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Changes in seasonal vegetation and sustenance of tussocky arid rangelands under different grazing pressures

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Abstract
Perennial vegetation provides ecological and economic stability to livestock based production systems in the arid regions. But, role of herbaceous annual and seasonal vegetation is poorly understood. In order to understand this, grazing experiments [T_1: Control (no grazing); T_2: Optimum carrying capacity with supplemental feed (6 sheep grazing); T_3: Optimum carrying capacity without supplemental feed (6 sheep grazing); T_4: Double the carrying capacity with supplemental feed (12 sheep grazing) and T_5: Double the carrying capacity without supplemental feed (12 sheep grazing)] were conducted for two consecutive years in *Lasiurus sindicus* dominated rangelands at Chandan, Jaisalmer. Study revealed that irrespective of supplemental feed, 70-80% of *L. sindicus* cover declined in paddock with double the carrying capacity (T_4 and T_5). Further, the preferential consumption of seasonal and low perennials such as *Ochthochloa compressa* and annual *Cenchrus biflorus* in monsoon and post-monsoon helped to defray the consumption of perennials and inter-alia prolonged the duration of range-use. It was concluded that spatial heterogeneity imparted by seasonal vegetation in an overall matrix of perennial tall grasses and woody perennials need to be managed optimally by grazing management of both seasonals and perennials.

Keywords: Arid zone, Grassland, Grazing, *Lasiurus sindicus*, Rainfall, Seasonal vegetation

Introduction
The area under permanent pastures (PP) and grazing lands (GL) in India has declined from 120 to 102 lakh ha during 1980-81 to 2007-08. However, livestock population in the country has increased from 4230 to 5297 lakh between years from 1982 to 2007 (Dixit *et al.*, 2015). Farming community in arid zone of Rajasthan earns 28-42% of their agricultural income from livestock rearing (Kar, 2014), the highest being in extreme arid part of Barmer, Jaisalmer, Bikaner, Jodhpur and Churu. Human population density is 67 per km² while livestock density is 24.4 per km². From 1901 to 2010, the region experienced drought in 52% of the years (severe 11%, large 19% and moderate 22%). Though cropping is increasing by 1-6% from 1981-1983 to 2006-2008, yet the twelve extreme arid districts have 67.2% area under cultivable waste which is used as grazing ground. While livestock provides insurance against drought in arid regions, it also provides highest quantum of meat, milk, and wool to the country from an area (36%) which is largely degraded wasteland, since 62% of these areas are very severely degraded,14% are severely degraded and 5-7% are moderately degraded. Encroachment of these grazing lands for both public and private purposes is too well known. Thus grazing area is shrinking and quality of the feed is also declining. How these continually shrinking and degrading grazing lands with less perennial grasses, sustain enhancing livestock pressure has been a paradox. This is specially so when its botanical diversity is known *i.e.*, 682 spp., habitat plant cover relationship is studied, successional trends, economic uses and extent are well documented (Kumar, 1998). Compositionally, climax vegetation in rangelands in arid Rajasthan would have dominance of perennial tussocky grasses like *Lasiurus sindicus* and *Panicum turgidum i.e.*, their dominance or RIV exceeding at least 40 (Kumar, 1992).The remainder of the range community has components like annuals and biennials amongst legumes, sedges, weeds, grasses and others (Kumar, 2005). Researchers, by and large, also argue that maintaining wide variety of such vegetation and diverse habitats in range production systems is essential for sustainable production by way of enriching biological complexity and diversity (Bosch and Kellner, 1991; Whitford, 1996). Though Snyman (1998) discussed in great detail about their dynamics in terms of stability, resilience and equilibrium for sustainable utilization of southern African rangelands, yet the role played by

seasonals is not highlighted. We, therefore, undertook this study and designed grazing experiments to assess the role of annual and seasonal vegetation in sustenance of arid grazing lands.

