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Management of Pastures and Rangeland in Arid Western Rajasthan: A Review

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Abstract: Ranges and pastures are the backbone of the animal rearing in arid zone. The climatic adversities, fodder availability for large animal population in the region completely depends on these pastures. Heavy grazing pressure, poor management and poor rainfall conditions are only responsible for poor yield and low carrying capacity (0.68 ACU ha^{-1}) of these ranges and grasslands. The restoration by reseeding and introduction of perennial grasses, shrubs and bushes are the only option for increasing the productivity. Response to 20 kg N ha^{-1} application to grasses appeared to be favorable in arid regions having less than 300 mm rainfall. Growing trees such as *Prosopis cineraria*, *Acacia nilotica* and *Ziziphus nummularia*, and grasses *Cenchrus ciliaris*, *C. setigerus*, *Dactyloctenium scindicum*, *Panicum antidotale*, and *Lasiurus scindicus* together has also been a traditional practice in the Thar Desert. The agri-horti-silvicultural system having fruit trees + fodder crops + fast growing nitrogen fixers tree species providing good fodder for animals is another option for increasing the intensity of crops and increase productivity per unit area. Additionally, grazing management like rotational grazing is most important for maintaining the sustainable production.

Key words: Range management, pastures, grass cover, grazing management.

Range management is, in a large part, applied ecology; it involves managing the environment in which plants and animals live in a way that provides the most favorable habitat for production. Much is known about how productivity can be managed through activities such as soil and water conservation, soil fertility management and plant species manipulation. Though the techniques reported to improve productivity in one region may not be applicable to another due to highly specific differences in the characteristics of the ecosystems.

The grassland area in India consists of 80.51 million ha (535,441 km^2; 17.32%) and the forest area is 768,436 km^2. With only 2% of the world's geographical area, India supports 20% of the world's livestock, with 16% of cattle and 55% of the world buffalo population and the world's second largest goat (20%) and fourth largest sheep (5%) populations (Malviya, 2015). The share of forages in cultivated land, however, has remained <5% in the country for many years.

The grazing lands, considered to be one of the most productive ecosystems in the Indian Subcontinent, have been at the receiving end for long. As per estimates, the country's pastures have reduced from about 70 million ha in 1947 to just about 38 million ha in 1997. The remaining grazing lands have either already degraded or are in the process of degradation with current average carrying capacity of less than 1 adult cattle unit (ACU) per ha. These grazing lands, often considered as 'wastelands' are suffering due to management neglect and are easily diverted for other uses.

The fodder resource from grasslands is also quite small due to denuded grazing lands owing to heavy grazing pressure. Indian grazing lands have a pressure of 3.42 animal units/hectare. Other major threats faced by Indian grasslands that lead to their degradation are (i) conversion to agriculture (or urban areas); (ii) habitats being marginal for plant growth hence vulnerable to climate change; (iii) invasive species of annuals *vs* perennials; (iv) competition for light, water, nutrients; and (v) excessive grazing pressure.

Traditional range management approaches like considering only biological factors and ignoring the social and traditional aspects of range management are changing leading

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to community based and co-management approaches. It is hard to determine the value of rangelands in terms of environmental services like carbon sequestration, watershed management, bio-diversity and eco-tourism. In arid and semi-arid areas rangelands are the major free grazing areas for livestock all year round (Ahmad and Islam, 2011; Mirza *et al*., 2006). The indicators of rangeland degradation may vary from region to region but the common ones are elimination of preferred species, reduction in plant cover and bio-diversity, reduction in forage production and increased soil erosion and runoff of rain water with little or no infiltration. All these factors are leading towards desertification.

Most of the rangelands belong either to tribes or open grazing rangelands. The pastoralists are facing number of challenges but the major one is shortage of feed and forage for livestock particularly in winter months (Bano *et al*., 2009; Ahmad *et al*., 2009). However, in arid and semi-arid rangelands, grazing management alone may not accelerate the succession of desirable species due to limited precipitation (Roundy and Call, 1988). A major concern of arid and semi-arid ranges is the progressive reduction of productivity and diversity. Heavily grazed grasslands have good recovery potential under favorable climatic conditions. Re-generation potential of native range species is limited due to insufficient rainfall distribution during germination and establishment of seedlings. Biomass availability gradually declines more so in winter months that are critical for grazing. Fodder shrubs like *Atriplex canescens* and *Salsola vermiculata* have potential for establishment as forage reserve blocks utilizing micro-catchment water harvesting technique (Ahmad and Ehsan., 2012).

