New Vistas in

Forage Production

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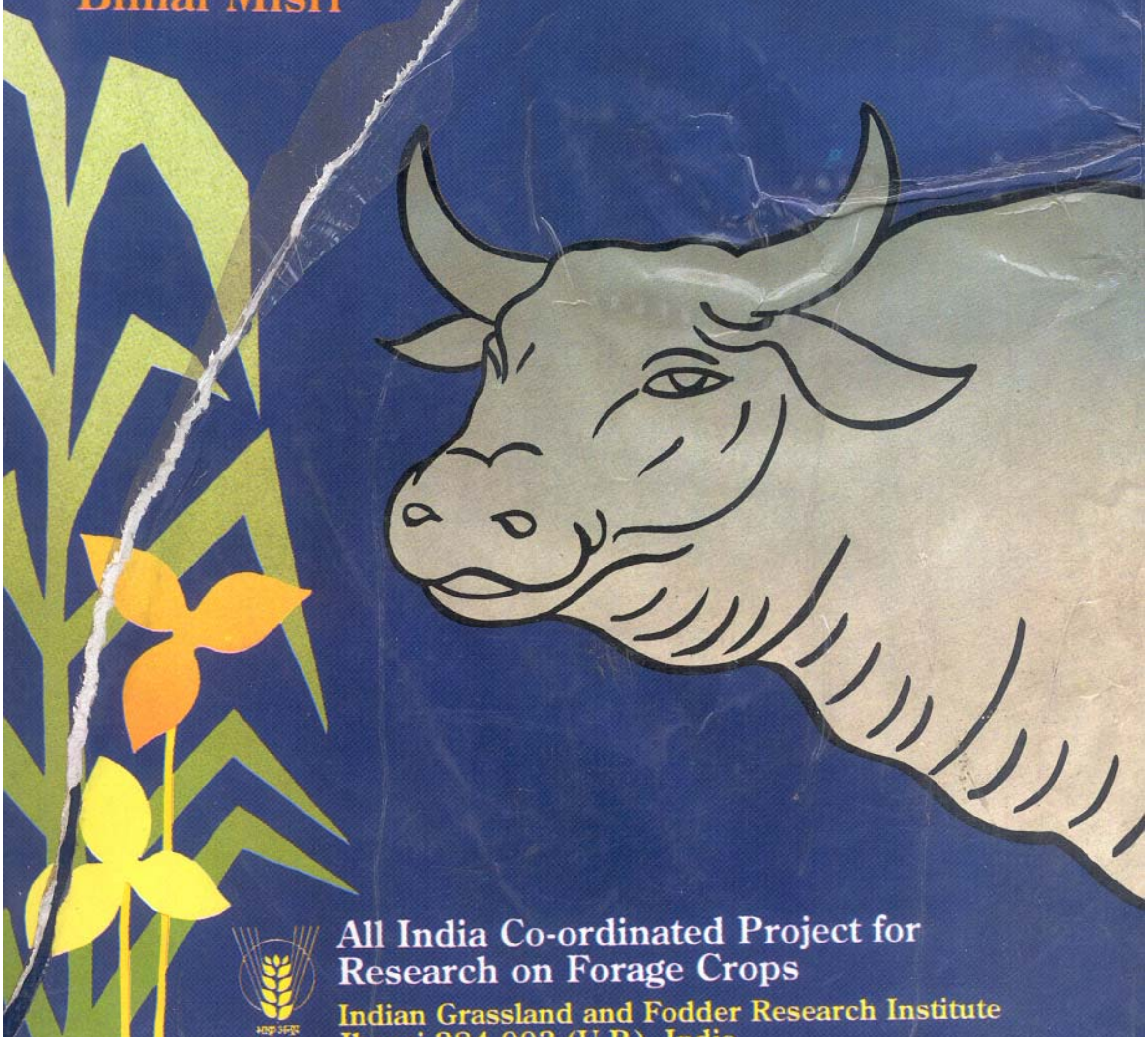

All India Co-ordinated Project for
Research on Forage Crops
Indian Grassland and Fodder Research Institute
Jhansi-284 003 (U.P.), India

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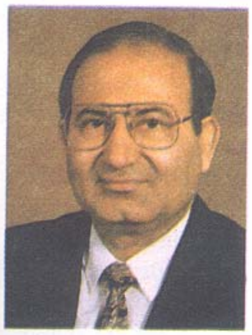

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Forage Production From Rangelands

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Abstract

Rangelands are an important forage resource. Although rangeland area and its carrying capacity has been shrinking over the years because of past misuse and neglect, they still meet out about 40 percent of the present forage supply; the remaining 60 percent supply comes from forage crops, agrowaste, crop residues and leaf fodders etc. As the overall forage supply-demand balance shows huge deficits and as there is remote chance of increase in area under fodder crop cultivation, the rangelands continue to be a major support for the livestock. Researches have shown that rangeland improvement techniques help in increasing forage production to about eight times and quality wise 32 times increase in the crude protein of the improved range forage has been achieved. This shows the huge potential of soil and water conservation and revegetation programmes for degraded rangelands. In this paper whole gamut of issues relating to ecological conditions, rangeland improvement and grazing management, silvipastoral systems and pasture based livestock production system have been described and discussed in the following text.

Key words: Agro-economy, Vegetation, Grazing resource, Management, Grazing ecology.

Introduction

An unique challenge India faces over the next few decades is how to speed up economic growth without exhausting the basic resources on which the sustained growth depends upon. The rangelands which are a renewable natural resource, play an important role in the overall agro-economy of India. The rangelands also referred as grasslands or grazinglands can be perceived as a production systems based on forage and animal components supported by the soil (Fig. 1.) Indian rangelands generally occupy class IV to VII types of land. The land degradation in India has

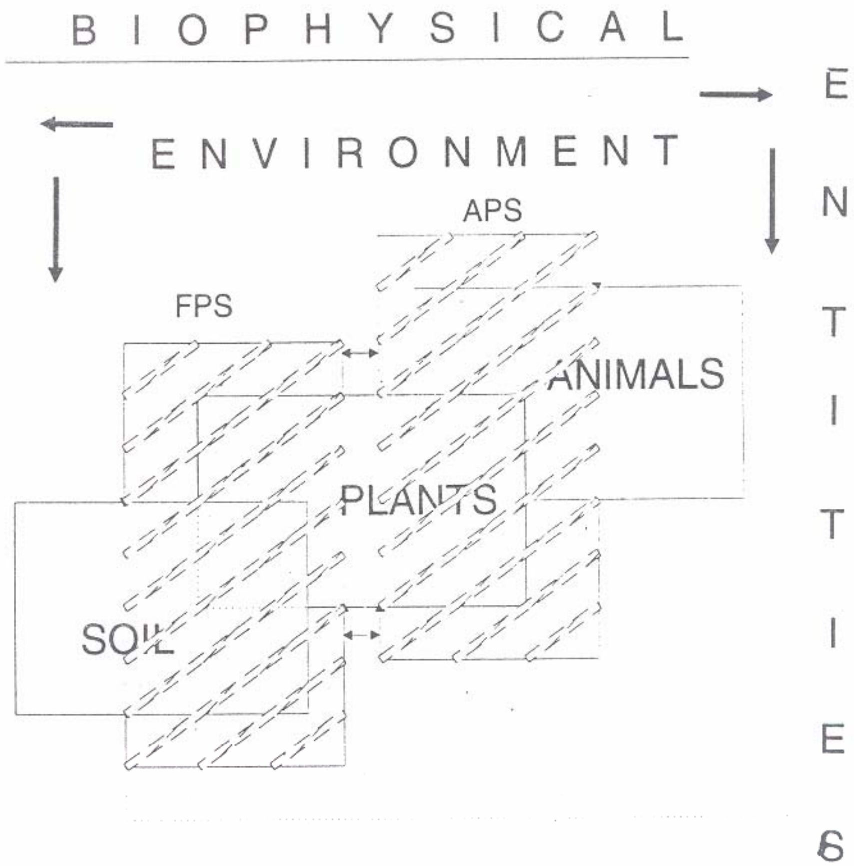

Fig. 1 : A views depicting multifactorial interactions of a rangeland

affected 180 m ha area and the degradation processes show temporal and spatial variability. The NAEB programme started with tree planting but soon additional measures like watershed development by involving local people were added to stem erosion and reduce local exploitation of regenerated vegetation. Since the inception of this project over 15 m ha of degraded lands have so far been revegetated. (Ministry of Environment & Forest and Tata Energy Research Institute, 1991).