Materials and Methods

Experimental area: The study was conducted at Experimental Area, Chandan, CAZRI, RRS, Jaisalmer, Rajasthan, India (latitude 26° 59' 31.32 N and longitude 71° 20' 29.59 E) having elevation of 196 meters (640 feet) and is 40 km away from golden city Jaisalmer. The Jaisalmer district is situated in the extreme west of Rajasthan and forms the major part of the Great Indian Desert. It is located between 26° 29' to 28° 02' north latitudes and 69° 29' to 72° 20' east longitudes. The rainfall in the district is scanty, uneven and highly variable. Chandan received 164.5 mm rain during the year 2013 against the average rainfall of 157 mm. The average rainfall of the district was 150 mm but in the year 2013 the total rainfall recorded in the district was 296 mm. The day temperature sometime goes up to 47°C throughout the summer (May-June) with intense heat waves. South-west monsoon in July cools the temperature that starts rising again when monsoon withdraws in the end of September. Temperatures decrease gradually in October onwards. January is the coldest month when the mean daily maximum temperature is 23.6°C and the mean daily minimum 5-6°C, often experiencing frosts and cold waves. The soil of the experimental site was sandy loam and slightly alkaline (pH 7.5) with 0.36% organic carbon, electrical conductivity (-0.16 mmhos cm^{-1}), available nitrogen (285 $kgha^{-1}$), available phosphorus (24 kg ha^{-1}), available potash (356 kg ha^{-1}). *L. sindicus* with sprinkling of *Prosopis cineraria* forms the dominant landscape in this area.

Grazing trials and methods of analysis: A field experiment was conducted from 2012-2013 at Chandan farm which is protected for last 25 years. Five plots of one hectare each were fenced for following five grazing treatments (Table 1). Sheep were allowed to graze from morning to noon (8 AM to 12 Noon) and then from 3 to 6 PM all the year around. They were given water and salt *ad libitum*. Vegetation parameters were recorded on monthly basis. Sequential observations were recorded on cover, density and height of plant following standard ecological methods (Mueller-Dombois and Ellen-berg, 1974) in permanently laid out quadrate (10 m ×10 m, five quadrates per plot) and line transact (10 m long five lines per plot) (Misra, 1968). Herbaceous vegetation was also sampled in 1m × 1m quadrate. Biomass was estimated in 2 m x 2 m quadrates at the end of growing season i.e. October. Data was analyzed for composition and dominance of different species following Ludwig and Reynolds (1988).

Results and Discussion

Changes in vegetation: Indian arid landscape is characterized by a free range grazing with no control over livestock number and frequency of livestock visit for grazing. Consequently 70% of the grazing lands in Indian arid zone are severely degraded, while other 14% are fair, 13% of good and 2-3% excellent class (Shankar *et al.*, 1988).These 70% degraded grazing lands are under continuous grazing. We aimed in this study to document changes in long-time protected paddocks due to optimal and supra-optimal grazing continuously by sheep. Results revealed that decline in *L. sindicus* cover and dominance was much less in paddocks where sheep grazing with supplemental feed (T_2, T_4) than without supplement feed (T_3, T_5) (Fig 1). Irrespective of supplemental feed, 70-80% of *L. sindicus* cover was declined in paddock with double the carrying capacity (T_4, T_5) in two years (Fig 1). Seligman and Perevolotsky (1994) and Kerven *et al.* (2003) also concluded that degradation in North African, Middle East and Central Asian rangelands was due to large amounts of supplementary feed provided to the animals. The variation in rainfall during monsoon period was evident from range of rainfall per day (0 to 88.0 mm) and cumulative rainfall (133.5 mm for 2012; 164.9 mm for 2013) and this caused the changes in *L. sindicus* cover as per time, duration and quantity of rainfall.

Table 1. Grazing treatments with sheep

T_1	Control	No grazing
T_2	Optimum carrying capacity with supplemental feed	6 sheep grazing
T_3	Optimum carrying capacity without supplemental feed	6 sheep grazing
T_4	Double the carrying capacity with supplemental feed	12 sheep grazing
T_5	Double the carrying capacity without supplemental feed	12 sheep grazing

