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Estimation of Carrying Capacity and Effect of Different Management Tools on Rangeland at Highland of Rasuwa District, Nepal

Birendra Khanal[1*]; Bodh Raj Baral[2]

Scientist, Nepal Agricultural Research Council, Pasture and Fodder Research Station, Dhunche, Rasuwa, Nepal
*Corresponding Author

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Abstract— *Rangeland in the highlands of Nepal plays a significant role in providing low-cost feed to grazing animals. The rangelands are facing threats from overgrazing, invasion of unwanted species, and poor soil conditions, which reduce sustainability and productivity. The study was conducted over two years, 2024 and 2025, to evaluate the carrying capacity and the effects of fertilizer, as well as the effect of fencing on rangeland located at 2700 masl in Gatlang, Aamachhodingmo Rural Municipality, Rasuwa District, Nepal. The results revealed that the rangeland could support 3.5 livestock units per hectare for a 60-day period in the first year and 3.3 livestock units per hectare for a 90-day period in the second year. A fertilizer trial tested varying levels of nitrogen (0, 50, 100, and 150 kg/ha) and phosphorus (0, 30, and 50 kg/ha). It was found that the highest herbage production was achieved when nitrogen was applied at 150 kg/ha and phosphorus at 30 to 50 kg/ha. The effect of fencing versus non-fencing on herbage production was also tested. It was found that the highest herbage yield and crude protein content were obtained from the fenced area compared to the open area. The findings highlight that nutrient management, controlled grazing, and fencing enhance the productivity of rangeland. These practices can help sustain livestock feeding systems and reduce pressure on rangelands. This research is particularly suitable for highland communities where rangeland degradation is a major threat to livestock production.*

Keywords— Carrying capacity, fence, fertilizer, highland, rangeland.

I. INTRODUCTION

Rangelands are the main ecosystem that supports an inexpensive source of feed for livestock (Barsila, 2008). However, these ecosystems are facing increasing pressure from overgrazing, invasive species, and climate change effects. These pressures have caused forage availability to decrease and the resilience of the ecosystem to decline. The productivity of rangeland has declined due to overstocking, inadequate nutrient levels, and insufficient protection. Fertilizer application is one option proposed to address these issues and has been proven to improve herbage production and promote more sustainable rangeland use. Nitrogen (N) and phosphorus (P) are important for the enhancement of forage growth, and their combined application increases green and dry matter yields. Nevertheless, the precise nutrient requirements for maintaining productivity of high-altitude rangelands in Nepal have yet to be fully explored (Devkota and Kolachhapati, 2010; Barsila, 2008).

Carrying capacity is an essential component of rangeland management. The maximum number of livestock units (LU) that can be supported on a given rangeland is the estimation of carrying capacity. When rangeland is overstocked beyond its carrying capacity, productivity declines and the rangeland deteriorates (Pande, 2010). In addition, harmful and toxic plants decrease the productivity of rangeland. Management tools such as appropriate stocking density based on carrying capacity, rotational grazing, fencing, and fertilizer management can enhance productivity (Fenetahun, 2018; Bengtsson et al., 2019). Crude protein content also differs between fenced and non-fenced areas. These situations highlight the urgent need for

research to estimate carrying capacity and evaluate the effects of different management tools on rangeland production. Such tools are important for developing rangeland management strategies that provide balanced feed for grazing animals in a sustainable way.

II. MATERIALS AND METHODS

2.1 Study Site

The experiments were conducted at Gombole Rangeland (2700 masl), Gatlang, Aamachhodingmo Rural Municipality, in the highland of Rasuwa District, Nepal, focusing on estimation of carrying capacity and the effects of fertilizer and fencing on rangeland.

2.2 Estimation of Carrying Capacity

The study was conducted in both years, 2024 and 2025. Five quadrats, each measuring 1 × 1 m, were used for this purpose. Dry matter was determined by oven-drying samples. Two harvests were taken for determining carrying capacity. A standard cut was done on the mid-May. In both years, the first harvest was conducted 30 days after the standard cut. However, in the first year, the second harvest was done 30 days after the first harvest, while in the second year, the second harvest was done 60 days after the first harvest. According to Devkota and Kolachhapati (2010), 10 kg of dry matter per day is required for 1 LU. The carrying capacity for a given period was calculated as follows:

$$\text{Carrying capacity of a given period} = \frac{\text{Cumulated herbage (dried wt. in kg/ha) for certain period}}{(\text{Requirement of one livestock unit (LU) per day} \times \text{time})}$$

Stocking density depends on the actual livestock population stocked per hectare (converted into LU). Adult cattle, buffalo, chauri, and horses were considered equivalent to 1.0 LU each, while sheep and goats were equivalent to 0.2 LU.

