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Estimating the population density of the Himalayan Rangeland weed *Swertia ciliata* (G. Don) Burtt.: An impact of topography and disturbance

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Abstract

Swertia ciliata (G. Don) Burtt. is one of the most problematic weeds in the Himalayan rangelands. The main objective of this work is to assess the magnitude of *S. ciliata* invasion and analyze the impact of topographic factors and the disturbances on the distribution and population density. The work was conducted during August and September 2012 in the Tinjure-Milke mountain ridge at Gupha Pokhari, Nepal. The rangeland aspects (east, south and west) were considered the first level factor; and slopes (≤45 degree and ≥45 degree inclination) and the disturbance intensity were the second and third factors, respectively. Line transects made up 4 m^2, 74 quadrats were laid down randomly to enumerate the weed population. The average population density of the *S. ciliata* was 127 plants m^{-2}. The population density was found significantly different by the effects of the disturbances as well as aspects whereas the effect of the two slopes was found insignificant to the population density. A space is left for further research by ecological and edaphic factors. The study reveals that the infestation degree of *S. ciliata* is at a considerable level in the Himalayan rangeland and needs immediate control measures.

Key words**:** Gupha Pokhari, Tinjure-Milke-Jaljale, Weed population

Introduction

Rangeland weeds are unpalatable and unwanted native or alien invasive species that have an adverse impact on the forage by becoming dominant in grazed areas. At this moment most of the Himalayan rangeland weeds are native species (Limbu *et al.*,2012a). Rangeland weeds have a negative impact on the rangelands throughout the world because they reduce forage quality (Pike & Stritzke, 1984; Cosgrove & Barrett, 1987), displace desirable species, alter ecological processes, reduce wildlife habitats, degrade systems, decrease productivity and increase management costs associated with herbicide application and pasture restoration (DiTomaso, 2000; Masters & Sheley, 2001).

Swertia ciliate (Family Gentianaceae) is an annual herb 20-100 cm tall, with quadrangular stems, sometimes branched. Leaves are opposite, sessile, narrowly ovate and pointed. Flowers are pale blue or bluish white with a purple band near the base above the gland (Noltie *et al*., 1994). It is locally called "*Bhale chiraito*". Usually, it is found between 2800 and 3800 m altitude and prefers a less disturbed open Himalayan rangeland. It is a serious weed of the Himalayan rangeland of Eastern Nepal.

Research in weed population dynamics is very important for the design of effective and environmentally friendly weed control strategies as knowledge of weed density, seed production and seed bank establishment can be used to improved weed management (Navas, 1991; Liebman *et al*., 2001; Primot *et al*., 2006; Jasieniuk *et al*., 2008). Spatial distribution of plant species differs in place to place and various environmental (Anderson *et al.,* 2003) and anthropogenic factors (Larson *et al*., 2001 cited in Limbu *et al*., 2012a) determine the distribution and population of weed species.

Numerous studies have been conducted on quantifying trends in weed population against different weed management practices. Notable quantification study of weeds has been done in crop field (Willinga *et al.,* 1999; Arnaud *et al.,* 2010; Vasileiadis, 2012) but less work in rangeland (Uygur *et al*., 2004; Limbu *et al*., 2012b).

The Himalayan rangelands are not well studied from the point of view of weed management and weed population estimation perspective. A lot of identification and management works on rangeland weeds have been carried out in developed countries, *viz*., Australia (Martin *et al*., 2006) and USA (DiTomaso *et al*., 2010). Rangelands cover 60% of the Hindu-Kush-Himalayan region (Shaoliang & Sharma, 2009) but information on weeds' infestation sizes, density and impacts are unknown. Thus in this study we attempted to estimate the population density of *S. ciliata* and how influence the topographical factors (such as aspect and slope) influence the distribution and density of the weed.

Materials and Methods

Study area

The research work was conducted in the Tinjure - Milke Mountain ridge and Gupha Pokhari area on the border of three districts, i.e., Taplejung, Tehrathum and Sankhuwasabha, (27°09'30.5"N to 27°22'15"N and 87°26'09"E to 87°34'14"E) of eastern Nepal (Fig. 1). The altitude of the study site ranges from 2650 m asl to 3400 m asl with an average temperature of 23° C and average annual rainfall of 2250 mm. The region is grazed by livestock throughout the year because yaks and sheep are brought down to this area in the winter from the high Himalayan regions like Jaljale Mountain. Livestock raised in the study area are taken down to the low lands (1000 m to 1800 m msl) for grazing during the winter months. In the summer season, however, livestock movement is just the reverse. The Tinjure-Milke ridge and Gupha Pokhari area, thus, serves as a habitat corridor between Makalu-Barun Conservation Area and Kanchenjunga Conservation Area of Nepal. Both of conservation areas touch the Qomolongma Biosphere Reserve, Tibet (Koirala, 2002).