Nearly all of the world's rangelands except those in the arctic are degraded and it is likely that many of the continent's rangelands will never regain their former ecological status (Child, 1991). The rangelands support native vegetation comprising of predominantly grasses, forbs and shrubs which are well suited as forage for wildlife and livestock (Joyce, 1989, Huntsinger, 1992). In India the rangelands suffer from various natural constraints viz., temperature regimes, steepness of slope, variable precipitation, and scarcity of water specially in arid and semi-arid situations.

The deteriorating state of Indian rangelands may be ascribed to increased bovine population, free range grazing, lack of management and deforestation for developmental activities (Chaturvedi, 1981). Over 80 per cent of the rangelands are in 'poor' range conditions class (Gupta and Ambasht, 1979). The Himalayan rangeland situation is much more alarming due to the severe biotic pressure of the sedentary, semi-migratory and migratory grazing patterns (Melkania and Tandon, 1985). Detrimental policies like overstocking (too many animals for the available feed), uneven grazing and heavy year round grazing are the major reasons for continued decline in range health in all the five grass cover types (Fig. 2) described by Dabadghao and Shankarnarayan (1973).

Technologies for the improvement of the rangelands in the arid and semi-arid tropics are available, albeit it needs a rejustification at the core level. In the case of humid tropics & temperate, alpine situations, a collaborative network is on the way to juxtapose ourselves with the ground truth situation through the site specific fit-in technological packages (Tandon *et al.* 1982; Singh, 1988 a; Singh, *et al.* 1988, Misri 1995).

The current impetus to improve this subcontinent's range conditions largely stems from a desire to restore the functions of watersheds. Overgrazing has compromised the soils ability to absorb rain and resulted in excessive run off, erosion, siltation and flooding (Chaney, *et al.* 1990). Finally, rangeland is a valuable resource for recreation while the use of rangleand to produce livestock forage has declined somewhat over the last two decades, its use for activities for other recreational purposes has to be increased. In fact, management plans for public rangeland now often sanction recreational use and sometimes recognize it as a significant source of income for local economics as in the case of United States (Holechek, 1992).

Grazing Resources and utilization

Ironically it is a fact that the animal production system (APS) in India which consists of nearly 15 per cent world's livestock population (400 m) occupying 2 per cent of world geographical area is linked with the forage production system (FPS) spread over about 4 per cent of the cultivated land under forage crops, 40 percent of the nonarable land used for grazing and the food crop residues used as dry forage.

A wide array of distributions of these resouces are under natural grasslands (barren and uncultivated lands), grazing lands, permanent pastures, degraded forests. Better FPS simulation can be done through proper agronomic practices with biofertilisers, control of major insect pests and diseases and adoption of agro-silvi-