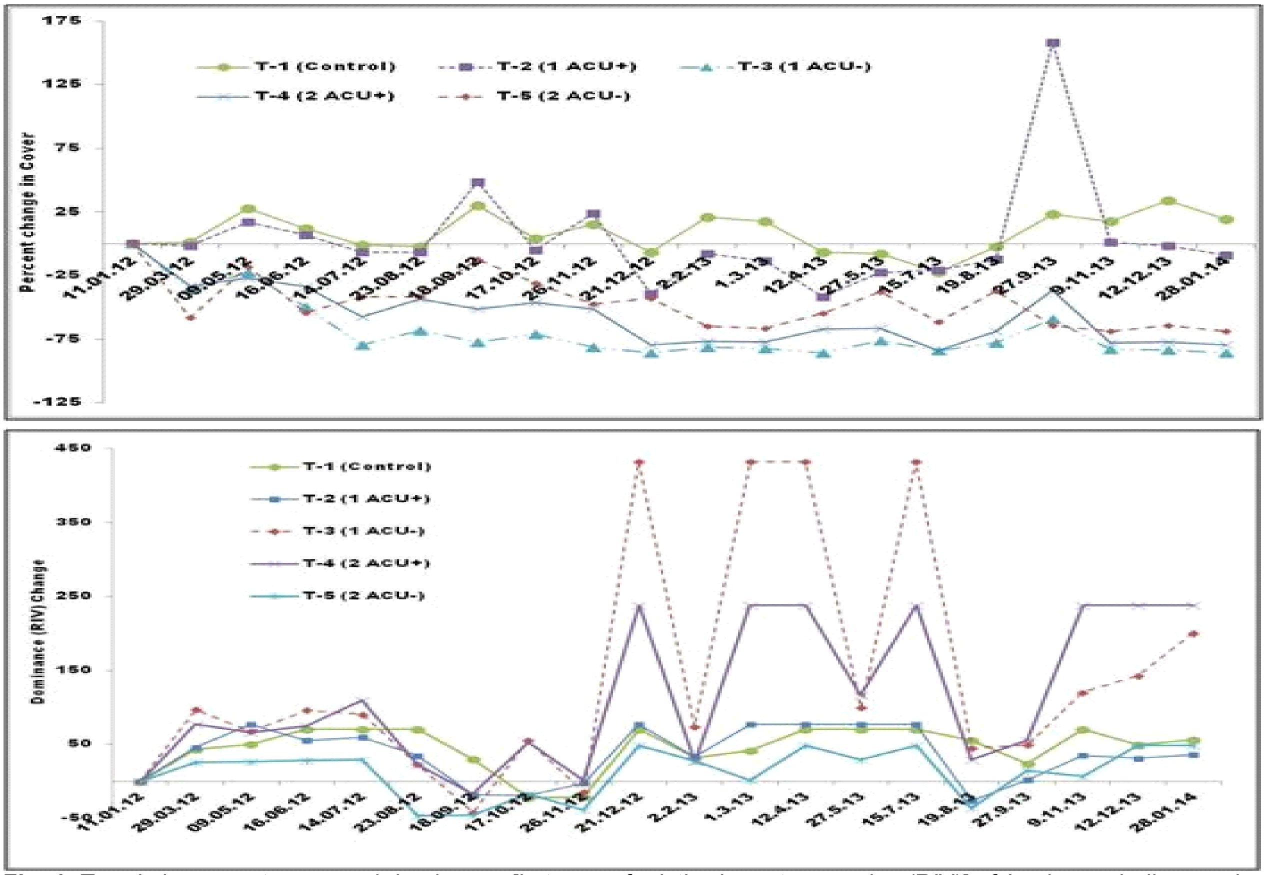

Fig 1. Trends in percent cover and dominance [in terms of relative importance value (RIV)] of *Lasiurus sindicus* under different grazing treatments in line transect (10m) method