Experimental design

A stratified sampling procedure (Cochran, 1977) was used to collect data during August and September 2012. The experimental design incorporated three parameters, *viz*., slope, aspect and disturbance. We classified the slope of the rangeland into two categories. The first category includes slopes with an inclination less than 45 degree and the second with 45 degree or above. We considered three types of rangeland aspects, namely east, south and west. Two types of disturbance pattern were identified: the highly disturbed e.g., overgrazing, over trampling and the moderately disturbed area. We used a transect line method to enumerate the weeds in each sampling unit. Within each site, we randomly selected a point to begin vegetation sampling (without any prior knowledge of plant population at that point) and marked it. From the central sampling point, we established 40 m transect and placed 4 m^2 (2 m x 2 m) quadrats at every 10 m intervals along this transect. A total of 74 sample quadrats were sampled in this study. Chi-square tests were employed by means of cross comparison to make sure whether our selection of the sample quadrats was biased or not.

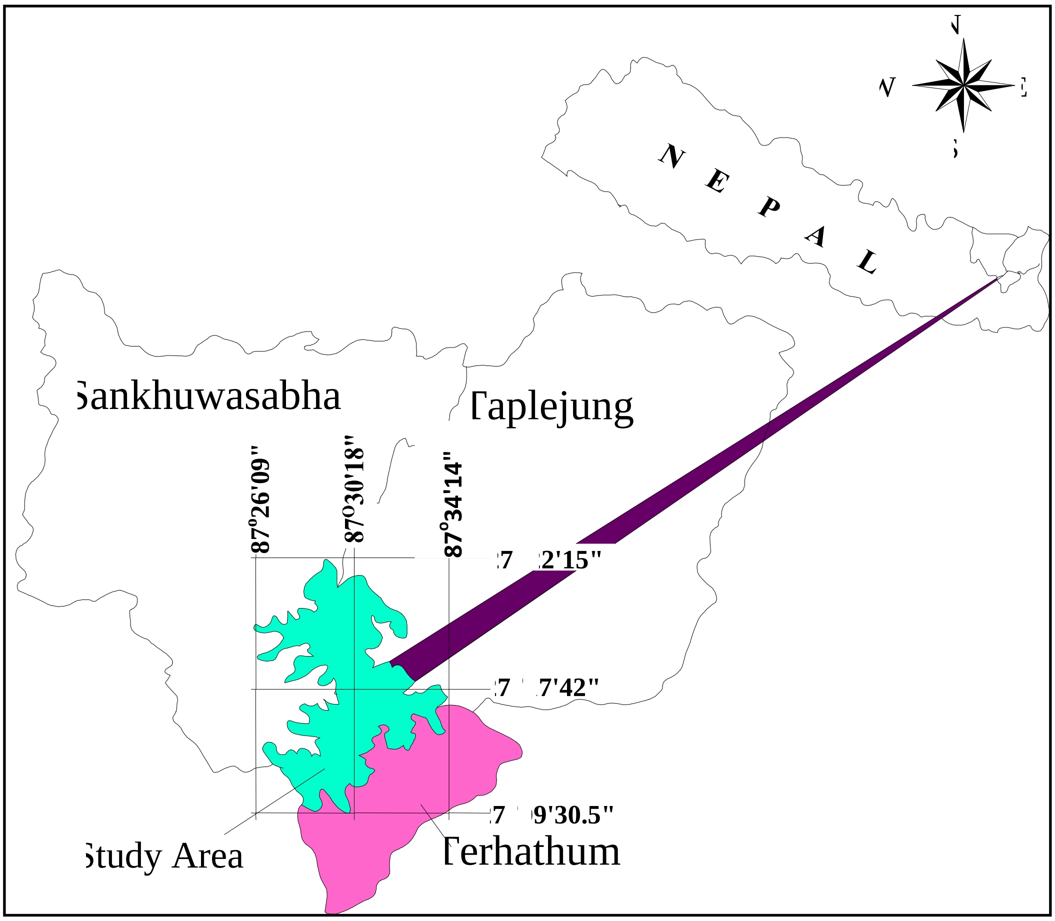

Figure 1. Map of Milke-Jaljale study area.

Test of independence for aspect, slope and disturbance were χ^2 = 1.546 (p = 0.462), χ^2 = 0.365 (p = 0.833) and χ^2 = 0.32 (p = 0.57) respectively. All three Chi-squared tests concluded that our selections were not biased.