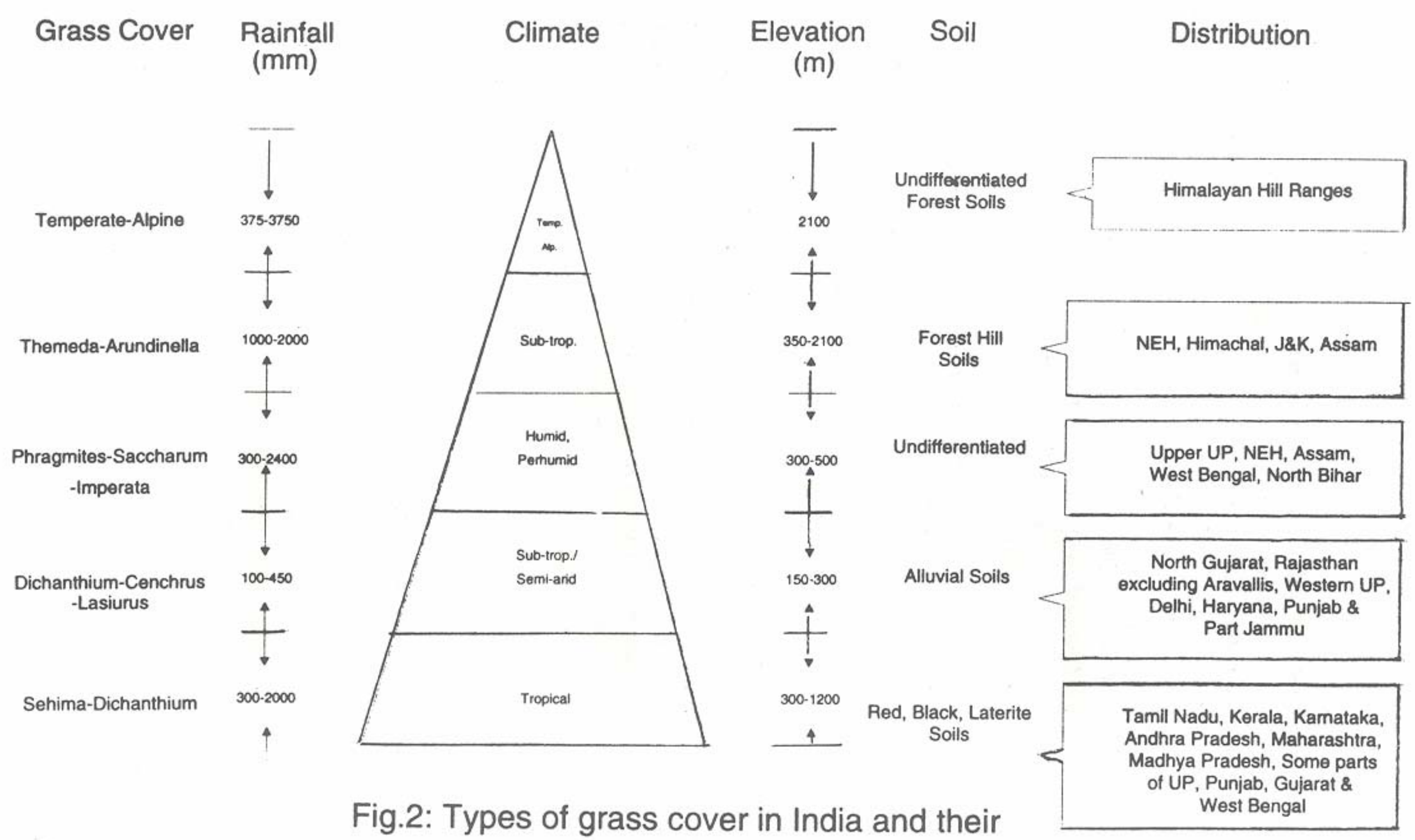

Fig.2: Types of grass cover in India and their distribution pattern

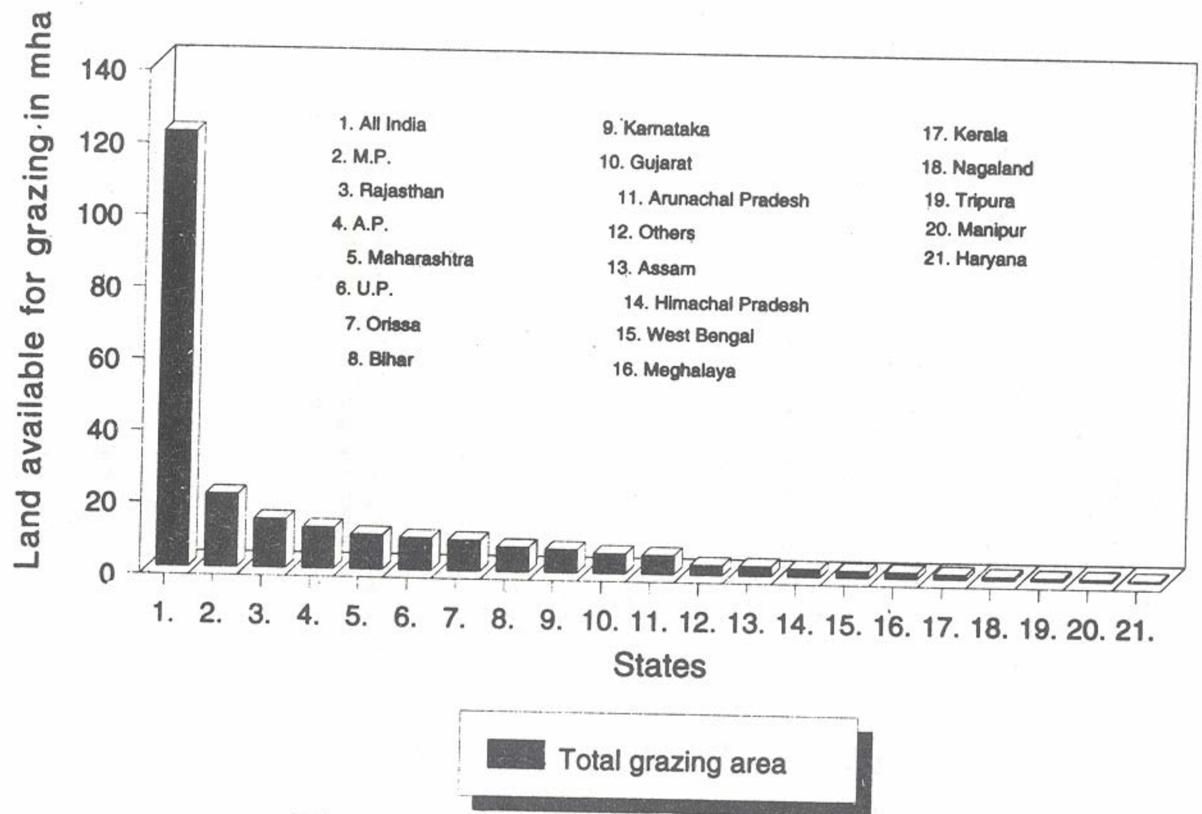

Fig. 3: Extent of grazingland in India

pasture concept in arable conditions. For synchronising this production system we should reconcile ourselves with the fact that in addition to the arable systems we have to juxtapose ourselves with a view to study and develop an environmental understanding of sustainable production system of the 12 m ha of tree crops, 15.45 m ha of cultivated wasteland, 67.33 m ha of forests and 22.87 m ha of fallow land comprising 40 percent of the total area of the country providing grazing resources (Fig.3). Consequently the grazing intensity is very high, for example in semi-arid areas the grazing intensity ranges between 1.04 to 51.08 ACU ha-1 against the normal carrying capacity of 1 ACU ha-1 jeopardizing the system. Gradual reduction in the carrying capacity is the result of continued neglect and anthropogenic interferences.

The grazing resources are getting depleted because of heavy grazing pressure and also because of variable soil-water interactive degradation which is estimated at about 180 mha. Rekib (1981) observed that in semi-arid rangelands the grazing intensity is about 3.2 ACU ha-1 yr-1, whereas its good condition class has the carrying cpacity of only 1 ACU ha-1 yr-1. Arid situation reveals that pressure ranges from 1 to 4 ACU ha-1 yr-1 as against the carrying capacity of 0.2 to 0.5 ACU ha-1 yr-1 (Raheja, 1966). Even though rangelands are degraded they meet out 40% of the current forage supply which of course, shows (Fig. 4) a huge deficit of green forage, crop residues and concentrates. Shankar and Kumar (1987 a) reported that in areas which are relatively inaccessible and face drinking water problem e.g. Jaisalmer district of Rajasthan state, there is a surplus of 1.46 m t dry forage from 39480 sq. km. of the grass cover.

The temperate and alpine rangelands of this subcontinent are characterized by altitudinal variations (100 m - 4500 m), steep slopes, low rainfall (100-600 mm), extreme temperatures, snowfall during winter, devious wind speed and higher solar radiation.

These rangelands are used for grazing by sedentary, seminomadic and nomadic pastoralists during May to October. The grazing pressure is frequently 2.5 to 4.7 times greater than the carrying capacity of the rangelands (Melkania and Tandon, 1988 a). The alpine and subalpine rangelands of Pakistan produce only 10-50 per cent of their potential and provide only 60 per cent of the requirement (Shah and Rafique, 1991). Katoch *et al.* (1991) have reported green herbage biomass of 4.46-4.90 t from the pastures of Himachal Pradesh.

The grasslands at the lower elevations of Himalaya are seral in nature having originated consequent to deforestation and abandoned cultivation (Saxena and Singh, 1980 a, b). The crux of the degradation of these rangelands are increasing biotic pressure and over-exploitation from the sedentary, semi-migratory and migratory graziers all round the year. Joshi and Pande (1991) report from Nepal a stocking rate of 3.9 adult ruminant units/ha of land which is indicative of over-exploitation.

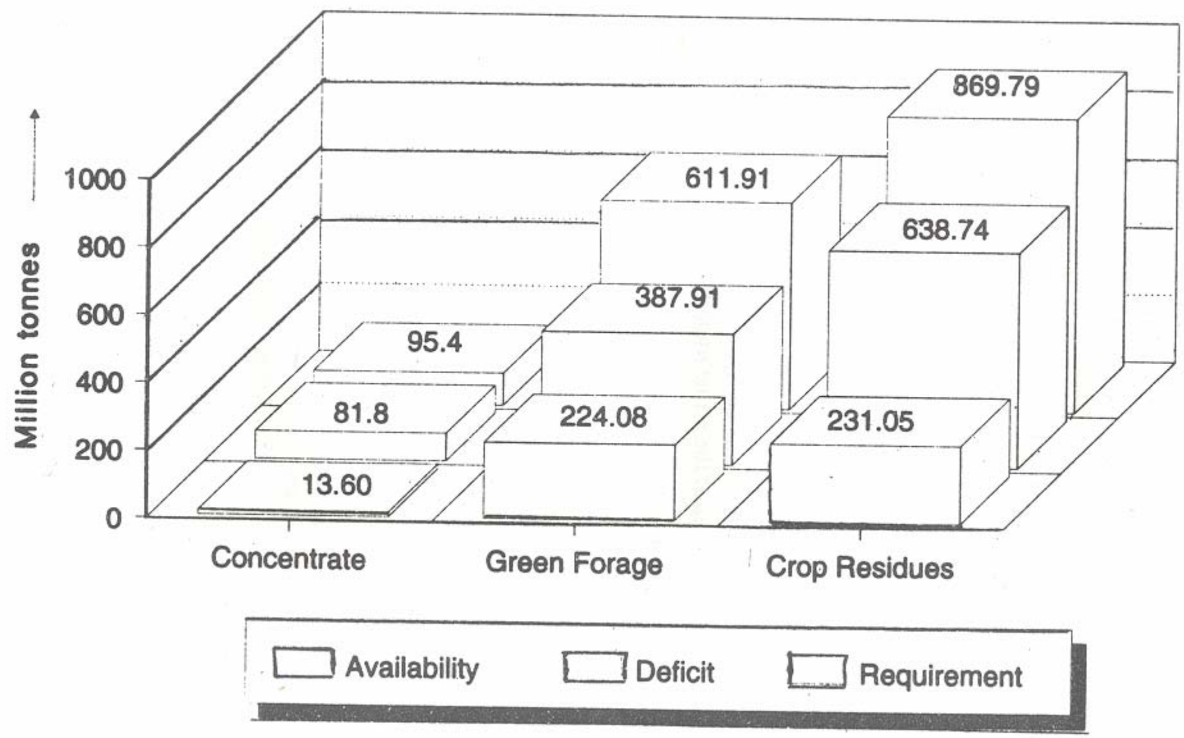

Fig.4: Forage supply-demand balance sheet in million tonnes

The average annual production of dry grass or hay in India is about 250 million tonnes which is approximately 38 percent of the total available dry fodder (Singh, 1988 a). It is a postulation that due to late harvesting in November-December, a loss of about 20 percent dry matter and over 50 percent crude protein occurs due to leaf shedding (Singh 1984).

We need to have a right kind of package of practices for grassland improvement related to hay making and also look into the techno-economic feasibility of hay densification for cheap and easy transportation to the place in need of forage supply from other locations.

Natural Grasslands

Natural grasslands provide a major part of forage resources and cover 23 per cent of the land surface globally. Natural grasslands are being changed at an alarming rate. A better understanding of the mechanisms and processes which are controlling various components of this ecosystem in the ligh of various environmental degradation processes is of the prime importance.

Borchert (1950) pointed out that climate of natural grasslands exhibits marked periodicity of precipitation both intraseasonally and interseasonally. Coupland (1974) reported that mean annual precipitation in temperate grasslands usually ranges from 250-750 mm and tropical and subtropical grassland and Savanas from 600 to 1500 mm whereas Indian situation shows 375-3750 mm and 100-2000 mm respectively. Soil formation process being an important basis for better and sustainable FPS are different in natural grasslands than that of forests (Weaver and Clements, 1938).

An important modifying factor in relation to the proportion of precipitation that enters soil and is available to the plants is the texture of soil. Beard (1953) conceptualised that a soil layer impermeable to moisture causes treelessness in some tropical areas where its absence resulting Savanna waterlogging of soil during rainy season are not suitable for tree growth and survivality in dry season.

While tropical forests store only about 19 per cent of the total carbon, the tropical grasslands are reported to store about 26 per cent of the total carbon. (Gifford, 1980; Gates, 1985). At this juncture it is very much necessary to have an understanding of how exchange of carbon in these communities may respond to the predicted climatic changes and their potential for ameliorating the 'green house effect' by sequesterring carbon. This is now the largest terrestrial biome (World Resources Institute, 1990) and in terms of biomass next to the tropical forest biome (Lieth, 1978).

