LONG TERM IMPACTS OF DIFFERENT LAND USES ON FORAGE GRASSES UNDER DEGRADED LAND OF NORTH-WEST HIMALAYA, INDIA

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SUMMARY

A long term field experiment was conducted to investigate the performance of different grasses under different land types in rainfed conditions under the NWH at experimental farm of ICAR – Vivekanada Parvatiya Krshi Anusandhan Sansthan, Almora. Significantly higher fresh and dry biomass was recorded with hybrid napier under all land conditions. However, in case of trees significantly higher biomass was recorded with deodar (*Cedrus deodara Roxb.G.don*) tree. Meanwhile, aus (*Thysanolaena maxima*) and local grass yielded significantly lower with all land uses, except under deodar tree, but its showed significantly lower production potential as compared to hybrid napier. In case of nutrient uptake (NPK) and concentration in forage were significantly higher with hybrid Napier as compared to rest of the grasses with different land uses. Results showed that the total forage (of all three grasses), were significantly reduced the nutrient uptake and concentration in forage grasses in consequently years; it may be due to the no application of the BMPs (best management practices). The forage yields of all the grasses were significantly higher in the area of deodar tree as compared to other land use situations due to favourable micro climatic conditions. The significantly increase in fodder production under deodar tree has been recorded to a combination of factors including IMPs (improved management practices) by shaded grass and its enhanced nutrient and water availability. From the six years study results showed that the hybrid napier grass under the deodar tree was the best management practices (BMPs).

Key Words : Land uses, Best management practices, land degradation

The agriculture and animal husbandry in India are interwoven with the intricate fabric of the society in cultural, religious and economical ways as mixed farming and livestock rearing forms an integral part of rural living (Prasad and Bisht, 2014; Yadav *et al*., 2018a). Although the contribution of agricultural sector in the Indian economy is steadily declining (from 36.4% in 1982-83 to 18.5% in 2006-07), the agriculture and livestock sector still provides employment to 52% of the work force. Livestock provides draught power, rural transport, manure, fuel, milk and meat (Yadav *et al*., 2018b). Most often, livestock is the only source of cash income for subsistence farms and also serves as insurance in the event of crop failure. Further, global energy crisis will lead to utilization of livestock-based bioenergy as well as waste recycling for organic manure and organic forage production for quality animal products (Kell, 2011).

India supports nearly 20% of the world livestock and 16.8% human population on a land area of only 2.3%. It is leader in cattle (16%) and buffalo (55%) population and has world's second largest goat (20%) and fourth largest sheep (5%) population (GOI, 2015). Thus, the region faces an acute shortage of fodder year-round, particularly during the winter season. In India ~ 175 Mha of geographical area is sub-jected to various processes of land degrada-tion leading to creation of wastelands (Bhattacharyya *et al*., 2015). The worldwide, a total of 680 Mha has been estimated as degraded wasteland. It is broadly classified as too dry or too sloping, to support crop production (Malik *et al*., 2015). Fod-der needs of livestock in nearly all developing countries now exceed the sustainable yield of rangelands and other forage resources. Ever-increasing human populations are likely to ag-gravate the situation further, as more livestock will be required to cater for their needs (Glover *et al*., 2010).

The Himalayan region of India covers about 16.4% of the geographical area and about 4% of the population of the country. It is currently under heavy stress on account of large-scale exploitation for fuel wood, timber, and fodder mismanagement of forest resources, and frequent fires (Yadav and Bisht, 2013, 2015). There is an acute shortage of fodder espe-cially green nutritious fodder, which is the major cause of low productivity of livestock especially in hilly and desert areas (Yadav et al., 2016). A prominent character of small holdings is the mixed farming patterns of crop cultivated. Invariably, some forms of livestock are kept for home consumption and the surplus provides supplementary income to that of main crops. Such being the situation, many of the integrated crop/ livestock farming systems existing in the Himalayan smallholdings are not as economically and agronomically efficient in terms of optimal use of the resources and income generated to farmers. Nonetheless, the wide diversity of farming systems existing in Himalayan region offers various potential ecological niches for the forage production.