Data collection and analysis

All weeds enclosed by each quadrat were counted and the population density m^{-2} was calculated. The following formula was used to determine the population density of the weed in each quadrat:

$$x_r = \frac{n_r}{A_r} \qquad \ldots \qquad (1)$$

Where, x_r denotes the population density of the weed m^{-2}, n_r denotes the number of weeds (*S. ciliata)* in the r[th] quadrat, *A* denotes the area of each quadrat and r =1, 2, ……., 74.
The average population density (m^{-2}) of the weeds in the study area was estimated by

$$\overline{X} = \frac{1}{N}\sum_{r=1}^{N} x_r \quad …. \ (2)$$

Where, N is the total number of chosen quadrats.

The formulae for the computation of the mean for the other factors of the study area were obtained similarly. All of the data analyses were carried out by using SPSS-20 (IBM-SPSS, 2011) software. To test whether there was a significant effect of the aspect, slope and disturbance of the rangeland on the population density of *S. ciliata*, we performed Univariate analysis of variance (UNIANOVA). ANOVA for general linear model was used to determine aspect, slope and disturbance effect on the single response variable population density. Treatment means obtained by ANOVA were compared using Tukey's HSD test at $\alpha = 0.05$ level of significance.

Results

Statistical measures (mean ± SE, 95% confidence interval for mean and the test statistics for significance) of the population densities of the weed were computed in different prospects of the rangeland. On the basis of observed mean in the studied rangeland, the overall weed density was 127 ± 23 (means ± SD) m^{-2}. Factor-wise, weed density was 136 ± 30 (means ± SD) m^{-2} on east aspect, 129 ± 25 (means ± SD) m^{-2} on flat area and 139 ± 24 (means ± SD) m^{-2} on moderately disturbed area. The grand mean was 124 ± 2 (means ± SE) m^{-2} (Table 1).

Table 1. Population density of *S. ciliata* (plant/m^2) at each level of three factors and condition of rangeland

Factors/Levels		Mean	Standard deviation (SD)	Number of samples (N)
Aspect	East	136.06	±29.8	29
	West	113.7	±11.8	25
	South	129.76	±14.4	20
Land inclination	$\leq 45^o$	128.9	±24.8	52
	$\geq 45^o$	121.7	±18.2	22
Disturbance	High	113.6	±13.4	35
	Moderate	138.6	±23.7	39
Total		126.8	±23.2	74

Whole model effect of aspect, slope and disturbance on the population of *S. ciliata* was determined by using univariate analysis of variance (UNIANOVA). The main effects of disturbance on weed density was highly significant such that less disturbance area had high weed density than high disturbance area (F = 17.67, p = 0.000) while weed density of inclined land and flat land were not significantly different (F =1.79, p = 1.85). Three levels of the aspect factor were significantly different among these. Tukey's HSD showed the west aspect of the rangeland had significantly less weed density than the other two aspects (F =8.15, p = 0.001) but east and south aspect was not significantly different (p = 0.42). Similarly, interaction effects of the different independent variables of the rangelands were computed. There was a significant interaction between aspect and slope (F = 4.526, p = 0.01). In eastern and western aspects, less inclined land had high weed density than more inclined rangeland (F = 5.72, p = 0.02) and (F = 3.86, p = 0.05) respectively. In southern aspect, land inclination had no effect (F = 2.56, p = 0.1). Interaction between aspect and disturbance and disturbance and slope were not significant (F = 0.77, p = 0.47) and (F = 1.09, p = 0.3) respectively (Table 2). In eastern and southern aspects, moderately disturbed area had high weed density than highly disturbed rangeland (F = 13.26, p = 0.01) and (F = 4.22, p = 0.04) respectively. In western aspect, disturbance had no effect (F = 3.0, p = 0.08). Similarly in less inclined rangeland, moderately disturbed area had high weed density than highly disturbed rangeland (F = 23.54, p = 0.00). In more inclined rangeland, disturbance had no effect (F = 3.54, p = 0.07). The interaction between aspect, slope and disturbance did not effect on weed density (F = 0.067, p = 0.93) (Table 2).

Table 2. Whole-model effect of aspect, slope, disturbance and interactions on the population density of *S. ciliata* m^{-2}.