Arid lands have been defined as having mean growing periods of less than 75 days per year corroborating with number of days in a year when moisture regime is available to sustain plant growth while semi-arid lands are those having mean growing periods of less than 180 days a year (Seŕe *et al*., 1996). Climate variability is a feature of arid and semi-arid lands (Gaur and Squires, 2018). Rangelands are semi-natural ecosystems, where people seek to obtain a productive output just by adding domestic livestock to a natural landscape (Harrington *et al*., 1984). Pasture lands constitute about 26% of the geographical area of region and are found mostly in tracts with mean annual rainfall of 250 mm or less. It is estimated that nearly two-thirds of these lands are in a state of severe degradation and the grazable biomass production is only one-half to one-third of that possible under rational management (Dhir, 1993). The native people of the Thar Desert have a healthy tradition of preserving village grazing lands called *gochars* and green woodlands called *orans*. *Orans* are preserved in the name of a local deity. The Thar Desert holds a high potential for development into a more productive rangeland. The highly nutritive fodder grasses such as *Lasiurus sindicus*, *Cenchrus ciliaris, C. setigerus* and *Cymbopogon jwarancusa* are well adapted to the Thar Desert environment (Gaur *et al.,* 2018).

Grass Cover and Ecological Distribution

The grassland cover of Indian arid zone with particular reference to western part of Rajasthan is of *Dichanthium-Cenchrus-Lasiurus* type (Dabadghao, 1960). Based on the edaphic factors, the vegetation cover may be categorized as different heads like (i) Sand dunes and sandy plains (ii) Well drained sandy alluvial soils (iii) Sandy clay loam to clay soils (old and young alluvium type) (iv) Hilly and piedmont regions and (v) Low lying heavy saline soils.

Studies indicated that in its optimum state *Sehima nervosum* recorded a plant cover of 11.5% at Pali in south western Rajasthan, but was reduced to 0.1 to 0.2% due to the impact of overgrazing (Gupta and Saxena, 1972). *Cenchrus ciliaris* and *C. setigerus*, on the sandy loam soil of Sojat, with a basal cover of 19.8% were reduced to a mere 0.5% cover. Likewise *Dichanthium annulatum* on the sandy loam soil in Harji, Ahor block, initially recorded a basal cover of 24%, but due to unrestricted grazing, it was reduced to only 5% (Gupta and Saxena, 1972). Many of the grazing lands have been invaded by non-palatable invasive alien species like *Lantana*, *Eupatorium*, *Parthenium*, *Prosopis juliflora*, *Leucaena*, etc. severely affecting their productivity. The once robust village level traditional institutions ensuring their sustainable management have broken down and there is no other agency to look after their management issues. Many of the ecologically sensitive pasture lands viz. Shola grasslands of Nilgiris; Sewan grasslands of Bikaner, Jodhpur

Table 1. Practices to improve rangeland health and mitigate GHG emissions

Practice	Benefits		
	Carbon	Methane	Bio/physical benefit/cost
Reduce animal numbers [(in animal unit months (AUMs)]	Increases carbon sink because of increasing vegetation cover and better root growth	Reduces animal methane production through reduction in total number	Increases plant cover, increases soil organic matter and improves productivity
Change mix of animals	Possible increase in carbon sink with change in plant species	No known effect	Potential changes in plant species composition
Provide livestock protein supplement	No effect	Decrease methane production	Perhaps will reduce extensive grazing to some degree
Increase native grasses and or plant adapted species	Increases carbon sink because of increasing vegetation cover overall	Possible benefit of methane reduction by increasing quality of diet	Benefit in retention of native species for gene conservation
Plant halophytes (salt tolerant-species)	Increase carbon sink and increase productivity	No known effect	Benefit with increased plant cover and productivity
Apply prescribed burning	Increase carbon sink and increase productivity in the long term on appropriate rangeland types	Possible benefit of methane reduction by increasing quality of diet	In systems adapted to fire, can increase productivity, maintain nutrient cycling
Implement agroforestry systems	Increase carbon sink and increase productivity in the long term on appropriate rangeland types	Possible benefit of methane reduction by increasing quality of diet	Possible benefit with increased plant cover, diversity and productivity
Develop large scale watershed projects	Increase carbon sink and increase productivity	Possible benefit of methane reduction by increasing quality of diet	Potential for large land disturbance, with benefit to human and animal populations because of regulated and regular water supply

