7 Gha of rangeland (Friedel et al., 2000), the amount of C stored by rangeland would be 368 Gt, which would be 18% of the total terrestrial C based on the above estimates. To this should be added the storage of sown grasslands.

The introduction of legumes to rangelands will improve production and also increase the C sequestration potential. In the llanos of Colombia, Fisher et al. (1994) measured C storage of 237 t/ha under a 6-year-old *Andropogon gayanus-Stylosanthes capitata* pasture compared with 186 t/ha under unimproved savanna with about half of it in the 40-100 cm deep soil layer. At another site, the soil under unimproved savanna held 197 t/ha C, that under *Brachiaria humidicola* alone 223 t/ha and under *B. humidicola-Arachis pintoi* 268 t/ha. In Queensland, Henzell et al. (1966) measured C accumulation of about 5 t/ha over 6 years in the top 30 cm under a *Desmodium uncinatum* pasture on a sandy soil of initially low fertility, but fertilised at different rates of P and K and micro-elements. P fertilisation had a large positive effect on soil C accumulation. In Peru, Ayarza et al. (1987) also measured C accumulation under a grazed *B. decumbens-D. ovalifolium* pasture.

Rangelands also release CO_2 to the atmosphere as a result of respiration, burning and the fermentation of feed in the rumen. The respiratory loss was included in the calculation of the C stored, because this was based on standing crop, which is the net result of photosynthesis, respiration and decomposition. Burning releases CO_2. Assuming that the amount of DM burnt on rangeland is less than 1 ton/ha, or 400 kg C, and the area of rangeland burnt annually would be about 1 Gha, than the total amount of C released globally to the atmosphere would be no more than about 0.1 Gt/annum. However, as Goudriaan (1990) pointed out the amount of C released by burning would have been released anyway by slow decomposition. Repeated burning of savannas increases the C content of the soil because every year a fraction of the burned wood is turned into the very stable charcoal. Furthermore, the C destroyed by burning rangelands will be restored by the photosynthesis of the regrowth (Minami et al., 1993).

Forest destruction is carried out for arable cropping and for grassland. Arable land stores little C in the soil, whereas grasslands have a much higher soil-C store (Detwiler, 1986). Ibrahim (1994) measured 47 t/ha C in the top 10 cm of soil under grazed *B. brizantha – A. pintoi* pastures, which had been established 3 years previously, in the Atlantic Zone of Costa Rica. This amount of soil C was comparable with that found under rainforest. Therefore, forest destruction, although deplorable for many reasons, does not lead to total C storage loss when the land is sown to grassland. The permanent destruction of rangelands by cultivation and desertification, however, is usually irreversible and therefore a significant addition to C release from terrestrial sources.

METHANE

As a contributor to greenhouse gas emissions, methane is second only to carbon dioxide. Methane is 4 to 6 times more thermogenic than CO_2. CH_4 emissions to the atmosphere arise largely from anaerobic ecosystems and human activities such as natural wetlands (20%), paddy rice fields (20%), fermentative digestion systems of ruminants and other herbivorous mammals that possess a hindgut fermentation system (15-22%), oceans, lakes, biomass burning, natural gas, coal mining and rubbish tips (Moss, 1993; Howden et al., 1994). In rangelands CH_4 is produced by wild and domesticated grazing animals and by a proportion of the faecal materials decomposing anaerobically (Leng, 1993). Rumen micro-organisms ferment the rangeland feed to volatile fatty acids with CH_4 and CO_2 as by-products (Moss, 1993). A proportionally larger part of the metabolisable energy intake of ruminants is transformed into CH_4 from poor quality feed (15-18%), such as that produced by rangelands, compared to high quality feed (7%) such as perennial ryegrass (*Lolium perenne*) (Leng, 1993).

According to Howden et al. (1994) globally, ruminant livestock produce about 80 million tons of methane annually, accounting for about 22% of global methane emissions from human-related activities. An adult cow may be a very small source by itself, emitting only 80-120 kg of methane, but with about 1.2 billion large ruminants in the world, ruminants are one of the largest methane sources. Highly digestible grass and concentrates produce less CH_4 per unit of feed intake (Goossensen and Meeuwissen, 1990) than poorly digestible grass, such as occurs in unimproved grasslands and with crop residues in the tropics. Therefore, it is not only important to improve grasslands in the tropics for higher food production, but as a side effect there will be less CH_4 emitted per unit of feed intake.