Despite of the differentiation in grassland communities encountered in our national scenario (dry, saline, flood plain, temperature etc.), the unifying theme which is coming out is that it is a dynamic ecosystem which can be able to adopt itself in a varying situation through its capacity for rapid turnover of biomass and changes in allocation of biomass in the above and below ground systems. Albeit major driving forces behind the determination of a grassland type and its productivity are the seasonal rainfall pattern, grazing, fire etc. which are in turn interlinked with the changing environmental parameters. Consequently a better reconciliation of this system should be there by ramifying it and coupled with the equivalent unit of parallel systems likely silvipastoral approaches.

Rangeland Abuse

On many rangelands, soil compaction and reduced plant cover from overgrazing decreased the soil's ability to absorb infrequent rain and started a general drying trend. Lower water tables and a decreased flow are common symptoms of this phenomenon.

In many areas, changes in plant cover documented by photographs and historic accounts, have been dramatic. Replacement of perennial grasses by the shrubby vegetation whose deep roots can lower water tables and alter the local hydrological balance has been reported. The disruption of the natural fire cycle, which naturally acted as a check on shrub invasion, accelerated this trend (Kruger, 1993).

Monitoring Range Conditions

Interpreting current range conditions and trends is controversial. Rangeland monitoring data are often incomplete or questionable. Formal assessments are carried out on most provincial rangelands, but the methods, intensity and frequency of monitoring vary. No monitoring system is in place for private land, and there is no federal or even provincial database of range conditions to give an overview of data collected locally or regionally.

Also there has been disagreement over just how to evaluate range status. Early on, it was judged only by the land's ability to produce livestock forage. Now, managers use a system based on the ecological status of a site.

Ecological status is determined by comparing a site's present vegetation - species composition, diversity, distribution, and quality - to its "potential natural community" or "climax community", that is, the vegetation that would dominate the site over time in the absence of human interference. A rating of excellent, good, fair, or poor is assigned, based on how closely the range vegetation resembles the climax condition. Excellent equals 76-100 per cent climax vegetation; good, 51-75 per cent, fair, 26-50 per cent; and poor, 0-25 per cent. (Fig. 5).

This method of quantifying ecological status is based on the theory, adopted some 40 years ago (Dyksterhuis, 1947; Parker 1951) that rangeland not covered in climax vegetation follows a fairly predictable path of plant succession that ulti-

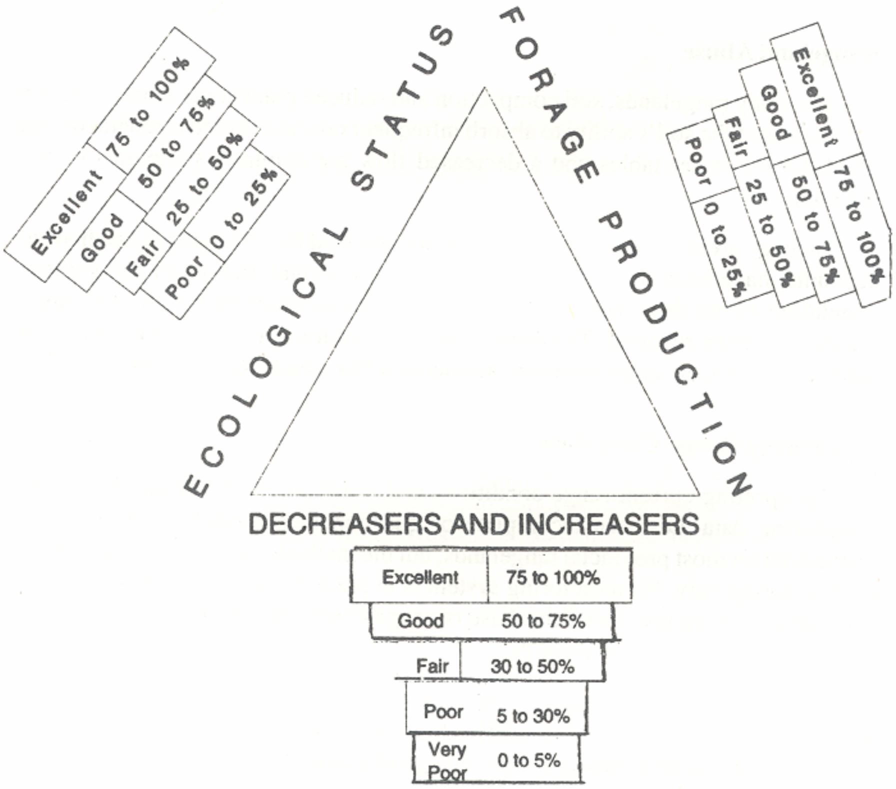

Fig. 5: Indicators of Rangeland degradation

mately reestablishes the climax community. It was essentially an ecological approach to use the land for grazing (Brown 1954). The expectation, then, is that rangelandof poor or fair condition will naturally progress toward the original climax community if managed correctly. In India this concept has been applied in semi-arid and arid rangelands and has been found of practical importance in defining range 'health' and also, in reverse, to assess the magnitude of degradation and desertification (Shankar, 1978a).

Within the last several years, this approach, while still the basis of most range data, has come under increasing attack. Some range managers complain that it is based on a faulty ecological model, does not accurately reflect range conditions, and compares against a standard - the original mix of plants - no longer attainable in many cases.

Critics contend that soil loss, the local extinction of some plant species, and the widespread invasion of exotic plant and animal species have effectively established a new climax state for some ranges. These areas may never reach their former climax state, no matter how well managed. However, if managed properly, they may produce sufficient plant cover to protect soil, provide forage and habitat for some animal species, and preserve watershed functions.

Plant succession theory, the under pinning of the current ecological status method of range evaluation, is now challenged by the "stable state and transition" model. This holds that various stable state, or stable vegetation communities can exist on a site depending on the combined effect of natural forces such as fire, grazing, rainfall, and other factors. According to this theory, if an environmental disruption occurs - drought or overgrazing, for instance - it may push a rangeland over the threshold to a new stable state, and natural processes will not necessarily return it to its former state. In other words, a single climax community does not define natural succession. It may proceed along several alternate paths, depending on the circumstances. This model is particularly applicable to many arid or mountain rangelands, where crucial climatic variables like rainfall and fire oscillate widely from year to year (Laycock, 1991 and Friedel, 1991).

Some environmentalists and many range managers fear that a monitoring system based on desired plant communities could discount the degraded condition of some ranges under ecological criteria - rather than commodity factors such as maximising livestock forage - are the primary basis for defining the desired plant community.

Disputes over evaluation methods aside, the most reliable and comprehensive data currently available on rangeland still follow the ecological status model. How figures are used to evaluate overall range health often depends on who is doing the analysis. Many environmentalists and other critics of range management policies feel the numbers deliver a more sober message. Progress on the range, critics contend, has fallen far short of the stated goals, with wildlife and watersheds still suffering and substantial acreage declining because of the continued overgrazing (Wuerthner, 1992).

Restoring Degraded Land

Virtually its a cogency to overcome the existing problems of forage production system with a two dimensional approach depending on the degradation condition classes. Firstly, by coupling the improvement of natural vegetation with soil and water conservation strategies and secondly, by establishing the grass-legume pastures and silvipastures.

Soil & Water Management

Generally the marginal lands belong to class IV to VII type of land and are exposed to erosional hazards. Soil conservation measures on land forms with shallow soils and undulating topography are of prime importance which exhilarate the natural recovery resulting into higher forage yield. In arid zone contour furrows (60 cm width and 25 cm depth) with a cross section of 930 sq. cm at a distance of 8-10 m across the slope have proved to be an important & effective check than others viz; contour bunds and staggered contour trenches. Efficacy of staggered pitting discer - a tractor attached device in the plain areas resulted in significantly higher forage yield. It helps in production upliftment (Fig.6) by retaining moisture in about 63000 staggered micropits/ha and yield increase from 83 to 115 percent and 53 to 70 per cent in natural grassland and reseeded pastures respectively. Ditching technique is more beneficial for soil and moisture conservation in the case of deep black soil (vertisols) as compared to contour bunds. Marvel grass plantation all along the side of ditches is useful for quality forage production and soil conservation.