and Jaisalmer; semi-arid grasslands of Deccan; Rollapadu grasslands in the semi-arid tracts of Andhra Pradesh; Banni grasslands of Gujarat and Alpine grasslands of Sikkim and western Himalaya are already on the verge of no return.

Carrying Capacity of Pastures/Rangelands

Carrying capacity (CC) is a useful concept for planning range improvement projects; it is based on the assumption of consistent average precipitation. CC is defined as the maximum number of animals, usually expressed as a standardized “Livestock Unit” of 250 kg that an area of land can support on a sustainable basis. It can be expressed numerically as a stocking rate (SR). A basic technique for determining CC is to calculate the total amount of forage at the end of the growing season, multiply this by a suitable correction factor and then divide by the average yearly feed requirements of a livestock unit (LU). CC is usually expressed as a stocking rate in hectares per livestock unit (ha LU^{-1}). A general assumption is that livestock require a daily dry matter (DM) intake of about 2.5% of their bodyweight.

The grazing pressure in the State of Rajasthan, in terms of adult cattle units (ACU), is 7.68 ACU ha^{-1} while existing carrying capacity is only 0.68 ACU ha^{-1} (Venkateswarlu, 1997) The conversion factors are 1.25, 0.17, 0.17, 0.50 and 1.5 for buffalo, sheep, goat, donkey and camel, respectively. In the arid zone of Rajasthan, the pressure was 0.87 ACU ha^{-1} in 1981 against the optimum desirable density of 0.2 ACU ha^{-1} for permanent pasture and other grazing lands (Gupta, 2000) Estimates, based on Table 1, indicated that the pressure increased to 0.96 ACU ha^{-1} in 1995 and 1.02 ACU ha^{-1} in 2001. Excellent, good, fair, poor and very poor condition rangelands (having approximate productivity of 2.0, 1.5, 1.0, 0.75 and 0.5 Mg ha^{-1}, respectively) can safely provide year-long grazing to 0.25-0.30, 0.20, 0.17, 0.13 and 0.01-0.06 ACU ha^{-1} blocks, respectively, during normal years (Bhimaya and Ahuja, 1969). In Thar Desert, relative grazing capacity estimated in sandy soil was 4.5 sheep per ha for *Cenchrus ciliaris*, 2.5 ha^{-1} for *C. setigerus*, 4.1 ha^{-1} for *Panicum antidotale* and 6.9 ha^{-1} for *Lasiurus sindicus* (CAZRI, 1983).

Rangeland Degradation

The major indicators of rangelands degradation are shift in species composition, loss of range biodiversity, reduction in biomass production, less plant cover, low small ruminant productivity and soil erosion (Ahmad and Ehsan, 2012). Perennial grass like *Chrysopogon aucheri* a highly palatable species is being gradually replaced by species of low palatability like *Cymbopogon jwarancusa.* Shrubs like *Artemisia* species or *Haloxylon* species have been replaced by unpalatable shrub species like *Peganum harmala* and *Othonophsis intermedia* with clear evidence of soil erosion also.

Range Management Problems on Common Property Resources (CPR)

A lot is known about how productivity can be managed through such instruments as soil and water conservation, soil fertility management and plant species manipulation. This is standard practice on commercial ranges worldwide, where a high degree of management control is possible. However, specific nature of techniques for a rangeland ecosystems found to be effective to improve productivity in one region may not be applicable in another. It must be stressed at this point that the problems facing rangeland development programs on India's CPR's are mainly social, not technical. Entitlement to use CPR may be under intricate and complex management systems, or it may be open to all users. Often between such groups, a wide social and economic differences exists, *vis-a-vis* access and entitlements to the range resources. Some groups, such as those without any private land or fodder resources, are more vulnerable than others, especially during droughts. Thus, a thorough pre-project assessment of the likely impact of any intervention on the weaker groups is essential without social organisation and a high degree of commitment among user groups. Technical interventions will not be sustainable and may widen the existing differences.