CONDITION, DEGRADATION, CONSERVATION AND IMPROVEMENT OF RANGELANDS

Rangeland condition is defined as the sum of various attributes (vegetation composition and biomass, soil stability and nutrient status), relative to a maximum production potential for a particular land use, which may consist of a combination of animal production or survival, fire wood collection, water harvesting and amenity value (Harrington et al., 1984). Rangeland condition is determined by soil and vegetation parameters. The main soil parameters are fertility, structure and depth. Rangeland in good condition has vegetation consisting of a good proportion of perennial species and no dominance of unpalatable species. Rangeland in good condition also possesses resilience against degradation and is able to regenerate after a temporary setback.

Rangeland degradation is a measurable decline in the condition of the land. Rangeland degradation leads to reduced above and below ground biomass production and therefore to reduced C storage and increased CH_4 production per animal. Degraded rangeland soils have reduced water infiltration rates giving rise to increased run-off and erosion. It is evident therefore, that rangeland degradation is a major contributing factor to the worsening condition of the earth and that a world-wide policy of rangeland conservation, and where possible improvement, would materially contribute to a reduction of environmental damage. At the same time, the extra animal production in developing countries, which would result from improved rangeland condition, would assist in the alleviation of hunger and malnutrition of people.

Most rangeland soils are nutrient deficient, particularly in nitrogen and phosphorus and there is uneven distribution of nutrients across the soil surface. There are small areas in which nutrients have accumulated over long periods of time. Soil depressions collect topsoil and nutrients in which vegetation grows abundantly, which in turn attract litter and wind blown particles, further encouraging biological activity and increased water penetration, with consequent reduced run-off. Animals tend to congregate near such niches and further increase their fertility. These “fertile islands” (Garcia-Moya and McKell, 1970) are very important for the germination of seedlings and thus for the regeneration of the vegetation. Once such niches are destroyed and their soil distributed over a larger area, regeneration of vegetation after natural or man-induced disasters will only be possible with purposeful management, including destocking and surface-restoring earth works.

In most (semi-)arid regions rainfall is erratic and falls in unpredictable storms of great intensity, rather than as regular showers, so that the annual rainfall is made up of rare, large rainfall events. Vegetation cover and “fertile islands” are of great importance to allow maximum penetration of water and to reduce run-off.

However, interestingly, the capability of some extremely dry regions to support agriculture can be attributed to run-off and the formation of thick layers of soil in natural depressions and valleys that are used for cropping. At the same time the crop residues sustain animal production on the surrounding rangeland, which acts as a watershed for the cropping areas as well (Kessler, 1989).

Soil fertility and soil moisture together determine the pristine condition of rangelands. The introduction of domestic livestock by European settlers to begin with on the best rangelands in south and north America, southern and eastern Africa and Australia has generally disrupted this condition and often caused degradation to start.

The worst mistakes were often made at the beginning of European settlement as has been described by Friedel et al. (1990) for arid central Australia. Early settlers (since 1840) and governments were ignorant of the environment, particularly its erratic rainfall (10-20% more variable than the world mean for comparable regions) and its consequences for vegetation growth and animal numbers. The annual rainfall is below “normal” for more than 50% of the years. Years of high rainfall give large responses in vegetation growth, which leads to high conception and birth rates of grazing animals (domestic, feral and wild), but by the time these increased animal numbers are evident, the vegetation response has faded, particularly in quality. This high animal pressure takes time to be reduced by take off and natural wastage, leading to overgrazing, the disappearance of valuable species and the lack of fuel for fires, which are necessary to control dense shrub growth.

Rangeland degradation in developed countries is caused by a lack of knowledge about ecologically correct management and overgrazing. Although it is in the producers’ own interest to conserve rangeland under their control there are many instances of overgrazing. Overgrazing can be caused by droughts, when the managers fail to destock in time, which can be made difficult because of low prices for livestock. However, the use of supplements and the oversowing of legumes allow for a greater percentage utilisation of the native herbage, causing the disappearance of desirable grasses and exceeding the safe limit of soil protection, when the stocking rate is increased to the maximum level of animal production. Overgrazing can also be caused by unforeseen economic events, for example, when suddenly the world market prices for animal products from rangelands (meat and wool) fall and the managers are not able to sell surplus stock.