The trend of dominance (RIV; Relative Importance Value) of *L. sindicus* indicated the consumption of companion vegetation such as *Ochthochloa compressa, Cenchrus biflorus* more passionately by sheep so much so that this companion vegetation cover /dominance declined by 100% over 2-years period (Figs 1 to 3). In contrast, sheep in optimum carrying capacity and given supplemental feed (T_2) nearly maintained the percent cover of *L. sindicus* though cover decline was 60-70% in T_3 paddock grazed by sheep and not given supplemental feed (Fig 1). This decline however did not aggravate with passage of time due to adequate compensatory regeneration of this grass favoured by adequate rains in 2013. Dominance (Relative Importance Value) of *L. sindicus* in all the four treatments over two years period either maintained (as in T_2) or increased by 50% in T_5, 200% in T_3 and 240% in T_4 (Fig 1). This indicated that companion vegetation was also consumed more preferentially over *L. sindicus* and though overall cover of *L. sindicus* declined, its RIV increased. If rains were less or failed and grazing pressure continues unabated, companion grass, *O. compressa* declined by 100% over two years both in terms of percent cover and dominance, trends in both being rain driven. The annual grass, *C. biflorus* followed similar trend. Severity of changes in *L. sindicus* became visible from number of tussocks per paddock over time in these treatments (Fig 4). Overall decline in number of tussocks was merely 10% in paddocks grazed twice the carrying capacity while it increased by 5-10% in paddocks subjected to optimum carrying capacity grazing. This was also confirmed by trends in dominance (Fig 5). Though, tussocks stood on the ground, but because of overgrazing their regenerated biomass available for grazing declined by over 80% in all the four treatment (Fig 6). Thus increasing stocking rate an important variable in our study, predictably causes a decline in biomass by 80% in two years i.e., from 461.5 (T_2), 306.6 (T_3), 450.5 (T_4) and 341,1 (T_5) kgha^{-1} to 70.3 (T_2), 29.6 (T_3), 28.7 (T_4) and 15.4 (T_5) kgha^{-1}. In an ecologically fragile arid zone, even small variations in environmental variables such as rain have a major effect on vegetation composition (Snyman, 1998) with accompanying high drought risk and resultant sustainable productivity of the rangeland ecosystem (Yunlong and Smit, 1994).

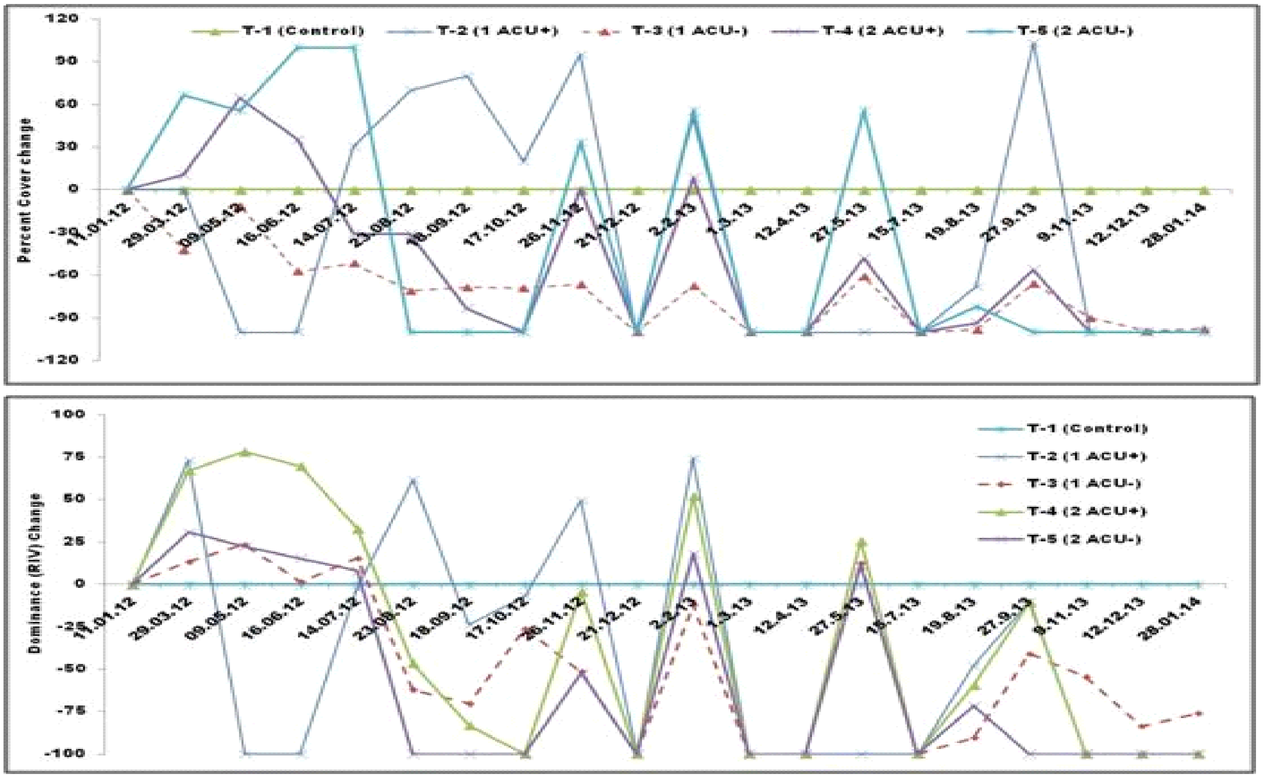

Fig 2. Trends in percent cover and dominance [in terms of relative importance value (RIV)] of *Ochthochloa compressa* under different grazing treatments in line transect (10m) method