Range Management Approaches

Range management is a combination of many factors like biological (vegetation, animals), physical (climate, topography etc.) and social (need, importance and participation). The objectives of range management programs may vary but optimizing the return by manipulating the range ecosystem is the ultimate goal of any range management intervention. Long-term range monitoring studies were conducted to assess rangeland dynamics and trends in terms of biomass availability and permanent vegetation cover. Regeneration of most grass species depends on the production of viable seeds, patterns of seed dispersal, seed predation, seed bank dynamics and the presence of suitable microsites and environmental conditions for germination and seedling establishment (Aguiar and Sala, 1997; Russell and Schup, 1998). Perennial grasses usually have a transient seed bank (Kinuc and Smeins, 1992) and livestock grazing can have a significant impact on aboveground vegetation and the soil seed bank in many grassland communities. Seedbed microhabitats and precipitation strongly influenced the emergence and survival of seedlings of both species. Plant establishment by seedling recruitment is only successful when plant requirements for seed germination, seedling establishment and subsequent growth are matched with the micro environmental factors of the seedbed (Harper, 1977).

Rangeland Improvement and Management

Improvement, fertilization and protection from fire substantially increases forage yield in the rangeland. Studies in the Thar Desert indicate that, with adequate protection and grazing on carrying capacity basis, aiming at 70% forage utilization level, forage yield increased by 148, 92 and 116% in poor, fair and good condition class of grasslands, respectively, after two years (Ahuja, 1977). The different practices like: Soil conservation measures, contour furrows at a distance of 8-10 meters across the slope, contour bunds and trenches positively influenced forage yield. An increase of 639% in forage yield was observed over control by adopting moisture conservation technique (Ahuja, 1984).

Grasses and their Varieties

The varieties and strains of grasses e.g. *Cenchrus ciliaris* (CAZRI-76, CAZRI-175 and CAZRI-416), *Cenchrus setigerus (*CAZRI-318, CAZRI-319) and CAZRI-575 of *Lasiurus sindicus* and CAZRI-491 of *Dichanthium annulatum* could be sown for better establishment and high production in the field. These have shown stability for production along with better persistence over years at some of the important locations. Different species are suitable for different zones e.g. *Lasiurus sindicus* in 200 mm rainfall and sandy soils; *Cenchrus* spp. 300 mm rainfall and above in well drained soils and; *Dichanthium annulatum* grows well in 400 mm rainfall and above on heavy soils.

Reseeding in Rangelands

Natural, succession of the high yielding perennial grasses in the arid regions is a time consuming process. Reseeding of suitable perennial grasses adapted to the specific agro-climatic conditions is the best intervention for increasing the forage as well as animal productivity. Based on the suitability of grass species as detailed in preceding paragraph suitable one could be used for re-seeding. Removal of unwanted bushes (*Mimosa hamata*, *Balanitis aegyptica*, *Gymnosporia montana*, *Lycium barbatum*, *Acacia jeueophiloa* and *Sueda fruiticosa* in saline soils) is the initiating for taking up the reseeding program. Complete soil working, involving ploughing and disc harrowing once, is essential for better establishment of perennial grasses (Chakravarty and Verma, 1970). Reseeding may be practiced to increase forage yield in the rangelands. Increase in forage yield was recorded in the range of 30 to 122% in “poor” and 29 to 107% in “fair” class rangelands after 3-5 years of reseeding (CAZRI, 1992). Pre-monsoon sowing of grass seeds gives 36% higher forage yield over monsoon sowing.