Agriculture along with Animal husbandry is still the principal occupation and source of livelihood for over 70% of its population. On the basis of the livestock census of 2003, the requirement of fodder for about 48.878 lakh animal populations ~ 251.71 lakh MT of fodder (Roughage) is required per annum for the entire state. The state is in deficit ~ 108.57 lakh MT (43.13%) of fodder (roughage) per annum. The production and availability of fodder is not uniform throughout the year due to shortage of irrigation facilities in hilly areas. The natural grasses are the potential source of green and dry fodder supplies in the hilly areas of NWH region (Yadav et al. 2016). The production source of grasses in Uttarakhand are the 75% of geographical area under various forests, natural grazing lands, alpine grasslands, pastures, orchards, bunds and rizers of agricultural fields, leftover and abandoned agricultural fields, barren and fallow lands, a total production of green biomass from the grasses ~ 54 lakh MT. The green and dry grasses contribute ~ 30.63 and 12.52%, respectively of the total supply of fodder of Uttarakhand. The hybrid napier and other grasses are successfully cultivated under pine forest, bunds and risers of agricultural land.

Environments that differ in soil fertility, water holding capacity and exposure to wind and sun light are likely to influence not only plant performance but also outcome of plant species interactions (Tilman, 2006). Similarly, physiological differences between species may also affect the outcome of interactions in various environments. Because of possible differences between environments in the outcome of the interactions, then, it is crucial to study species interactions on soils of widely different fertility (Lambers et al., 2008) and different climatic conditions. Since, it is well known that soil type affects the relative performance of species (Trevisan et al., 2010). Hence, the objectives of this study were:

(i)   Identification of suitable grasses and its productivity under different land use system of North West Himalayans (NWH) region.

(ii)   To determine the effects of long-term land management, grass species and slope on nutrient availability under degraded land after six years land uses

(iii)   To assess the best management practice (BMPs) that mitigates soil degradation

MATERIALS AND METHODS

Sites and experimental design

The study took place within experimental plots established at the experimental farm of ICAR – VPKAS. The experimental sites/ conditions were sloping land (~ 4%), under deodar tree and marshy land. This study was started in 2000 and continued for six years till 2005. The site is located at 29?36´ N longi-tude and 79?40´ E latitude at an elevation of 1250 m above mean sea level. The climate of this region is sub-temperate. The maximum temperature ranges from 17.3?C during Janu-ary to 32.0?C during May and the minimum from 0.3?C during December to 21.9?C dur-ing July. The average rainfall per year over a period of six years was 1049.77 mm with 96 rainy days (Fig. 1). This was ~ 70% of rainfall per year was received from June to September. The experiment was conducted using a split-plot design (SPD) with three replications, with land types in the main plots and grasses species in the sub-plots. Three strains of forage grasses were selected for the study. Row to row distance was 50 cm and plot size was 3 × 4 m². Grasses were maintained without irrigation and fertilizer application. Weeding and hoeing was done manually whenever needed.

Soil sampling and processing

The field-wise soil samples were collected from surface (0–15 cm) soil in rainy season by using
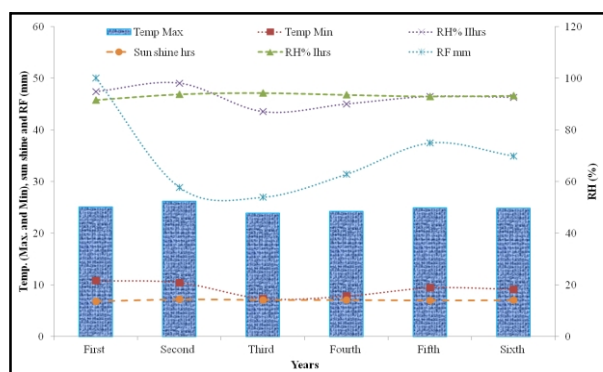
Fig. 1. A long term meteorological data (monthly average) during study period of six years.

a core sampler (7.5 cm diameter). Random soil sampling was preferred due to very small size of plots present in this region. Ten sampling points were selected at each sampling site, thereafter samples were collected from up to 15 cm soil depth (plough layer) and the required amount (~ 250 g) of soil sample was taken by quartering method. Root part and other plant residues were removed from the soil and then these soil samples were thoroughly mixed, air-dried, and passed through a 2.0 mm sieve. Air-dried soil samples were placed in plastic bag and stored at ambient laboratory temperature.