The main causes of rangeland degradation in (semi-)arid regions in developing countries are cultivation and overgrazing, both caused by too high a human and animal population pressure. Increased population pressure in developing countries leads to encroachment of villages and the taking into cultivation of the best rangelands, with increasingly shorter fallow periods, thus continuously reducing the area and quality of rangeland for an ever increasing animal population. Firewood collection further denudes the rangelands. Inevitable erosion removes topsoil with organic matter and nutrients, preventing the establishment of seedlings of perennial plant species, necessary for the regeneration of the vegetation. Thus the potential productivity and the protection of the ecosystem against degradation are lost.

Degradation leads to erosion, which in turn can lead to desertification, which is the end point and irreversible, leaving the soil unprotected and without any potential for food production.

In the long term the only sustainable use of rangelands is conservative use, i.e. grazing only at stocking rates commensurate with carrying capacity, cultivation only in areas of adequate rainfall with an addition to or a return of nutrients and rangeland improvement where the production system allows it.

RANGELAND CARRYING CAPACITY

Basic to rangeland management is the concept of carrying capacity: the number of livestock units that can be carried per unit area, in addition to wild herbivores, for the purpose of the production system for which the area is intended, given an acceptable risk factor and provided that no permanent damage is done to the ecosystem.

Carrying capacity is a function of:

1. the productivity of the ecosystem;
2. the purpose of the production system;
3. an acceptable risk factor.

1. The productivity of the ecosystem depends on the primary production of the area, which is determined by rainfall, soil fertility, the condition of the range and management.
2. The number of animals that can be carried on an area depends on the feed requirements of the animals. Therefore, the carrying capacity is smaller for dairy cattle than for beef production, which in turn is smaller than for animal survival.
3. The acceptable risk factor is the risk the manager is prepared to accept of not achieving the set production goals. The magnitude of the risk depends on the reliability of the production system (rainfall), on the level of utilisation of the primary production, on the reserves of the system, the financial ability of the landholder and the pressure on the system by the human population. If a rangeland area has a chance of one year in three to experience a severe drought, the landholder can decide to avoid all risk by stocking the area at the carrying capacity of the drought year. This low stocking rate would give maximum production per animal, but two years out of three the area would be under-utilised. The output of the system would be greater if the landholder would accept a risk of reduced production during the drought year. He could try to build up a financial reserve to tide him over. There may also be a feed reserve in the ecosystem, for example from edible shrubs. In a drought year the shrubs are cut down to provide feed for the sheep or cattle grazing the area. There should be adequate seed available in the soil for regeneration of the shrubs.

STOCKING RATE

Stocking rate is the number of livestock units per ha and it determines the amount of feed that will be utilised. The higher the stocking rate, the more of the feed will be consumed, but also fouled and trampled, whilst the ability of the animals to select the most palatable and nutritious parts of the vegetation decreases. Increasing stocking rate will therefore lead to reduced production per animal (Jones and Sandland, 1974).

With more animals per ha, the production per ha will first increase, till a maximum has been reached and subsequently decrease to a point of no gain and eventually weight loss will occur. Conversely, with decreasing stocking rate, production per animal will increase to a maximum that is determined by the genetic potential of the animal and the quality of the feed. The nearer the stocking rate is to the point where maximum utilisation of the feed and thus maximum production per ha take place, the greater is the risk of losses due to extreme conditions, such as drought. In the relationship between animal production and stocking rate, three phases can be distinguished:

(i) maximum production per animal; changes in stocking rate have no effect on production per animal, whilst production per ha increases linearly with increasing stocking rate;

(ii) declining production per animal (Y) with increasing stocking rate (X); $Y = a - bX$, where a is the theoretical maximum production per ha, and b is the amount of production per animal that changes with a change in stocking rate of 1. The greater b, the more production per animal will change with a change in stocking rate. The constant b will increase as the resilience of the rangeland decreases and deterioration begins to develop, until the following phase has been reached;

(iii) overgrazed deteriorated range. The relationship between stocking rate and production per animal becomes steeper (b increases). The botanical composition deteriorates, with perennial grasses being replaced by unpalatable species and annuals.