Vegetation management

Undesirable shrubs can have an adverse impact on herbage yield of the grasslands due to their higher magnitude of infestation by reducing the open space for the grasses to grow. Consequent steps are the large scale removal of undesirable shrubs from the rangeland. Desirable shrubs likely *Grewia flavescens, Securinega virosa, Helecteres isora* and *Ziziphus nummularia* etc. should have a better ramified maintenance for browsing during the lean period. Trees and shrubs can better ensure the supply of leaf fodder at the time of scarcity in drought and famines. Fodder-cum-fuel trees likely *Albizia amara, A. procera, Acacia cupressiformis, Leucaena leucocephala, Dichrostachys cinerea, Dalbergia sissoo, Terminalia arjuna* plantation can be viewed as long term benefit for restoring the degraded grasslands. Vegetation management has to be contemplated through the identification of suitable species and varieties of grasses, legumes & fodder trees and shrubs.

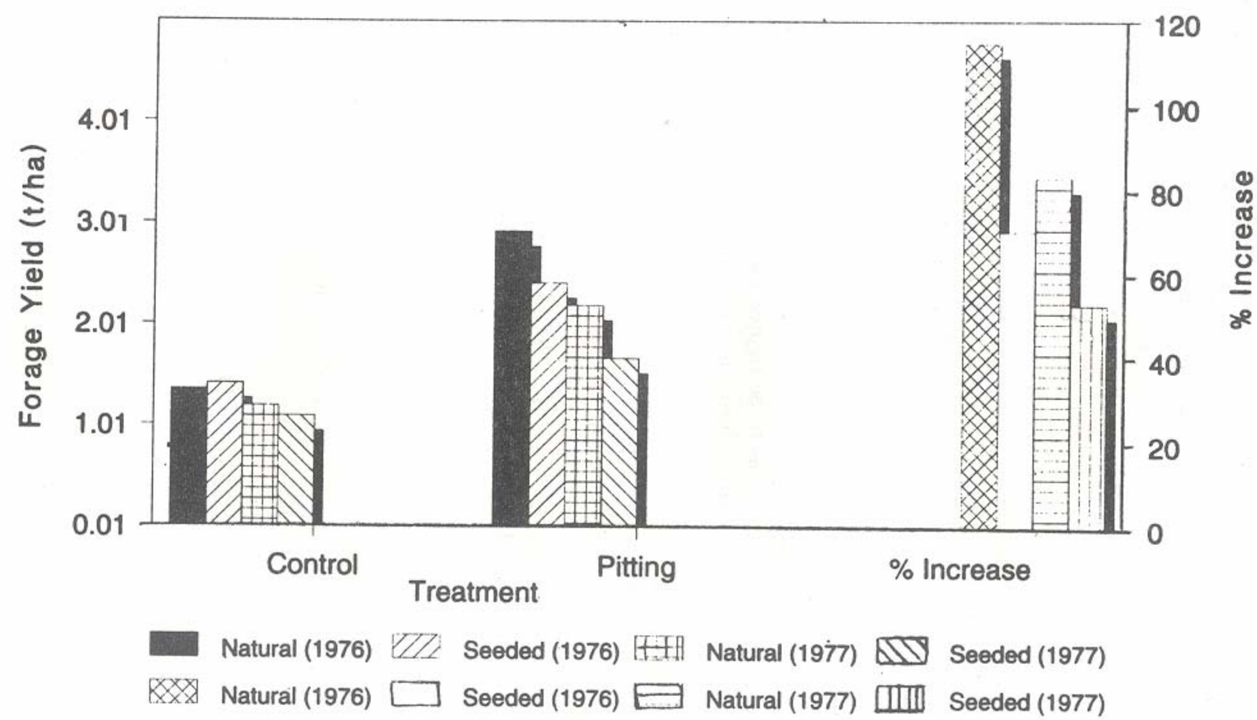

Fig. 6: Forage yield (t ha^{-1}) as influenced by the use of " pitting discer "

Planting and sowing of varied nature as a subsequent step of selection at the onset of monsoon alongwith the soil conditioning is important for establishing the grasses and legumes keeping in view the specific reflective observations from varied regional context.

Fertilization

Fertilizer application is no mirage in case of protected grasslands, rather extrude in maximising forage production. It has been opined that 60 kg N/ha in 3 equal splits at 3 weeks interval during the monsoon period is better for forage quality & quantity upgradation. Ammonium sulphate stands better in comparison to other nitrogenous fertilizers.

Harvest Management

Being a vital component of utilization management profiles and a counterpart of grazing management hence it has to be figured out mostly by ramifying the harvesting schedules for stall feeding during lean period besides *in situ* grazing of grasslands. Jhansi case studies on the intensity and intervals of cutting on a large number of grasses reflected that the highest productivity can be achieved when harvesting was done at 60 days interval at 10 cm above ground height with 30 kg N/ha. Quality aspects in relation to crude protein content shows maximum level at 30 days intervals harvesting. Monthly harvesting at 10-15 cm. height during growth period provides better simulation. For *Stylosanthes* species the optimal harvesting profiles has to be 90 to 120 days intervals and 10-15 cm above ground height.

Grazing ecology & Management

Grazing ecology and management focuses on the ecology of rangeland grazing, practical management of animals and vegetational manipulation which can be seen in the light of rangeland conservation, defoliation studies, physical effects of grazing animals, energy flow and nutrient cycling, redistribution of minerals by plants and animals, animals induced palnt distribution, fire ecology and its implications, basic rangeland synecology, forage resource utilization, distribution of animals, mixed species grazing and management, and seasonal managemenmt and grazing plans and its responses etc.

Controlling the timing, duration, and intensity of grazing appears to be the key. Many perennial range grasses are adapted to periodic, sometimes intense grazing. Periods of rest allow grazed perennials to replenish leaf area, set seed, and store food reserves in their roots (Merrill, 1983; Adams *et al.*, 1991). Continuous or too frequent access by large numbers of cattle to the same range impedes the ability of new growth to store food. When perennial grasses are repeatedly cropped back, leaf growth takes precedence over root growth. With continued severe grazing, roots die and plants become less vigorous. The result is reduced forage and greater plant susceptibility to drought and disease. Watershed protection also suffers as plant cover and leaf litter diminish, leaving erodible, exposed soil (Savory, 1992).

Livestock do not graze on all plant species equally, they concentrate on the most palatable and nutritious first. Thus grazing can lead to the disappearance of beneficial species, the domianance of less palatable species, and the invasion of agreesive weeds, brushy and poisonous plants. Livestock managers generally control such undesirable impacts by adjusting three critical variables: the number of livestock per hectare of range, called the stocking rate; the grazing system, in otherwords, the location and timing of grazing; and the placement of watering sites and salt blocks, which can spread grazing more evenly over the range.

The single most important factor is the stocking rate, because it directly influences the total amount of forage removed from the range (Walt van Poollen and Lacey, 1979; Holechek and Pieper, 1992). The number of cattle or sheep a range can sustain depends on vegetation as well as precipitation. Plants in dry areas regenerate much more slowly than those in humid areas (Holechek, 1983, 1988, 1991).

The relationship between the plant height and percentage of the total harvestable biomass is known so just by measuring the stable height amount of herbage grazed is determined. When the stable height indicates 50 to 70 per cent herbage removal grazing is stopped. Research shows that the vertical distribution of biomass among species is variable as is their temporal growth pattern (Singh and Yadava, 1974). Carrying capacity of the grassland is a considerable torque for the growing season or year round as the case may be. For this the total harvestable biomass estimated earlier is related to the normal forage intake @ 2 percent of the body weight of proposed grazing livestock per day.

Deferred rotational grazing system was found superior in *Sehima* dominated grasslands at Jhansi (Upadhyay *et al.* 1971) resulting in greater number of animal days (2925) as compared to continuous system approach (2097 animal days). Research shows that in case of arid rangelands there is 22 per cent dry matter yield of *Cenchrus* species under deferred rotational grazing whereas 6.3 per cent increase in case of continuous grazing (Das and Paroda, 1980). Deferred rotational grazing also exhibits the enhancement in the stocking rate from 0.49 to 0.73 sheep ha-1 whereas continuous grazing resulting into 0.53 sheep ha-1. The deferred rotational grazing system was superior in terms of average body weight gain of Tharparker breed of heifers over continuous grazing system in the case of *Lasiurus* dominated grassland of Western Rajasthan (Jaisalmer). Shankarnarayan *et al.* (1981) observed that the calving of animals was also higher (26 percent) in deferred rotational grazing system than continuous one. The reported best management strategy for the dry-sub-humid grassland at Varanasi as a result of clairvoyant simulation optimization modelling arrest that moderate grazing punctuated by a light-grazing year every 4-5 years in order for the legumes to recoup (Swartzman and Singh 1974).

Research shows that, over the long term, many desert and mountain rangelands can tolerate light to moderate stock levels that result in the consumption of about 30 to 35 per cent of the forage. With this practice, conditions on many degraded ranges could gradually improve and forage production increased (Holeckek, 1988, 1991). Studies show that reducing consumption from heavy (60-80 per cent) to moderate (40-60 per cent) or from moderate to light (20-40 per cent) can raise overall forage production by about one third (Walt van Poollen and Lacey, 1979).