Parameter	Df	MS	F	P.
Main effects				
Corrected Model	11	1928.25	6.683	0.000
Intercept	1	878600.06	3044.97	0.000
Aspect	2	2353.5	8.157	0.001
Slope	1	518.15	1.796	NS
Disturbance	1	5100.6	17.677	0.000
Interaction effects				
Aspect × Slope	2	1305.8	4.526	0.015
Aspect × Disturbance	2	221.6	0.768	NS
Slope × Disturbance	1	312.95	1.085	NS
Aspect × Slope × Disturbance	2	19.34	0.067	NS
Error	62	288.54		
Total	74			

Homogeneity test based on the observed mean provides the information that the average population density of the east and south aspect is homogeneous.

Leven's test was used for the tests of equality of error variance of the dependent variable across all the groups (different aspects of the rangeland). It was found that there is no equality of the variance of the weed density in all aspects of the rangeland (F = 5.404, P = 0.000).

Discussion

Distribution of rangeland weed, *S. ciliata*, was significantly influenced by disturbance but land inclination was insignificant. Similarly the population density of *S. ciliata* in the southern aspect was different than eastern and western aspect of rangeland. In addition soil pH, nutrient and age of rangeland drive the weed distribution. However some research results reveal that distribution of *Swertia* sp. is not uniform; it depends upon the altitude and slope. It was higher population density on north facing sloppiness than fattened area**.** It prefers to grow in acidic soil condition with pH of 4.7 to 5.5 in association with other species like *Fragaria indica*, *Anaphilis triplinervis*, *Cynodon dactylon* and *Digitaria adecendens* (Bhattarai & Shrestha, 1996).

Limbu *et al.* (2012a) have reported 30 plants m^{-2} density of *Senecio chrysamthemoides,* a problematic Himalayan rangeland weed in Milke-Jaljale area. The present work shows the density of *S. ciliata* is much greater than that of the former species. It is more problematic to the rangelands. Fowler (2002) pointed out that some plant species prefer to grow on slope and other on flat land, but Fowler's observation is falsified by this study, which shows the population density of *S. ciliata* is not affected much by the slope of the land. The finding of the present study was in agreement with McIntyre *et al.* (1995) observation that intensive grazing (disturbance) can result in reductions in native plant species' richness.

Vegetation distribution is influenced by various factors. The spatial distribution, pattern and abundance of plant species in a rangeland have often been related to three groups of factors: physical environmental variables, soil chemistry and anthropogenic disturbances (Enright *et al*., 2005). A disturbance could act as a strong selective force on plant species traits (Denslow, 1980; Miao & Bazzaz, 1990) allowing particular species to tolerate or even take advantage of specific environmental changes due to a disturbance (Martinsen *et al*., 1990; McIntyre *et al*., 1995). Disturbances may have positive effects on some plant species, but negative when the disturbance is extensive, resulting in bare soil patches (Austrheim & Eriksson, 2001; Klug *et al*., 2002; Cairns & Moen, 2004; Olofsson *et al*., 2005).

Vegetation distribution is also affected by topographical factors (Kingston & Waldren, 2003; Sebastia, 2004). Topographic characteristics like elevation, slope and aspect are closely associated with local climate (e.g., precipitation, evaporation and solar incident radiation) that have a great impacts on plants (Davies *et al*., 2007). Topographic characteristics regulate seed, water and nutrient redistribution, thereby impacting plants distribution pattern (Parker, 1982; Pinder *et al*., 1997; Canton *et al*., 2004; Fu *et al*., 2004). Upland (slope) and lowland (flat) areas have different impacts on plant distribution (Hook & Burke, 2000). Due to erosion and cattle movement, surface soil, humus and plant’s seed from upland move down to lowland and are deposited there. Thus lowland plots are enriched with silt, clay, carbon and nitrogen relative to adjacent upland plots. Cattle graze lowlands preferentially (Senft *et al.,* 1985; Milchunas *et al.,* 1989). As a result, plants luxuriantly grow on lowland compare to upland. Similarly forage is grazed by cattle but weed plants are left.

This work has addressed only a handful of factors (disturbance, slope and aspect of rangeland) that affect the distribution and population of the weed, *S. ciliata*, in the high altitude Himalayan rangeland, i. e. in our study area. Further research will address the remaining factors and predict the population density of weed precisely and reveal the population growth projection of the Himalayan rangeland.

Conclusion

The estimation of density of the *S. ciliata* is very important for weed management strategy in rangelands. A weed, with about 60 cm height, having the population density of 127 plants/m^2 on a rangeland is a serious threat to the rangeland quality and management. It needs some control measures immediately to arrest further infestation. Notable disturbance (grazing and trampling) regulates infestation and distribution of weed, *S. ciliata*, on rangeland. Aspect and disturbance appear more influential factors than slope for determining the distribution of *S. ciliata*. In addition, there are other more influencing factors i.e. ecological and edaphic for the spatial distribution and infestation of the weed.

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