2.3 Fertilizer Experiment

The study was conducted in 2024. Nitrogen was applied at different rates: 0, 50, 100, and 150 kg/ha. Phosphorus was applied at 0, 30, and 50 kg/ha. Fertilizer was broadcast by hand and then incorporated using a rake without disturbing the vegetation. Half the dose of nitrogen and the full dose of phosphorus were applied at the beginning of the vegetation stage. The remaining nitrogen was applied at the beginning of the rapid growth period of vegetation. Herbaceous vegetation was harvested from all plots when plants reached the full flowering stage. The harvested herbage (200 g) from each plot was then oven-dried to determine dry matter yield.

2.4 Fencing Experiment

The study was conducted in 2025. The experiment was conducted at a selected site on the rangeland. The plot was divided into fenced and unfenced sections. Fencing was done at three selected sites using locally available materials. Herbage production was recorded at the flowering time in both fenced and unfenced areas. Herbaceous vegetation was harvested from all plots in both fenced and unfenced areas when plants reached the full flowering stage. The harvested herbage (200 g) from each plot was then oven-dried to determine dry matter yield. The crude protein content of all plots in both fenced and unfenced areas was determined in the laboratory of the National Animal Nutrition Research Center, Khumaltar, Nepal.

III. RESULTS AND DISCUSSION

The results obtained have been thoroughly analyzed and interpreted under the following subheadings.

3.1 Estimation of Carrying Capacity

Green and dry herbage production for 2024 is presented in Table 1. It was found that the maximum herbage was obtained from the second harvest compared to the first harvest. This may be due to favorable environmental conditions, such as rainfall after the first harvest. The cumulative dry herbage was 2.10 t/ha.

Requirement of dry matter for 1 livestock unit (LU) = 10 kg DM/day

Total requirement of dry matter for 1 LU for 60 days = 10 × 60 kg = 600 kg DM

Total available dry matter = 2.10 t/ha = 2100 kg/ha

Therefore, carrying capacity = 2100 / 600 = 3.5 LU/ha

This means that 3.5 livestock units can be sustained on one hectare of land for 60 days. Stocking rate must be carefully managed to avoid overgrazing. If the stocking rate exceeds 3.5 LU per hectare, the availability of forage declines, resulting in decreased overall productivity of the rangeland.

TABLE 1
CUMULATIVE HERBAGE PRODUCTION, 2024

Harvest	Green herbage (t/ha)	Dry herbage (t/ha)
First harvest	3.23	0.67
Second harvest	6.84	1.43
Cumulative	**10.07**	**2.1**

Green and dry herbage production for 2025 is presented in Table 2. It was found that in the second year, the maximum herbage was also obtained from the second harvest compared to the first harvest. The cumulative dry herbage was 2.97 t/ha.

Requirement of dry matter for 1 livestock unit (LU) = 10 kg DM/day

Total requirement of dry matter for 1 LU for 90 days = 10 × 90 kg = 900 kg DM

Total available dry matter = 2.97 t/ha = 2970 kg/ha

Therefore, carrying capacity = 2970 / 900 = 3.3 LU/ha

This means that 3.3 livestock units can be sustained on one hectare of land for 90 days. Stocking rate should be carefully managed to avoid overgrazing. When the stocking rate exceeds 3.3 LU per hectare, forage is consumed faster than it can regenerate, leading to deterioration of rangeland productivity.

TABLE 2
CUMULATIVE HERBAGE PRODUCTION, 2025

Harvest	Green herbage (t/ha)	Dry herbage (t/ha)
First harvest	4.67	0.86
Second harvest	10.25	2.11
Cumulative	**14.92**	**2.97**

The herbage production at the second harvest in the second year was higher than that in the first year. However, in the second year, the second harvest was conducted 60 days after the first harvest, whereas in the first year it was conducted 30 days after the first harvest. Therefore, this may be the reason for the higher yield at the second harvest in the second year's experiment. The longer interval between harvests contributed to comparatively higher yields. The higher yield in the second year suggests that harvest timing influences regrowth. Extending the time interval between two harvests resulted in accumulated more herbage and improved the carrying capacity of the rangeland.