In additon to determining appropriate stocking rate, range managers must choose a system that will best regulate how and when livestock graze. Even with low livestock numbers, poor distribution or timing of grazing can quickly degrade a rangeland. Over the years, a number of systems have been developed, the most appropriate for a given range depending on the local climate, the steepness of the terrain, and the competing needs of various range users (Holechek, 1983).

Other grazing systems involve various strategies for rotating livestock from one area to another, with the goal of periodically resting vegetation (Adams *et al*, 1991). Despite the cost of fencing and moving cattle and the years it takes to master the need system, rotational grazing has steadily gained the popularity over the last two decades because it offers better control over livestock distribution and feeding patterns. Rotational grazing is particularly beneficial in areas with steep terrain to ensure that grazing pressure is not confined to lowland areas, which cattle generally prefer.

The simplest rotational system divides the range and then grazing takes place in separate pastures in a regular sequence. Short duration grazing is rotational grazing in which a range is divided into many pastures that are each grazed intensively for just a few days, then rested for a period of many weeks. The most common form of short-duration grazing-and easily the most controversial grazing system today - is known as the Savory grazing method or more recently, as holistic resource management (HRM) (Bingham, 1987; Johnson, 1987).

Deferred rotation, an important variation of the model, delays the start of grazing in the spring to protect plants during a particularly vulnerable growth period. Deferred grazing allows plants to set seed and complete much of their growth cycle before defoliation begins.

Another option is complete rest from grazing for one or more years. This system, often used on severely degraded rangelands, is frequently preferred by environmentalists and wildlife advocates. Rest not only allows range plants to grow more abundantly but also allows plant litter to accumulate, conserving scarce moisture.

Most observers caution that the ability of a degraded rangeland to recover if allowed to rest indefinitely varies. Some interventions, such as brush control, prescribed burns, species introduction, or occasional grazing may be required for full restoration.

Silvipastoral Approaches

Assessing the range health by studying the levels of degradation, the restoration concepts at the light of ecological approaches (protection from grazing, soil & water conservation, controlled burning, bush clearing, fertilizer applications, seeding of grasses and legumes and pasture based animal production system etc.) has to be perceived. Conservation of fodder can be taken into account as a lean period feeding resources in the tropical monsoonal belt of India. The herbage production level which can be increased through fertilizer application and legume introduction, however, may reduce, substantially resulting large scale livestock migration.

The better resonance to meet out this situation and to provide green browse material during the lean period is the silvipastoral approaches as a restraint against unforseen situations. Strutous introduction of forage shrubs & trees in the grassland system in a proportion that they don't stymie for the herb stratum. Arid rangeland exposed to 350 mm annual average rainfall zone covered (14 per cent) by shrubs and tree canopy was optimum for high forage and browse production (Kaul and Ganguli, 1963). Silvipastoral network details with ancilary database are given in Shankar (1980, 1988).

Himalayan rangelands exhibited enormous gain in forage production over the existing situation due to the multitier silvipasture techniques amulgamated with a adaptable complementary plant species (Sharma and Koranne, 1988) (Table 1). Various micro-climatic sites present within the Himalayan region can possibly be gainfully utilized with the reconstructed canopies of adaptable floristic composition.

Table-1 : Forage production under existing and modified silvipastoral systems in a Himalayan rangeland (Subtropical)

Systems	Maximum production ($gm^{-2}yr^{-1}$)
I. Existing	
Heteropogon contortus + Chrysopogon fulvus	300
II. Modified network	
(i) Digitaria decumbens + Bauhinia purpurea	2400
(ii) D. decumbens + Quercus incana	1800
(iii) D. decumbens + Grewia optiva	2100
(iv) Cenchrus ciliaris + Celtis australis	2450

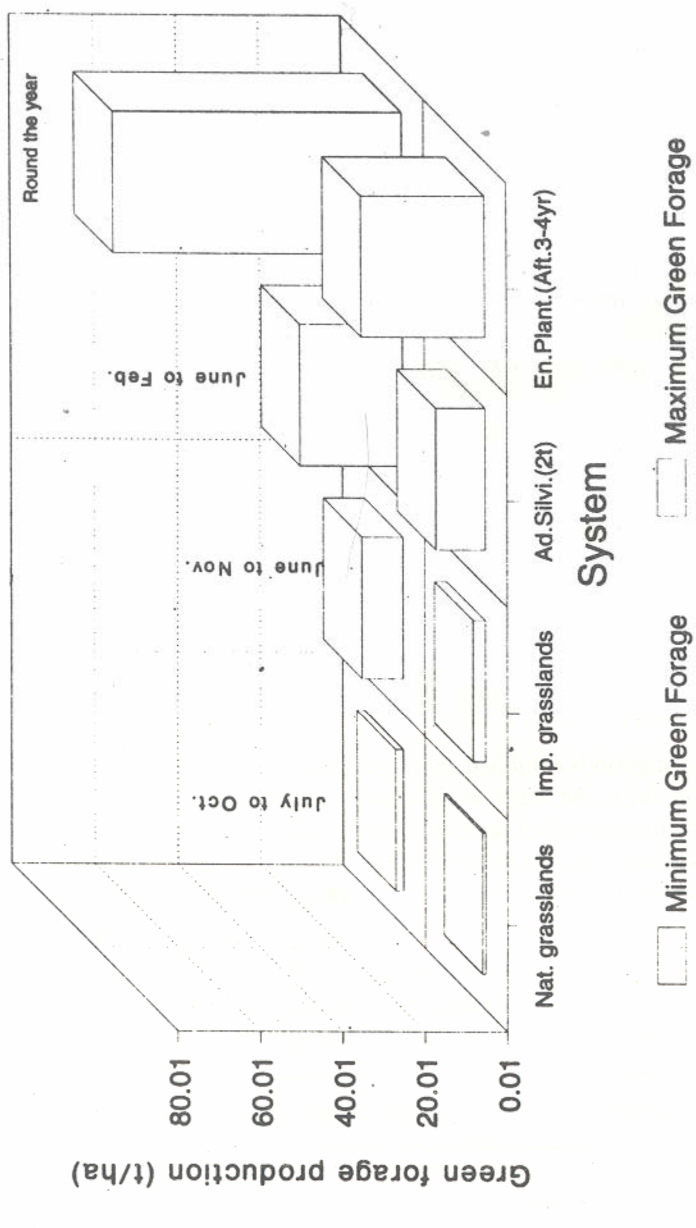

Fig. 7 : Production level and period of forage availability under different systems in temeperate rangeland

This new dimensional axioms in silvipastoral network can better augment towards providing the nutritous forage alongwith better grazing facilities in comparison to the present context (Fig. 7). The available herbage biomass from pastures of Kashmir and Central Himalaya have been studied by Misri (1988), Ram and Singh (1994).