Plant sampling and processing

For each treatment, the entire plot was cut to ~ 5 cm above the soil surface using a sharp knife and fresh weight was recorded. Five samples of the fresh material (500 g each) from each plot were placed in perforated paper bags, brought to the laboratory, oven-dried at 60?C to a constant weight and weighed. The fresh weight of the grasses was converted into oven-dry biomass. Data on fresh and dry matter yield were collected from the same plots in growing season of
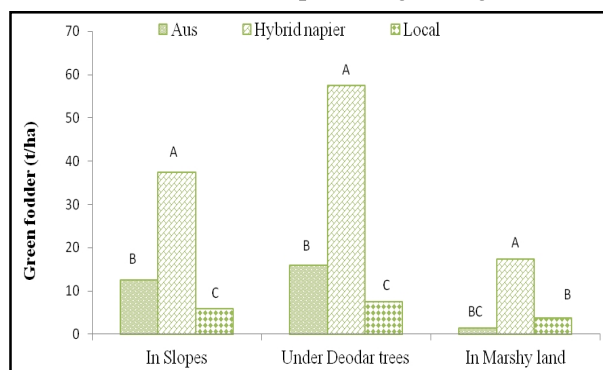

Fig. 2a. Long term interaction effects of different land use and degraded soil on green fodder yield under North-West Himalayan conditions.
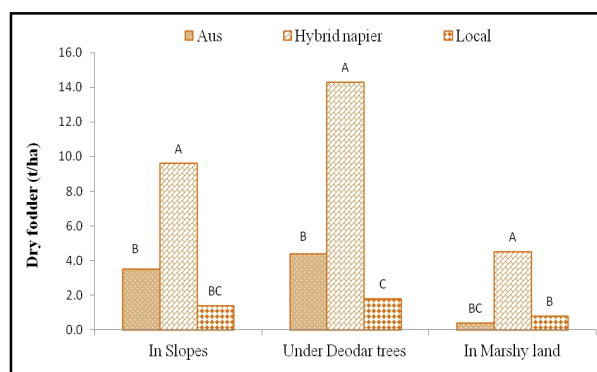

Fig. 2b. Long term interaction effects of different land use and degraded soil on dry fodder yield under North-West Himalayan conditions.
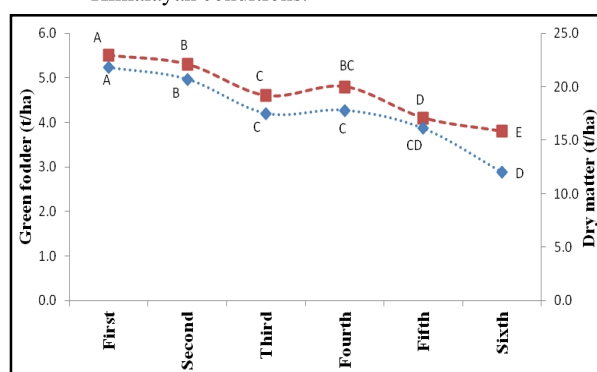

Fig. 3. Long term effects of different land use and degraded soil on fodder productivity of three grasses (mean of six year) under North-West Himalayan condition.

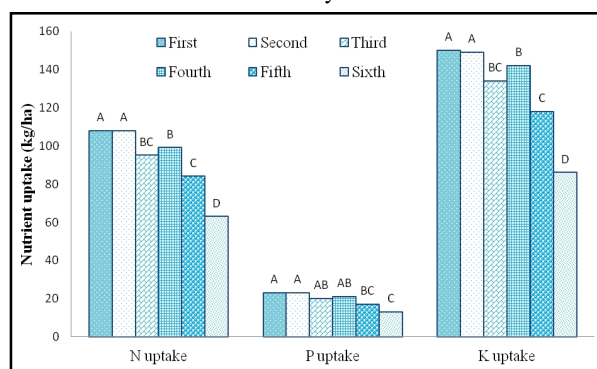Fig. 4. Long term effects of different land use and degraded soil on nutrients (NPK) uptake (mean of six year) under North-West Himalayan condition.

2000 to 2005. The fresh biomass was measured by using the formula as under:

$$\text{Fresh biomass (t/ha)} = \frac{\text{Fresh biomass weight} \times 10000}{\text{Area in m}^2 \times 1000}$$

Plant and soil analysis

Harvested plant samples were washed in

detergent solution (0.2% liquid), 0.1 N HCl solution and deionised water in sequence and dried at 70?C till the constant weight. Plant samples were digested in a di-acid mixture ($HNO_3:HClO_4$:: 3:1 v/v), and analyzed for P and K, however, N was determined in samples digested in H_2SO_4.