The stocking rate should be determined by the carrying capacity, but the optimum stocking rate can be based on ecological or economic considerations. The ecological optimum is highly variable and depends on rainfall, the forage reserve, the animal production system and the proper use factor. Proper use is the degree of grazing which ensures the fullest possible use of forage while maintaining growth, vigour and reproduction of the herbage, taking into account the conservation of the soil and other land uses. From this a proper use factor can be derived, which is the percentage of vegetation growth that can be grazed without lasting damage.

The economically optimum stocking rate is based on profit maximisation, in which short term and long term goals can be distinguished. Short term profit maximisation can be aimed at when there are good market opportunities and only when the rangeland has sufficient resilience to withstand heavier grazing. However, in the long term it would be better to aim for sustainability of production and to accept lower short term profits.

Overgrazing will lead to a reduction in rangeland condition and eventually to degeneration.

CONSERVATIVE USE

On a global scale rangelands are used for ranching or in nomadic and transhumance systems. Ranching is carried out in Australia, Africa and North and South America in subhumid, semi-arid and arid regions for beef and wool production. Properties are often very large (1000 ha to thousands of km^2), particularly in semi-arid and arid regions and hold 500 to several (20-50) thousand head of cattle or sheep. Production of beef and wool is for urban and export markets. Production is extensive, i.e. with low inputs and low production per animal and per unit area. Land tenure is either private or state ownership with long term leases, with the potential to allow producers to exercise a conservative use, i.e. grazing to carrying capacity with due regard for the long term sustainable production potential. According to Friedel et al. (1990) there are two extreme approaches to management being applied in arid rangelands under conditions of uncertain markets. The first approach is a highly conservative stocking policy aimed at drought resistance (long term survival), relying on low animal numbers and relatively high production per animal. This approach gives an assured take off of better quality meat for speciality markets in good as well as bad years, with a steady basic income. The opposite approach is to get the most out of good years by high stocking densities after good rainfall with high utilisation of the herbage and rapid destocking at the start of drier seasons. The first approach contains low risk and lower incomes in good years and the second approach requires higher management skill, is extremely risky, both financially and ecologically and can only be practised successfully on resilient landscapes (fertile soil, flat land). Failure to destock in time, for example as a result of low prices, will lead to degradation of susceptible landscapes, unless there is reserve pasture on hand.

Conservative management is hindered by variable markets and prices for animal products from rangelands, as well as by banking and taxation policies. A manager's wish to apply conservative management is often not possible, because of the danger not to survive economically. However, taxation laws in some countries allow the averaging of farm income and "income equalisation deposits", making it possible to use occasional high incomes to be used (and taxed) in years of low income. Friedel et al. (1990) stress, however, that these income buffering mechanisms must be balanced by the removal of "drought relief" schemes, which are meant to minimise the effects of drought by subsidising the purchase of feed and movement of livestock. Such schemes tend to support the high risk, high utilisation managers, because they know that the government will bail them out when they get into difficulties as a result of feed shortage caused by drought.

Sound ecological management should contain the following features (after Friedel et al., 1990):

1) a conservative upper limit for stocking rate;
2) small flocks or herds per watering point;
3) subdivision into "small" paddocks according to pasture type and stock distribution;
4) recognition of the importance of key seasonal events for vegetation recovery coupled with
5) pasture resting to allow for recovery of perennial species;
6) burning for shrub control;
7) conservation or re-establishment of "fertile islands".

There is evidence that sound ecological management in the long run also gives higher economic returns.

Nomadism is the way of life of indigenous peoples in arid and semi-arid regions, particularly in Africa, who have no permanent place of settlement and move with their livestock and all their possessions in search of water and forage. Regions in which nomadism is practised are characterised by a primary productivity that is so low that people cannot sustainably avail themselves of their food requirements within a day's reach of a permanent settlement. The animals provide the people with blood, milk, meat and income from the sale of surplus animals. In transhumance or semi-nomadic systems, the people have permanent settlements with some food cropping on better soils and a few animals for sustenance, but the main herd is moved to often distant grazing lands in search of water and forage, returning to the settlements in the wet season. These rangelands are communally or state owned and in pre-colonial times tribal regulations ensured a proper sustainable use. Some colonial regimes imposed forms of regulated land use. However, since independence regulations have been abolished in many countries, which together with highly increased populations has led to cultivation of unsuitable lands and overgrazing. Controlled land use and rangeland improvement will remain difficult to achieve with communal land rights, because it is not to any individual's advantage to reduce his pressure on the land if others continue at the former, or even increased, pressure. The only solutions are controlled use and management of the grazing lands, either instigated by the community using it or by government and population growth control.