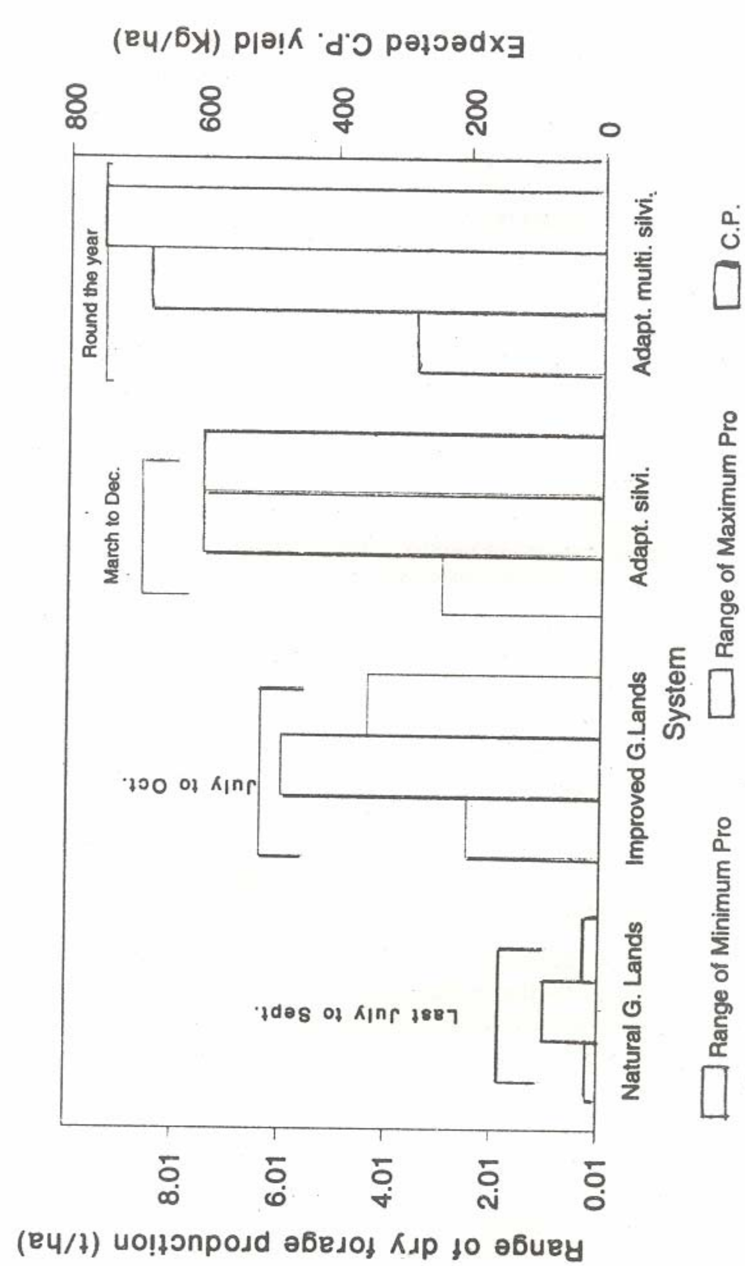

Fig. 8: Forage periodicity and production under various systems in arid and semi-arid tropical rangeland

The silvipastoral systems compared with other land uses in the sub-marginal and marginal lands execute forage/grazing availability alongwith the quality aspects for a long term and also yield seven times more forage compared to natural systems (Fig. 8).

Epilogue

An unprecedented demand for recreational access and an environmental awakening have combined to focus public attention on range conditions and management as never before in the developed countries (U.S. Forest Service Report, 1990) which needs a new dimentional axioms for better reconciliation towards system optimization and its sustainable use in a regional context.

Environmentalists maintain that the benefits are actually much less than is generally perceived in case of other countires (U.S. House of Repr. 1986; Jacobs, 1991; U.S. General Accounting Office, 1991). If the livestock production is marginal on these lands, they are increasingly valuable for other possible uses, which most environmentalists believe directly conflict with grazing as currently practiced. Safeguarding public rangelands requires lowering the number of livestock there, more carefully regulating grazing, and elevating the interests of wildlife to a more prominent place in management. Other environmentalists go further; they maintain that only complete removal of livestock from the public range will allow full recovery of its ecosystems (Jacobs 1988; Wuerthner, 1989, 1990).

Livestock ranchers may counter that cattle & sheep, when properly managed, can be a tool for maintaining rangeland health. Judiciously regulated grazing pressure stimulates seed dispersal and the growth of range grasses. Livestock interests maintain that private rangeland offers fencing and other services that public rangeland often lacks. Paying a higher price, if at all the system - land grazing fees can be incorporated, for public range would place a burden on the rancher and devalue the land for grazing purposes. More important, ranchers should regard their use of the land as a public service: they keep the land in production, provide a valuable commodity to the regional market, and protect rangeland from damage by uncontrolled public access (Nielsen, 1991).

No matter, whatever the facts are, livestock are not likely to disappear from public rangeland. Consequently the managers should adopt a more ecological approach to their ranges. As in the case of United States the livestock numbers on its lands are likely to decline, at least in the short term, as it curtails the use of marginally productive sites and seeks to rehabilitate deteriorating rangeland (U.S. Forest Service Report, 1990).

In Indian context it has to be acknowledged that some of the least productive and most fragile rangeland may indeed be more valuable as wildlife habitat and watershed. Even on the most productive sites, range managers maintain their new ecosystem approach will result in grazing being used as a land management tool, that is, as a means of maintaining the plant community appropriate for that site.

The management of private rangeland has also begun to change, partially in response to the harsh economics of modern livestock ranching. Expensive techniques such as fertilization, seeding and brush removal that were used in the 1960's and 1970's have all been severely curtailed in most parts of the world (Holechek and Hawkes, 1993).

Many range advisers are now recommending a low input approach that favours better breeding programs, more efficient placement of watering stations, more careful attention to stocking rates that minimize supplemental feeding and other inexpensive approaches to increase ranch efficiency.

In addition, many ranchers should seek other sources of income on their private ranges to augment livestock income. Some should take the advantage of the rising demand for recreation by charging for such activities as hunting, fishing and wilderness park trips as it has already been practiced widely in many developed countries.

To the extent that these new uses encourage better standardship and more attention to wildlife needs, they may promote range recovery. They have the added benefit of providing financial bridge to a diversified ranch economy that moves away from exclusive focus on livestock to have an unique rangeland ecosynthesis for better sustainability.

References

Adams, B.W., Ehlert, G. and Robertson, A. 1991. "Grazing systems for Public Grazing lands," Range notes No. 10 (Alberta Forestry Lands and Wildlife, Public Lands Division, Lethbridge, Alberta, January), pp. 1-8.

Beard, J.S. 1953. The Savanna vegetation of northern tropical America. Ecological Monographs, 23 : 149-215.

Bingham, S. 1987. "Allan Savory : Creator of a Socratic Approach to Land Management,". High country News (April, 27, Paonia, Colorado), pp. 11 and 13.

Borchert, J.R. 1950. The climate of the North American Grassland. Annals of the Association of American Geographers, 40: 1-39.

Brown, D. 1954. Methods of Surveying and measuring vegetation. Commonwealth Agril. Bureau, U.K.

Chaney, E., Elmore, W. and Platts, W. 1990. Livestock grazing on Western Riparian Areas (U.S. Environmental Protection Agency, Washington, D.C.), pp. 2-6.

Chaturvedi, J.K. 1981. A plea to reverse the rapidly declining downward trend of rangelands productivity. Indian Institute of Forest Management, Bhopal, India (Mimio).

Child, D. 1991. In: Gregory Mock's Focus on Forest and Rangelands of W.R.I, 94-95 report, p, 137.

Coupland, R.T. 1974. Grassland. In the New Encyclopaedia Britanica, 8: 280-294.

Dabadghao, P.M. and Shankarnarayan, K.A. 1973. The Grass covers of India. Indian Council of Agricultural Research, New Delhi.

Das, R.B. and Paroda, R.S. 1980. Rational utilization of grazing resources for sustained primary and secondary productivity in arid zone of western Rajasthan. Ann. Arid Zone, 19: 407-412.

Dyksterhuis, E.J. 1949. Condition and management of rangeland based on quantitative ecology. J. Range Manage., 2: 104-115.

Friedel, M. 1991. "Range condition Assessment and the concept of Thresholds : A view point, "Journal of Range Management, Vol. 44, No. 5, P. 422.

Gates, D. M. 1985. Global biospheric response to increasing atmospheric CO_2 concentration, In: Direct effects of Increasing Carbon Dioxide on vegetation (eds B.R. Strain and J.D. Cure), Deptt. of Energy, Washington, pp 171-184.

Gifford, R.M. 1980. Carbon storage by the biosphere, in carbon dioxide and climate: Australian Research (ed. G.I. Pearman), Australian Academy of Sciences, Canberra, pp. 167-181.

Gupta, R.K. and Ambasht, R.S. 1979. Use and Management. In: R.T. Coupland (Editor), Grassland Ecosystem of the world, IBP18, Cambridge University Press, Cambridge. pp 241-44.

Holechek, J.L. 1983. Considerations concerning Grazing systems, "Rangelands, Vol. 5, No. 5, p. 208.

Holechek, J.L. 1988. "An Approach for setting the stocking rate, "Rangelands, Vol. 10, No. 1, P. 11.

Holechek, J.L. 1991. "Chihuahuan Desert Rangeland, Livestock grazing, and sustainability," Rangelands, vol. 13, No. 3, P. 115.

Holechek, J.L. 1992. In: Gregory Mock's Focus on Forests and Rangelands of W.R.I., 94-95 Report, p. 138.

Holechek, J.L. and Pieper, R. 1992. " Estimation of stocking rate on New Mexico Rangelands, Journal of Soil & water conservation, Vol. 47, No.1, p. 116.

Holechek, J.L. and Hawkes, J. 1993. "Desert and Prairie Ranching Profitability under changing economic conditions, "Rangelands, Vol. 15, No. 3, pp. 104-109.

Huntsinger, L. 1992. In: Gregory Mock's Focus on Forests and Rangelands of W.R.I., 94-95 report, p. 137.

Jacobs, L. 1988. "Amazing Graze : How the livestock industry is ruining the American West."Desertification Control Bulletin, No. 17, pp. 13-17.

Jacobs, L. 1991. Waste of the West (Lynn Jacobs, Tucson, Arizona), pp. 25-27.