The processed soil samples were used to different soil parameters such as the soil pH was determined in 1: 2.5 soil : water ratio using the pH meter with glass electrodes (Jackson, 1973); electrical conductivity (dSm^{-1}) was determined by the method of Jackson (1973). The organic carbon in the soil was estimated by methods suggested by Walkley and Black (1934); available N by alkaline potassium permanganate (Subbiah and Asija, 1956); $NaHCO_3$ extractable P (Olsen *et al.*, 1954) by spectrophotometer, ammonium acetate extractable K (Hanway and Heidel, 1952) by flame photometer.

Statistical analysis

Statistical analysis of the data was done by using analysis of variance (ANOVA), assessed by Duncan's multiple range tests (Duncan, 1955) with a probability, the treatment mean was compared at P < 0.05 by using SPSS 10.0 and SAS 9.3 software.

RESULTS AND DISCUSSION

Impact of different land use and degraded land on biomass yield production

Results showed that the effect of land types significantly influenced with green and dry fodder production. Significantly higher fodder yield (green and dry) was recorded with deodar trees, which were similar to in the slopes. However, it was significantly higher as compared to marshy land. However, pooled analysis of green and dry fodder yield over the years (2000-05) results showed that the green and dry fodder sig-nificantly higher was recorded with deodar trees as compared to marshy land (Table 1). Among species hybrid Napier produced highest green and dry fodder, which is significantly higher than both aus (*Thysanoleana maxima*) and local throughout the study and in pooled analysis. Interaction effects of land types and grasses were significant (Fig. 2a). Land types showed differential responses to differ-ent grasses in combined analysis. Hybrid Napier had the highest green and dry fodder under deodar trees (57.4 & 14.3 t/ha), Aus and local followed the trend of hybrid Napier but too much differed quantitatively. Evidence of improved forage production under tree canopies has been observed in many experiments. Jose *et al.* (2004) reported that many crop species tend to have reduced yield when shaded, but yields of pasture species tend not to change or may even increase under moderate shading (Fig. 2b). As a result, silvopastures can be economically beneficial. Garrett *et al.* (2004) reported that financial analyses of silvopasture systems in the southern U. S. show consistently improved profitability compared to traditional tree plantations or pasture systems. For example, Clason (1999) found that two of three forage types tested in combination with trees provided greater future net values than the pine plantation alone. In field experiments in Virginia

TABLE 1
Nutrient status of all three experimental sites

Treatments	pH	EC (dS/m)	OC g/kg	N (%)	P	K	Zinc	Copper	Iron	Manganese
					---------kg/ha---------			---------mg/g---------		
Slopy lands										
Aus	6.3	0.034	6.84	0.4275	29.8	280.6	1.22	1.40	47.3	68.1
Hybrid napier	6.2	0.026	6.93	0.4874	21.7	291.3	1.21	1.41	50.2	66.5
Local	6.1	0.025	6.54	0.4403	27.6	284.9	1.09	1.32	49.8	67.2
Initial	5.9	0.025	7.09	0.4513	25.9	276.5	1.15	1.51	50.4	66.8
Deodar tree area										
Aus	6.5	0.085	7.15	0.4124	20.8	298.8	1.04	1.41	53.4	60.5
Hybrid napier	6.6	0.079	6.44	0.4091	22.5	278.2	0.97	1.39	49.9	53.4
Local	6.7	0.065	6.83	0.4274	21.7	265.3	1.15	1.50	51.1	63.9
Initial	6.0	0.065	6.49	0.4098	22.2	275.4	1.10	1.50	48.7	64.1
Marshy land										
Aus	6.6	0.131	7.11	0.5014	23.9	281.7	1.19	1.50	51.1	57.3
Hybrid napier	6.3	0.066	7.04	0.4474	24.6	286.9	1.28	1.39	50.9	58.9
Local	6.7	0.026	6.86	0.4654	28.7	275.9	1.21	1.47	49.3	60.6
Initial	6.5	0.064	7.03	0.4963	26.5	268.8	1.19	1.39	46.1	61.2

(Buergler *et al*. 2005) and West Virginia (Belesky, 2005), greater forage production was observed at sites under moderate tree cover than in the open. The shading effects of trees vary depending on species characteristics and relative position of the trees to the forage or other crop (Kohli and Saini, 2003). Interactions between trees and forages can lead to improved resource use. Using stable isotopes in a study in a savanna in Arizona, Weltzin and McPherson (1997) found that most of the water uptake by Emory oaks (*Quercus emoryi*) more than 2 years old was from deeper soil horizons not accessed by associated bunchgrass (*Poaceae* spp.). In Argentina, Fernandez *et al*. (2008) observed partitioning of soil water usage between ponderosa pine (*Pinus ponderosa*) and mixed grasses where 75–90% of the water used by grasses came from the upper 20 cm and less than 20% of the pine's water came from the same layer (Figs 2a and 2b).