Fertilization Application

The nutrient content and production-potential of forage species on the rangelands in western Rajasthan is quite low and therefore for optimum production, it is essential to provide adequate nutrients to the soils as these are often subjected to erosion hazards and are highly depleted. Fertilization may also be considered as a mean to improve rangeland productivity. Application of 22.5 kg N ha^{-1} during normal year resulted in additional increase in forage yield by 20 to 70% (CAZRI, 1983). Studies on response to fertilization @ 40 kg N+20 kg P_2O_5 ha^{-1} in dry land ranges revealed that forage production increased in the semi-arid regions receiving relatively more rainfall, whereas the response to 20 kg N ha^{-1} was evident in arid regions getting less than 300 mm rainfall. It has also been reported that the fertilizer application increased the yield of crude protein in *C. setigerus, L. sindicus, C. ciliaris* and *P. antidotale* by 108, 82, 58 and 26%, respectively.

Silvi-pasture System

Studies conducted on the contribution of the understory in afforested areas with *Prosopis cineraria, Albizzia lebbek, Tecomella undulata* and *Acacia senegal* have revealed that the production of forage under first three species did not differ significantly (15.46, 14.06, 14.78 q ha^{-1}, respectively) but the yield under *Acacia senegal* was significantly lower (6.91 q ha^{-1}) than the other three species (Ahuja *et al*., 1978). Growing trees such as *Prosopis cineraria*, *Acacia nilotica* and *Ziziphus nummularia*, and grasses *Cenchrus ciliaris*, *C. setigerus*, *Dactyloctenium scindicum*, *Panicum antidotale* and *Lasiurus scindicus* together has been a traditional practice in the Thar Desert. It has been revived on a large scale for rangeland development. *L. sindicus* gives high yields (4 Mg ha^{-1}) on sandy soils with annual rainfall of 250 mm and below, while *C. ciliaris* and *C. setigerus* produces good tonnage of 2 to 3 Mg ha^{-1} on light to medium textured soils with annual rainfall of 300 mm and above. Trees provide nutritious top feed in form of leaves and pods (rich in proteins and minerals) to livestock during lean periods of the year and consequently increase the range productivity. The potential of some systems has been tested and relatively better systems which can be adopted in the development of sustainable production system in rangelands have been identified. Various silvi-pastoral systems were found to be very important for increasing fodder production from marginal, sub-marginal and other wastelands (comprises 50% of available area). Production can be increased to 5-7 t ha^{-1} of green fodder against only 2-4 t ha^{-1} without a tree component. The agri-horti-silvicultural system having fruit trees + fodder crops + fast growing nitrogen fixers tree species also provides good fodder for animals. Tree lopping gives fodder (2.5-3.0 t ha^{-1}) and fuel wood (1.8-2.5 t ha^{-1}) in horti-pastoral system could be grown up to an elevation of 2000 metres above sea level e.g. introduction of fescue in apple orchards produced 83.50% higher fodder yield over local grasses in Himachal Pradesh (Malviya, 2015).

Grazing Management

Sustained primary and secondary productivity of the range1ands is only possible when the ranges are to be managed scientifically. Results of studies conducted at CAZRI Jodhpur on different systems of grazing management in the rangelands representing varying agro-climatic conditions of western Rajasthan are briefly summarised below.

Continuous v/s deferred grazing: In arid regions, deferred grazing frequently means keeping the livestock away from the range until major grasses have produced seed. Under different systems of deferment, maximum gain in body weight of adult cows (average body weight 270 kg) was observed in continuous controlled grazing (based on carrying capacity) system on year long basis irrespective of different types of rangelands. However, adult cow exhibited gains in body weight by 25.8, 35.8 and 56.0 kg on an average in 'Poor', 'Fair' and 'Good' condition rangelands, respectively. However, deferment to grazing for 120 days from growing period of vegetation resulted in decrease in body weight by about 30 kg per cow. Similarly, adult sheep exhibited body weight gain of the order 9.2 and 7.1 kg sheep^{-1} in 'Good' and 'Fair' class rangelands, respectively under continuous controlled grazing system. Deferment to grazing on rangelands for 110 days from July gave less body weight gain in sheep.