Johnson, S. 1987. " Allan Savory: Guru of False Hopes and an overstocked Range, High country News (April 27, Paonia, Colorado), pp. 12 and 16.

Joyce, L. 1989. An Analysis of the Range Forage situation in the United States, 1989-2040, (USDA, Forest Service, Washington , D.C.), p. 9.

Kruger, W. 1993. In: Gregory Mock's Focus on Forests and Rangelands of W.R.I. 94-95 report, p. 138.

Katoch, B.S., Dogra, K.K. and Singh, B. 1991. Nutritional status of the herbage of selected alpine pastures of Bara Bangahal. Paper presented at Reg. Workshop. Himalayan Pasture and Fodder Research Network Palampur, Shimla, 14-18 Nov.

Kaul, R.N. and Ganguli, B.N. 1963. Fodder potential of *Ziziphus* in the shrub grazing lands of arid zones. Indian For., 39: 623- 630.

Joshi, N.D. and Pande, R.S. 1991. Himalayan pasture and Fodder Research Network, Country Report Nepal. Regional Workshop held at Palampur and Shimla, 14-18 Nov.

Laycock, W. 1991. "Stable states and thresholds of Range condition on North American Rangelands: A view point, "Journal of Range Management, Vol. 44, No. 5, p. 427.

Lieth, H.F. 1978 Ed. Patterns of Primary productivity in the Biosphere. Hutchinson Ross, Stroudsberg.

Melkania, N.P. and Tandon, J.P. 1985. Dry matter yield and strategies for regeneration of pastures in Central Himalaya. In: J.S. Singh (Editor), Environmental regeneration in Himalaya: Concepts and strategies. Gyanodaya Prakashan, Nainital, India. pp. 399-408.

Melkania, N.P. and Tandon, J.P. 1988a. Management of Rangelands in Himalaya - A regional study. 3rd International Rangeland Congress, Abstracts vol. II, Range Management Society of India, Indian Grassland and Fodder Research Institute, Jhansi. pp, 361- 363.

Merrill, J. 1983. "The xxx Ranch : Managing Range for Ecology and Economy, "Publication No. ys-83-1, Chapter offprint from 1983 Yearbook of Agriculture (U.S. Department of Agriculture, Washington, D.C., pp, 87-94.

Ministry of Environment and Forests India, 1991. Developing India's Wastelands (Ministry of Environment and Forests, New Delhi, n.d.), p. 8.

Misri, B. 1988. Forage Production in Alpine and subalpine region of north west Himalaya. In: Panjab Singh (Ed.). Pasture and Forage Crop Research - A State of knowledge Report. R.M.S.I, Jhansi: 43-55.

Misri, B. 1995. Range and Forest Grazing in the Himalaya. Workshop of Temperate Asia Fodder and Pasture network Kathmandu. Feb.

Nielsen, D. 1991. "Total cost of Grazing Public Lands," Western Livestock Journal (January, 14), p. 10.

Parker, K.W. 1951. A method of measuring trend in range condition on natural forest ranges. U.S. Deptt. of Agriculture Forest Service (Mimeo).

Raheja, P.C. 1966. Rajasthan desert can bloom with forage. Indian Farming, 15: 47.

Ram, J. and Singh, S.P. 1994. Ecology and Conservation of Alpine Meadows in Central Himalaya, India. In: Y.P.S. Pangtey and R.S. Rawal (Eds.) High Altitudes of the Himalaya. Gyanodya Prakashan, Nainital.

Rekib, A. 1981. Some aspects of livestock feeding on herbage in Bundelkhand region (Unpublished).

Savory, A. 1992. "Time and Overgrazing, "Holistic Resource Management Newsletter, No. 37 (Centre for Holistic Resource Management, Albuquerque, New Mexico, Fall), P. 5.

Saxena, A.K. and Singh, J.S. 1980a. The grass cover in the Himalayan region. In: Proceedings of the National Seminar on resources, development and environment in the Himalayan region, New Delhi. Department of Science and Technology, New Delhi. pp. 164-203.

Saxena, A.K. and Singh, J.S. 1980b. Analysis of forest grazingland vegetation in parts of kumaun Himalaya. Indian J. Range Mgmt. , 1: 13-32.

Shah, B.H. and Rafique, S.M. 1991. Himalayan Pasture and Fodder Research Netwrok; Country Report Pakistan. Regional Workshop held at Palampur and Shimla : 14-18 Nov.

Shankar, V. 1978 a. Ecology of the past and the present vegetation of the Indian desert, vegetational indicators and a score card for measuring desertification. In: J.S. Singh and B. Gopal (Editors), Glympses of ecology. International Scientific Publication, Jaipur, India. pp. 269-293.

Shankar, V. 1980. Silvipasture research : a review. Forage Res., 6: 107-122.

Shankar, V. and Kumar, S. 1987a. Herbage yield and carrying capacity of grass covers in the desert district of Jaisalmer, Trop. Ecol., 28: 239-245.

Shankar, V. 1988. Silvipasture research in India. In: Panjab Singh (Editor), Pasture and forage crops research Range Management Society of India, Indian Grassland and Fodder Research Institute, Jhansi. pp. 291-304.

Shankarnarayan, K.A., Kackar, N.L. and Mertia, R.S. 1981. Productivity of large herbivores cattle and sheep productivity of arid grazingland ecosystem. Monograph no 19- Central Arid Zone Research Institute, Jodhpur, India.

Sharma, B.R. and Koranne, K.D. 1988. Present status and management strategies for increasing biomass production in North- Western Himalayan rangelands. In: Panjab Singh and P.S. Pathak (Editor), Rangelands - resource and management. Range Management Society of India. Indian Grassland and Fodder Research Institute, Jhansi. pp. 138-147.

Singh, J. 1984. Mechanical contrivances in hay quality amelioration. Ph.D. Thesis, Jiwaji University, Gwalior India.

Singh, J.S. and Yadava, P.S. 1974. Seasonal variation in composition, plant biomass and net primary productivity of a tropical grassland at Kurukshetra, India. Ecol. Monogr., 44: 351- 376.

Singh, P. 1988a. Forage production from the Himalayan hill regions : Present status and future strategies. Souvenir, 3rd International Rangeland Congress, Range Management Society of India, Indian Grassland and Fodder Research Institute, Jhansi, India. pp. 14-25.

Singh, S.P., Ram, J. and Singh, R.P. 1988. Forage production and utilization in Central Himalayan rangelands. In: Panjab Singh (Editor), Pasture and forage crops research. Range Management Society of India. Indian Grassland and Fodder REsearch Institute, Jhansi. pp. 86-96.

Swartzman, G.L. and Singh, J.S. 1974. A dynamic programming approach to optimal grazing strategies using a successional model for a tropical grassland. J. Appl. Ecol., 11: 537- 548.

Tandon. J.P., Melkania, N.P. and Singh, S.P. 1982. Herbage production, structure and possible measures for improvement of mid- Himalayan Grasslands. Indian J. Range Mgmt., 3: 21-27.

Tata Energy Research Institute, Environmental Considerations in Energy Development: India country study, final report submitted to the Asian Development Bank (TERI, New Delhi, 1991), p. 5.

Upadhyay, V.S., Dabadghao, P.M. and Shankarnarayan, K.A. 1971. Annual Report, Indian Grassland and Fodder Research Institute, Jhansi.

U.S. forest Service, 1990. The Forest Service Programme for Forest and Rangeland Resources (U.S. Department of Agriculture, Washington, D.C.). pp. 5.16-5.18.

U.S. General Accounting Office (GAO), 1991. Rangeland Management : BLM's Hot Desest Grazing Programme Merits Reconsideration (GAO, Washington, D.C. p, 43.

U.S. House of Representatives, 1986. Committee on Government operations, Federal Grazing Programme : All Is not well on Range, Committee Print (May).

Walt Van Poollen, H. and Lacey, J.R. 1979. "Herbage Response to Grazing systems and stocking intensities, "Journal of Range Management, vol. 32, No. 4, p, 250.

Weaver, J.E. and Clements, F.E. 1938. Plant Ecology, New York, Mc Graw - Hill Book Co.

World Resources Institute. 1990. World Resources 1990-91: A guide to the global Environment, Oxford University Press, New York.

World Resources Institute 1994. World Resources 1994-95: A guide to the global Environment, Oxford University Press, New York.

Wuerthner, G. 1989. "Public Lands Grazing: What Benefits at What Cost? "Western Wild - Lands, p. 24-29.

Wuerthner, G. 1990. " The Price is wrong, "Sierra, pp. 38-45.

Wuerthner, G. 1992. "Some Ecological Costs of livestock," Wild Earth, Vol. 2, No. 1, p. 10.