This study has shown the importance of soil type and climate in determining plant adaptation. The different grasses were selected on different soil types. In erosion prone areas persistent plants that provide ground cover may be more important than high yielding species. The different (lower forage production) performance of the grasses on the Marshy land compared with the other land types reflects the generally unfavourable nature of the marshy land type. These soils are unfavourable for plant growth due to a combination of low fertility, water logging. In contrast under the deodar tree are more favourable environments with higher level of fertility/soil properties, reasonable water entry and storage characteristics. The slopy lands are much less fertile

than the under the deodar trees. The poor performance of all the three grasses on marshy land and slopes highlights the need for suitable grasses for these land types. The hybrid Napier was the most suitable available species but none could be considered satisfactory for these two land types. The high survival rates/performance of hybrid Napier during these years together with their tolerance of dry seasons and its subsequent good performance suggest that it will be able to produce persistent stands under even more extreme seasonal conditions. The experiment has achieved the aims stated in the introduction – to identify suitable grasses for different land types. The hybrid Napier is the superior than aus and local grasses for all the land types and best for under the deodar trees. To determine their full potential these grasses need to be grown under a range of cultural and management conditions and many more measurements made (e.g. establishment ability, nutritive value, etc.).

Although over all forage yield was higher under the deodar trees, individual species responded to different environments in different ways. Of three species, hybrid Napier performed better in all land types in comparison to other two (Figs. 2a, 2b and 3). In the small holdings, the mean forage productivity of promising grasses was 15-19 tons/ha/year (Izham and Hassan, 1983). In a commercial farm, forage productivity of 14-29 tons /ha/year (Duabif, 1982) and 11 tons/ha/year in plantation holdings (Tan *et al*. 1973). Odedire and Babayemi (2008) study indicated that *Tephrosia candida* and *Leucaena leucocephala* improved the yield of *Panicum maxicum* and *Andropogon gayanus* when compared to the grasses without tree inter-planting. Inter-planting *Hymenachne*

TABLE 2

Impacts of land use on green, dry fodder yield (mean of six years) and nutrient (NPK) uptake by various grasses under rainfed condition of NW Himalaya

Treatments	Green fodder yield	Dry fodder yield	N uptake	P uptake	K uptake
	------------------------t/ha-------------------------		------------------------------kg/ha------------------------------		
Land types (L)					
Slopy	18.6	4.9	95.9 (17.4)	22.1 (3.99)	134.4 (22.5)
Deodar trees area	26.9	6.9	143.5 (18.0)	28.8 (3.69)	198.9 (23.3)
Marshy land	7.5	1.96	39.9 (17.6)	8.5 (3.85)	57.5 (23.2)
LSD (p = 0.05)	2.4	0.46	9.32 (0.26)	2.17 (0.12)	14.2 (0.16)
Grass type (G)					
Aus	10.0	2.8	50.5 (17.9)	10.7 (3.82)	59.7 (21.3)
Hybrid napier	37.4	9.5	209.8 (21.8)	44.5 (4.68)	309.4 (32.4)
Local	5.6	1.4	19.0 (13.4)	4.3 (3.04)	21.7 (15.2)
LSD (P=0.05)	2.17	0.4	8.64 (0.33)	2.13 (0.13)	12.63 (0.17)

LSD-Least Significant Difference, Data in parentheses indicate mean nutrient concentration (g/kg).

acutigluna or *Paspalum astratum* with S*esbania sesban* resulted in increased yield of DM of 11% of the associated grass (Nhan *et al.* 2009). Semple *et al.* (2003) found that some warm season species viz. *Panicum coloratum*, *Chloris gayana* and *Cynodon dactylon* approached their growth potential at some severely scalded sites but over all rates of establishment were very low. Some author have observed that in many situations the dry matter yield of forage species was higher in the shade than in the full sunlight and presented higher nitrogen concentration (Wilson, 1996). (Seresinhe and Pathirana 2000) observed that growing *Panicum Maxicum* grass under leguminous trees significantly increased grass dry matter yield.