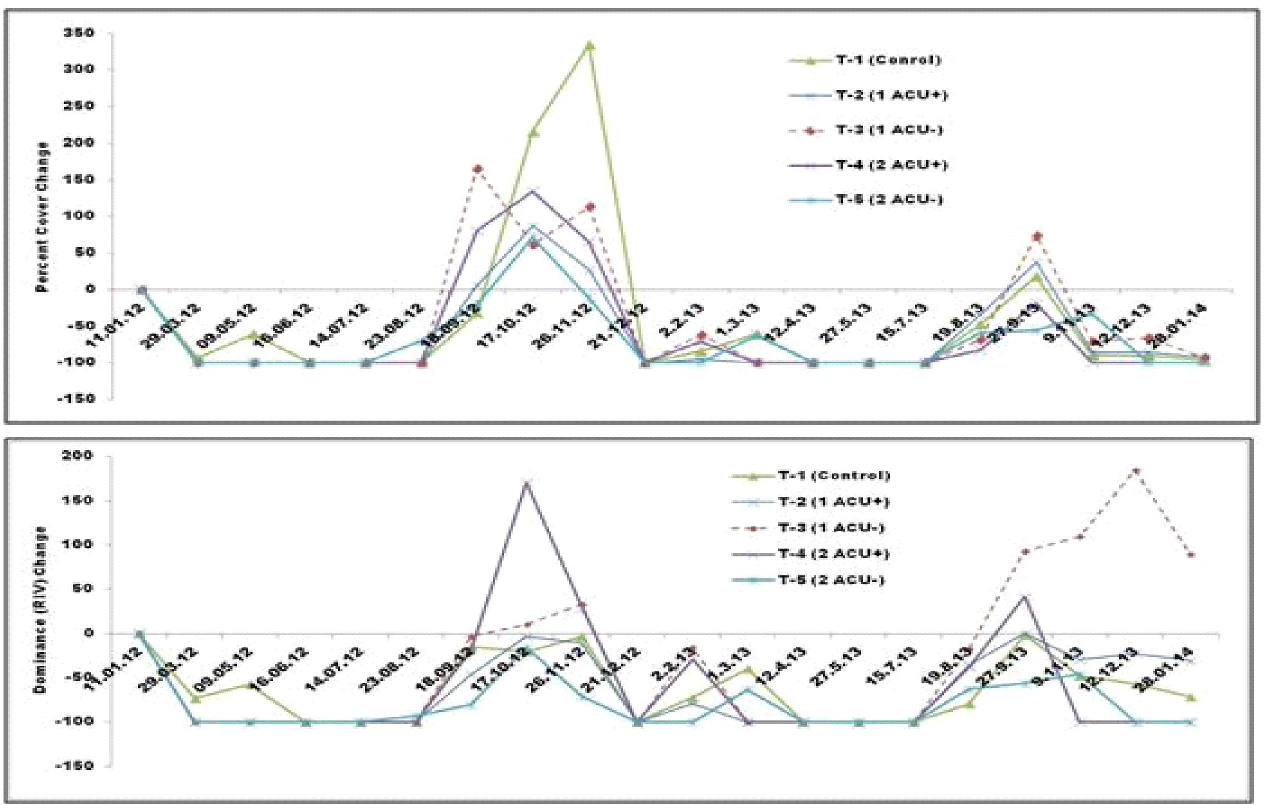

Fig 3. Trends in percent cover and dominance [in terms of relative importance value (RIV)] of *Cenchrus biflorus* under different grazing treatments in line transect (10m) method