The management of stocking rates relative to carrying capacity is critical. Overstocking beyond 3.5 LU/ha in 2024 and 3.3 LU/ha in 2025 reduces overall vegetation cover and long-term productivity. Similar findings have been documented by many researchers. Carrying capacity is not fixed; it may differ with year and location, and can even increase with higher herbage production because carrying capacity is determined not only by herbage yield alone but also by grazing duration, livestock type, vegetation recovery rate, and management practices (Li et al., 2024; Li et al., 2025). Devkota and Kolachhapati (2010) reported that overstocking beyond the appropriate stocking density reduced herbage vegetation and lowered the overall production level of rangeland. The average productivity of rangeland in Nepal ranges between 0.12 and 3.2 t/ha, depending on location, climate, and altitude (Pande, 2009). Grazing pressure on rangeland affects soil properties, ultimately influencing carrying capacity (Zhou et al., 2025). In addition, Zhang (2024) reported that overstocking reduces rangeland vegetation and leads to long-term degradation of rangeland. The experiment demonstrated that harvest interval and stocking rate directly affect forage yield and carrying capacity. The results are consistent with previous findings, emphasizing the need to balance livestock pressure with vegetation growth on rangeland.

3.2 Effect of Fertilizer on Rangeland

The effect of fertilizer on green and dry herbage production in 2024 is presented in Table 3. It was found that with increasing amounts of nitrogen fertilizer, green and dry herbage production increased. However, the highest green and dry herbage was

produced at a nitrogen-to-phosphorus ratio of 150:30, followed by 150:50. Nitrogen fertilizer plays a vital role in increasing forage production (Pereira Neto et al., 2024). In addition, adding phosphorus improves herbage production by supporting root development. It was found that the highest green and dry herbage was obtained when applying N:P in the ratios of 150:30 and 150:50, but there was no significant difference between them, suggesting that 30 kg P per hectare may be sufficient. This finding is supported by Aydin and Uzun (2005), who showed that a moderate level of phosphorus combined with nitrogen maximizes forage yield. Excessive phosphorus did not enhance herbage yield, indicating that the optimum level is 30–50 kg/ha. Nitrogen and phosphorus fertilizer together increase overall herbage compared to nitrogen alone (Walsh et al., 2024). Our finding reveals that nitrogen alone produced high biomass; however, the addition of phosphorus at 30–50 kg/ha further enhanced production. The combined N and P fertilizer increased herbage production. Overall, balanced fertilizer maintains long-term rangeland productivity. This finding is supported by Dasci and Comakli (2011).

TABLE 3
EFFECT OF FERTILIZER ON GREEN AND DRY HERBAGE PRODUCTION ON RANGELAND, 2024

Treatments (N:P, kg/ha)	Green herbage (t/ha)	Dry herbage (t/ha)
00:00	23.78^{c}	5.46^{c}
50:00:00	25.31^{c}	5.81^{c}
100:00:00	29.02^{b}	6.65^{b}
150:00:00	30.98^{b}	7.17^{b}
50:30:00	23.42^{c}	5.37^{c}
100:30:00	30.56^{b}	7.02^{b}
150:30:00	34.32^{a}	7.86^{a}
50:50:00	24.98^{c}	5.73^{c}
100:50:00	30.23^{b}	6.94^{b}
150:50:00	34.16^{a}	7.85^{a}
Mean	**28.68**	**6.59**
SEM	±0.96	±0.21
$LSD_{0.05}$	2.75	0.65
CV%	10.5	9.8

Note: Means within a column followed by different superscript letters differ significantly (P < 0.05)

3.3 Effect of Fencing on Rangeland

In heavily grazed rangeland, the fenced (protected) area produced 54.32% more green herbage compared to the unfenced (open) area, whereas in lightly grazed rangeland, the fenced area produced 22.57% more green herbage compared to the unfenced area. It was found that the highest crude protein (7.9%) was found in protected/fenced rangeland compared to the open area (7.2%). The unfenced area had lower nutritional quality compared to the fenced area. Furthermore, the fenced area allows forage to mature properly. In the open area, continuous grazing pressure reduces plant regrowth as well as protein levels. This finding is supported by Altinay and Yuksel (2024). Forage plants in open areas experience more stress from overgrazing, leading to poor regrowth and lower nutrient levels (Kim et al., 2024). Additionally, Barsila et al. (2023) reported that fenced areas produced higher herbage compared to open areas.

IV. CONCLUSION

The findings of this study indicate that animals should be grazed on rangeland according to its carrying capacity. When grazing exceeds the carrying capacity, vegetation production from the rangeland decreases. Fertilizer application with appropriate levels of nitrogen and phosphorus increased herbage production. However, the role of nitrogen was particularly significant for herbage production. In addition, fencing provides protection for vegetation, increasing herbage production and improving forage quality. Together, fertilization and fencing practices provide opportunities for higher herbage production. Management of stocking density according to carrying capacity, along with appropriate levels of fertilization and fencing, are important rangeland management tools for the long-term sustainability of range resources.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest regarding the publication of this paper

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