Attempts have been made in several African communities to encourage conservative land use, as was reported by Hunter (1990). For example, in Swaziland 10 enclosed Grazing Land Management Demonstration (GMLD) sites, ranging between 20 and 250 ha, were set aside in 1983 for exclusive use by village livestock owners, with the co-operation of the Chief and his advisors. The set aside areas were grazed at pre-determined stocking rates, for which the livestock owners paid a fee to cover management costs such as fencing, veterinary care and cattle herding. Farmers were encouraged to keep female calves for breeding and to sell surplus and unproductive animals. Where these GLMD schemes had been operating for several years, badly damaged rangeland recovered, calving percentages doubled and animals reached maturity at younger ages. More important than these direct improvements were the changed attitude of the livestock owners towards conservative stocking and the culling of unproductive animals.

RANGELAND IMPROVEMENT

Rangeland improvement can serve three purposes:

1) to restore or reclaim degraded land;
2) to arrest degradation;
3) to improve the feed supply and carrying capacity.

1. Degraded land has lost its productive capacity, because the soil profile is damaged and there is no live vegetation or seed reserve available. The restoration or reclamation of such land consists of earth works, such as ponding banks, pitting and tyning (Harrington et al., 1984; Friedel et al., 1990) to improve water penetration and to re-establish fertile islands. In addition woody and herbaceous vegetation should be planted or sown. In arid regions leguminous shrubs can be planted in small run-on areas and *Atriplex* species in pitted contour lines. In regions with more than 600 mm of rain and less than seven months of dry season per annum legumes can be oversown (‘t Mannetje, 1991).
2. Early warning signs of degradation consist of lack of vigour of the vegetation, but the soil profile and seed reserves are still largely intact. To arrest the process of degradation it may be sufficient to reduce stocking rate and/or to defer grazing, i.e. to destock for a period to allow species to re-establish. However, spelling only serves a purpose when the desirable species are actively growing so that they will flower and produce seed. Spelling when the vegetation is dormant will achieve little improvement. In not too arid regions, leguminous shrubs can be planted to act as feed reserves in dry times and herbaceous legumes oversown to restore vegetation vigour.
3. The feed supply and carrying capacity of non-degraded rangeland can be increased by oversowing with legumes in regions with more than 600 mm of rain and less than seven months of dry season per annum provided a conservative grazing policy is used. This can be very beneficial in certain animal production systems (‘t Mannetje, 1991).

However, socio-economic constraints preclude rangeland restoration or improvement in most developing countries. The main limitations are lack of financial resources (poverty, credit facilities) and subsistence agriculture on communally used land. There is usually no controlled management, which is necessary for the introduction of improvement and sustained use. Secondly, there is no seed or fertiliser available and no infrastructure for their distribution, or for surplus animals. However, there are possibilities for rangeland improvement in organised communities and in ranching.

Improved rangeland, together with fodder or protein banks can be judiciously used by producers for a variety of purposes, such as:

1) to reduce mortality losses, which occur during dry times; extra feed from improved pastures, protein banks or fodder crops can be used for the whole herd to provide (near) maintenance nutrition or for a nucleus of animals to ensure continuation of the herd;
2) to increase the conception and calving rates; mating periods can be introduced to synchronise calving and to give better chances to lactating cows and their calves; supplementary forage provided just before the mating period can enhance the conception rate;
3) to keep the herd on a smaller area of land during the whole year or part of the year in order to reduce mustering costs; this can be achieved by improving a proportion of the existing grasslands by oversowing with a legume;
4) to fatten younger stock steers can be selected for finishing on improved pasture or on feed from fodder crops or protein banks. With improved rangelands the same or greater production can be achieved with fewer animals.

CONCLUSIONS

Rangelands play an important role in the global environmental issues of today and they are equally as deserving of international attention as rain forests. They are a major sink of carbon, which can be increased by reversing degradation and improving the production capacity, reducing the need for so many animals, at the same time reducing the methane emission per animal and increasing the livelihood chances of people in developing countries.

National governments should adopt policies for the conserved use of rangelands and where possible of rangeland improvement consisting of extension and aid programs, supported by the local community, with the help of international development programs.

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