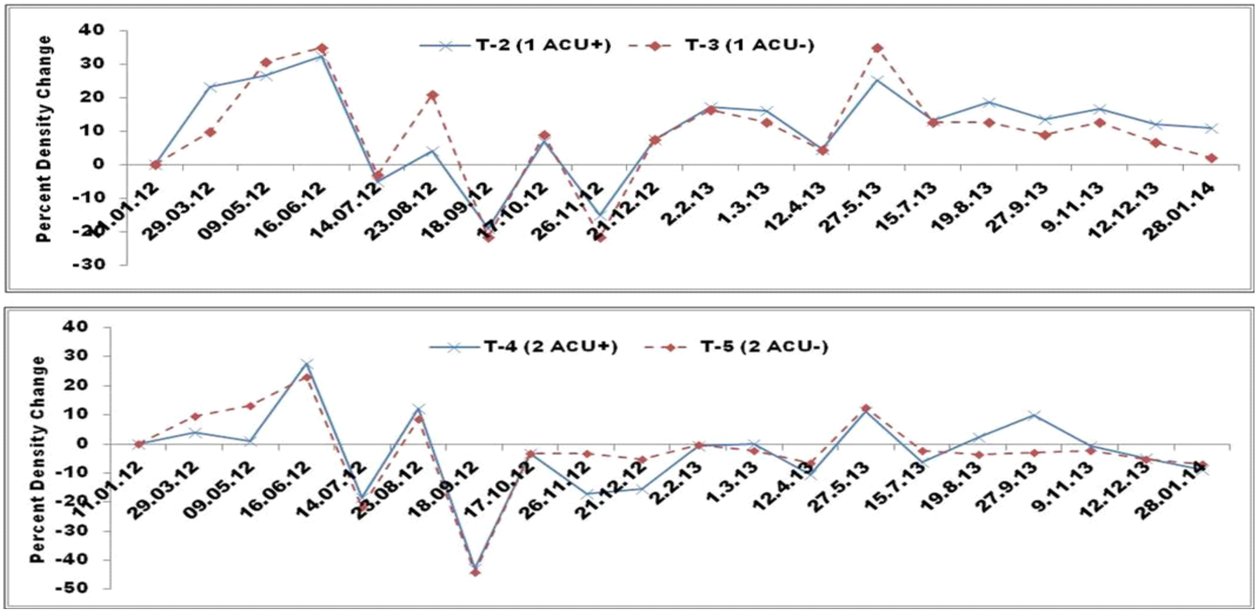

Fig 4. Trends in number of tussocks of *Lasiurus sindicus* per 100 m^2 in different grazing treatments

Sustenance of vegetation: It emerges from foregoing that companion annuals and low spreading, herbaceous perennial grazable species as mediated by rain, give temporary or seasonal rest to *L. sindicus* when it grows and builds up cover and biomass. Such differences in composition, structure, diversity and forage production potential of vegetation under different grazing intensities are widely understood and agreed (Vetter *et al.*, 2006). The reason, behind this is that, these seasonal and herbaceous perennials can draw water from whole soil profile throughout the growing seasons where as climax grasses withdraw water from deeper layers of 2-5 m during droughts (Snyman, 1998). Such a partitioning of resources utilization actually increases the duration of livestock grazing by providing resilience. Fynn (2012) also reported that functional wet seasons habitats dominated by short, nutritious grasses facilitate optimum intake of nutrients and energy for lactating females, for optimal calf growth and building body stores. He further argued that rotational grazing compartments, negating these functional range biomass dynamics, had therefore not out performed the continuous grazing systems. Importance of heterogeneity in vegetation composition was also emphasized for achieving optimum grazing use by McGranahan and Kirkman (2013). There are conflicting views on continuous versus rotational grazing as both seem to affect rangelands equally good or equally bad and a biotic factor considered responsible for this degradation (McGranahan and Kirkman, 2013).This will also take into account the spatial patterns of landscape created by patches of seasonal vegetation and temporal patterns of biomass (= productivity) availability of seasonals in post monsoon and perennials in winter and summer, as evident from present study. Similar conclusions were also arrived at in decade-long detailed grazing experiments conducted earlier in rangelands in Jaisalmer in Indian Thar desert by Mertia (1984). It also emerged from an excellent review of grazing studies by Fynn (2012) that neither rotational nor continuous grazing is ecologically sound and economically viable; rather grazing based on spatial and temporal variability in forage quality and quantity would be the best option. This would allow seasonal grazing and seasonal rests for more effective recovery periods, a conclusion also reached by Mertia (1984). Singh *et al.* (2006) also proved that seasonal vegetation had higher crude protein than perennial grasses and therefore meets the nutritional needs of the livestock. It is therefore, important to realize that seasonal vegetation that provides heterogeneity and complexity prolonged the period of range use and delayed the onset of degradation. Managing this heterogeneity and complexity in order to enhance resilience thus becomes an important management priority for arid rangeland (Vetter, 2009).