Continuous v/s rotational grazing: Rotational grazing means grazing of two or more range paddocks in sequence for the purpose of permitting the forage to recover between the use. Growth of yearling heifers under a system of monthly rotational grazing based on carrying capacity on an average gave monthly growth of 7.4 kg heifer^{-1} in *C. setigerus* cover, 6.6 kg heifer^{-1} in *Cenchrus-Sporobolus* cover, 7.9 kg heifer^{-1} in *Cenchrus ciliaris* cover and 4.5 kg heifer^{-1} in *Lasiurus sindicuss* cover. From July to October, growth rate of animals remained highest on the range and it was 11.2 to 13.7 kg heifer^{-1} without detrimental effect on the existing range conditions. Similarly, continuous and rotational grazing at fortnightly intervals with lambs of Marwari breed on *Cenchrus-Eleusine-Aristida* cover exhibited no significant effect on range condition between the two different systems of grazing management. However, a satisfactory gain of 12-16 kg lamb^{-1} year^{-1} was observed irrespective of different systems of grazing treatments.

Continuous v/s deferred rotational grazing: Continuous controlled grazing versus deferred rotational grazing at 2 to 4 months interval revealed that grazing management did not influence growth rate of animals (yearling heifers) on any type of rangelands studied. However, the growth rate varied from year to year. During the year of sub-normal and above normal rainfall, growth rate of yearling heifers on *Lasiurus-Eleusine-Aristida* cover varied from 45.0 to 58.0 kg animal^{-1} year^{-1}, it ranged from 66.2 to 73.3 kg animal^{-1} year^{-1} on *Sporobolus-Desmostachiya-Cyperus* cover and 54.8 to 87.3 kg animal^{-1} year^{-1} on *Dichanthium-Aristida* cover (Verma and Ahuja, 1979). A deferred rotational grazing system increased forage production by 47% over a continuous grazing system (CAZRI, 1992).

Mixed grazing: Studies on mixed grazing with cattle and sheep on *Lasiurus-Cymbopogon-Aristida* rangeland in rainfall zone below 250 mm was conducted wherein heifers and lambs grazed separately and in another area with both the animals together. Results revealed that the growth of animals per unit area was highest when heifers grazed alone followed by mixed grazing with heifer and sheep and the least when sheep grazed alone.

Rangeland Health Improvement and Mitigation of GHG Emissions

Rehabilitation of degraded rangelands improves the health of the rangeland and offers a potential opportunity to sequester carbon. GHG emission (particularly methane) from rangelands can be effectively reduced by wild and domestic ruminant grazers thereby increasing storage of carbon. Modifying land use practices can influence the rate of changes in soil organic matter (SOM) levels which mitigates efflux of CO_2 into the atmosphere. Good soil management practices positively influences the carbon storage, amount and kind of vegetation and thus protects rangeland health. So improving rangeland health, in other words, will reduce methane emission from ruminants through improvement in the quality of diet. Researchers suggested that small reductions in the number of grazing animals (stocking rate) or modifying the timing of grazing could result in large soil sinks for atmospheric CO_2 (Metherell *et al*., 1993) and in methane emission reduction (Howden *et* *al.*, 1996). Involvement of local communities by way of benefit sharing is a viable option to improve rangeland health besides mitigation of GHG emission. These practices will improve the productivity and health of the rangelands and also have positive effects on reducing methane or increasing carbon storage (Sathaye and Meyers, 2013).

Conclusion

Rangelands have been badly degraded and now need immediate attention for their improvement. Utilization of rangelands without any grazing management plan and exploitation of vegetation for fuel wood are the major causes of rangeland degradation. Pitting of flat lands encouraged seed trapping, water and seedling establishment helps in better establishment of grass seedlings under rainfed condition of arid zone. Reseeding, fertilizer applications are the only option available now for regeneration of most of these areas. Research should focus on the breeding, selection and management of drought and salt tolerant pastures, management of drought tolerant livestock, nutritional requirements of livestock, especially during drought and other means of minimizing rangeland degradation. Feed scarcity particularly in winter months is the major constraint of small ruminant production. Provision of water stock particularly in mountain rangelands during summer months may provide additional grazing period. Reseeding either with native or exotic grass species is not feasible, uncertain and very costly intervention. However, management and conservation of rangelands and pasture is a need of the time but is very difficult without the people's participation.

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