Impact of different land use and degraded land on nutrients (NPK) uptake and concentrations

Data showed that the three grasses significantly increased its NPK concentrations and uptakes under deodar trees followed by slopy and marshy land, however NPK concentration in hybrid napier was higher than in aus and local grasses in all land types (Table 2 and Fig. 4). During dry seasons when soil water limits plant growth in the slopy land, tree shade reduces evaporative demand, thus increasing grass growth. The productivity of all grasses under slopy land would decline when soil moisture and fertility was growth-limiting factor. We anticipated that Fodder Production would increase under shade, but that the increase would depend on grass species, shade intensity, and fertility of land. Although fodder production of all grasses increased under deodar, yields did not increase to the levels either equal or above those found of hybrid napier. The significantly higher forage NPK concentrations in grasses under deodar than in slopy and Marshy land may be attributed to these grasses' greater growth and NPK uptake under shade. The production varies by species and is moderated by available light are of the view that species which can better exploit growth-limiting resources are superior and plant species are known to modify their morphology to utilize nutrients and light under resource-limited conditions (Tilman, 2006). Greater fodder production observed for grasses under shade suggest these species are superior under shaded conditions. Decline in fodder production in all grasses in slopy and Marshy land was due to inverse relationships with fertility and moisture content. But greater fodder production by hybrid napier under deodar tree suggests this species is more tolerant to

shade and better suited for exploiting in silvi-pastoral systems (Fig. 4).

Trees in the systems create a horizontal structure above grasses and modify availability of the growth resources (light intensity, soil moisture and nutrients) and thereby influence growths and yields of the grasses by facilitative or competitive mechanisms. Facilitative effects of trees on grass growth and yield occur when soil moisture and nutrients are growth-limiting in open pastures, particularly when soil moisture is a primary limiting factor. Under such conditions, trees reduce evaporative losses by moderating temperature (both soil and air) (Pandey *et al.*, 2010), and make soil moisture relatively greater (Belsky, 1994). Greater soil moisture in turn stimulates net soil N mineralization rates and increases N availability (Pandey *et al.*, 2007). These facilitative effects greater soil moisture and N availability increase grass growth under trees (Gea- Izquierdo *et al.*, 2009). Competitive effects of trees on grass growth and yield are common under irrigated conditions.

Impact of different land use and degraded land on forage production and uptake over successive years

The annual differences in precipitation, soil fertile status and environment of different land types as well as year-by-site interaction led to reduction in forage production and uptake over the years (Fig. 4). Grasses that are to produce well for several growing seasons will need to accommodate changes in soil nutrient status with time. Where species differ in their environment, the uneven availability of resources to become accentuated with time and can lead to the reduction of forage of the less vigorous grass species. Grass species adapted to soils of different nutrient status can even display reversal of performance over the time. Grasses effect on soil may lead to nutrient supply rate for which it is not a good competitor. For example, N-fixing plants are typical of low fertile soil during early succession in many natural ecosystems. These plants are good competitor under low fertility, but are usually displaced under more productive conditions. This led to a prediction that, because of differences in nutrient use efficiency (NUE), a decline in soil fertility with time should eventually favour the C_4 grass and the legume but not the C_3 grass. The grass species which are dependent on high soil fertility declined with time and forage yield reduced over successive year. Additional studies with this, or an analogous species, will need to account for changes in soil nutrient status with time.

CONCLUSIONS

The hybrid napier was clearly most vigorous/best performed of the three grass species in all land types followed by Aus and local. All three grass type best performed under deodar trees followed by in slopes and least in marshy land. When soil moisture is limiting, shade from deodar trees increases fodder production of hybrid napier, Aus and local grasses in comparison to slopy land. However, the increase in fodder production is greater for hybrid-napier than for Aus and local grasses. Under deodar tree, the grasses respond to increasing moisture content and low temperature condition. The higher N, P, K uptake and concentrations in the forage result in greater fodder production by hybrid napier under deodar tree, slopy and marshyland. Hybried napier grass is superior in all three land types but best under deodar tree. Although fodder production of Aus and local grasses increased under deodar tree, the increase was neither at par nor greater than fodder production by hybrid napier. These observations suggest that hybrid napier grass can be exploited under all three land types and high fodder production can be managed with this grasses in the silvopastoral system.

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