Fynn (2012) recommends grazing distribution in such a way so as to utilize above mentioned spatial and temporal patterns. Our observation in the present study is that free range animals in monsoonal rangelands themselves do selective grazing based on seasonal availability of biomass i.e., they graze annuals first (August to November) and then perennials (December to April) and

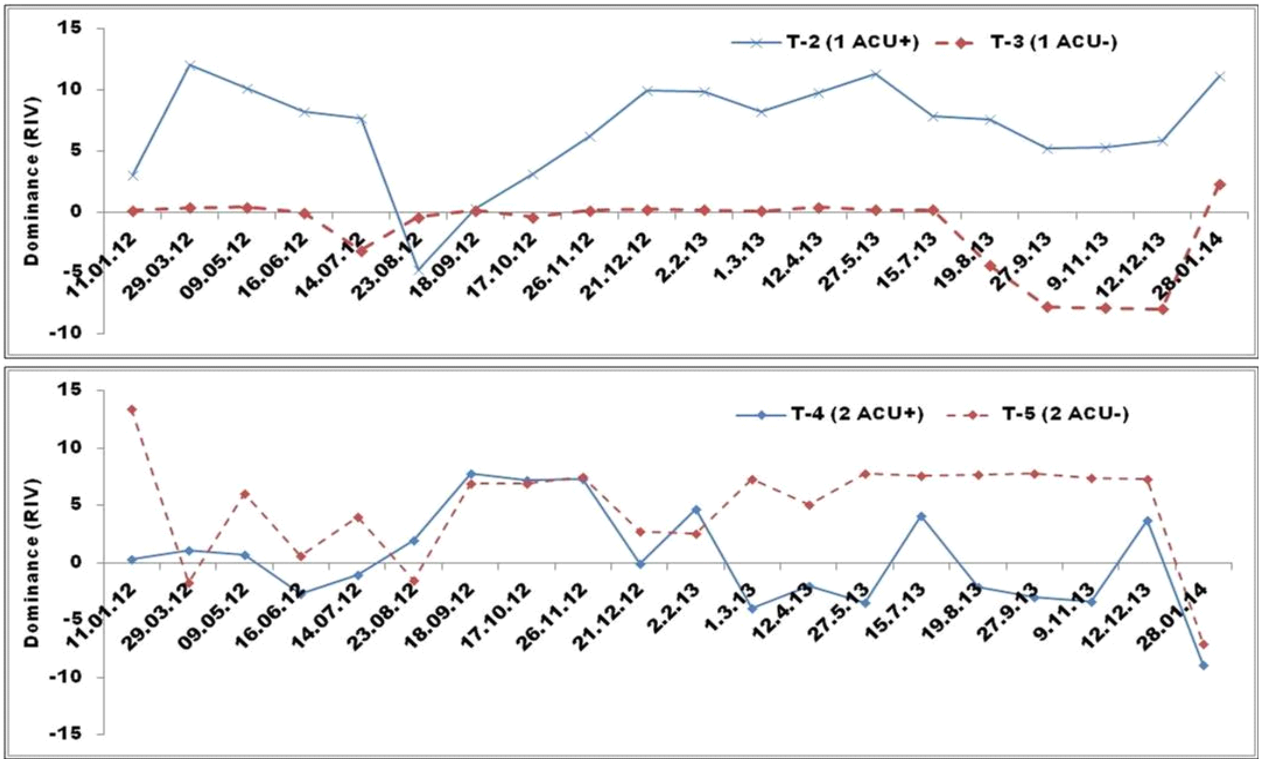

Fig 5. Trends in dominance of *Lasiurus sindicus* per 100 m^2 in different grazing treatments

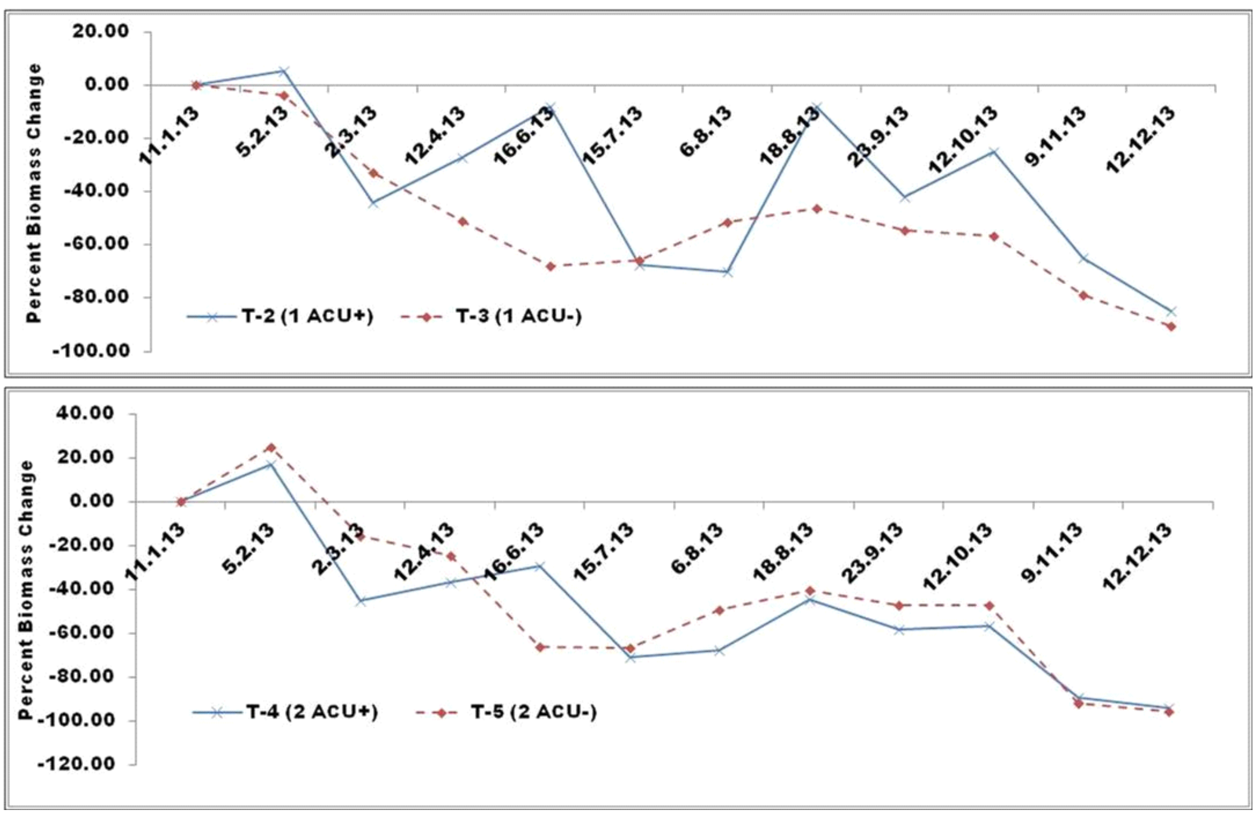

Fig 6. Trends in total dry biomass of *Lasiurus sindicus* per 100 m^2 in different grazing treatments

both litter and perennials in summer. A mix of cattle, goat and sheep would further optimize to increase range utilization. Similar results were also reported by Weber and Horst (2011), while examining the roles of sedentarization, mobility and rest of livestock in desertification caused by grazing. Further, a study by Tasadoq *et al.* (2015) revealed degradation of soils of the grazing lands under uneven grazing intensity (an inherent feature of a transhumant grazing system in Kashmir) by means of decrease in soil organic carbon, calcium and magnesium content.

Conclusion

It was concluded that a) arid rangelands have intrinsic heterogeneity in species composition, b) this mix of seasonal and perennials (= heterogeneity) is ably supported by the landscape by way of partitioning of resources, c) lifecycle pattern of seasonal fits well to meet the nutritional needs of livestock and d) grazing of such seasonal vegetation thus helps sustain perennial tussocky rangelands for longer range-use.

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