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ORIGINAL ARTICLE

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Ecological Study of Swertia chirayita (Roxb. ex Fleming) H. Karst in the Upper Region of Gorkha, Nepal

Bishal Subedi[1], Mukesh Kumar Chettri[1] and Suman Poudel[2]

[1]Department of Botany, Amrit Science College, Kathmandu, Nepal
[2]Department of Botany, Tribhuban University, Kathmandu, Nepal

ABSTRACT

Objective: The study aimed to evaluate the population size of Swertia chirayita across different environmental gradients.

Methodology: Systematic sampling was conducted in three locations within the Gorkha district of Nepal (Laprak, Barpak, and Kashigaun), covering elevations from 1860 to 2825 meters above sea level (masl). Soil samples were analyzed for pH, nitrogen, organic carbon, and phosphorous content. Data analysis was performed using SPSS, R, and Excel.

Results: Soil pH ranged from 3.2 to 5.9, nitrogen content from 0.01% to 0.14%, and organic carbon from 0.3% to 4.65%. Phosphorous content varied between 47.84 kg/ha and 85.9 kg/ha. The slope angle ranged from 19.7° to 37.4°. Swertia chirayita density was positively correlated with soil nitrogen (0.57) and organic carbon (0.61) but negatively correlated with phosphorous content (-0.61). The plant showed non-uniform distribution, with populations influenced by edaphic factors and invasive species.

Conclusion: The study found that S. chirayita distribution was either contagious or random, influenced by soil nutrients and invasive species. This plant grows best in nitrogen-rich and organic carbon-rich soils but does not thrive in high-phosphorous environments.

KEYWORDS

Medicinal plant; Population density; Soil relation; Ecosystem; Swertia chirayita

ARTICLE HISTORY

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Introduction

Nepal harbors 118 ecosystems, encompassing over 2% of the world's phanerogams, 3% of pteridophytes, and 6% of bryophytes [1]. Around 23% of the phanerogams in Nepal possess medicinal properties, with Swertia chirayita (Roxb. ex Flem.) Karst emerged as a notable medicinal plant [2,3]. There exist 29 species of Swertia in Nepal, nine of which are exclusive. S. chirayita holds significant value and is extensively utilized in Nepal and India [4]. Nevertheless, unsustainable harvesting practices in recent decades, motivated by domestic consumption and commercial gains, have exerted considerable pressure on its natural populations [5-7]. Despite its elevated conservation significance, limited efforts have been made to safeguard and perpetuate this species.

Method and Methodology Study Area

This research was conducted in the Dharche and Sulikot Rural Municipalities of Gorkha district. Both of these municipalities are situated in the northern region of the district, with vegetation that spans from subtropical to alpine zones.

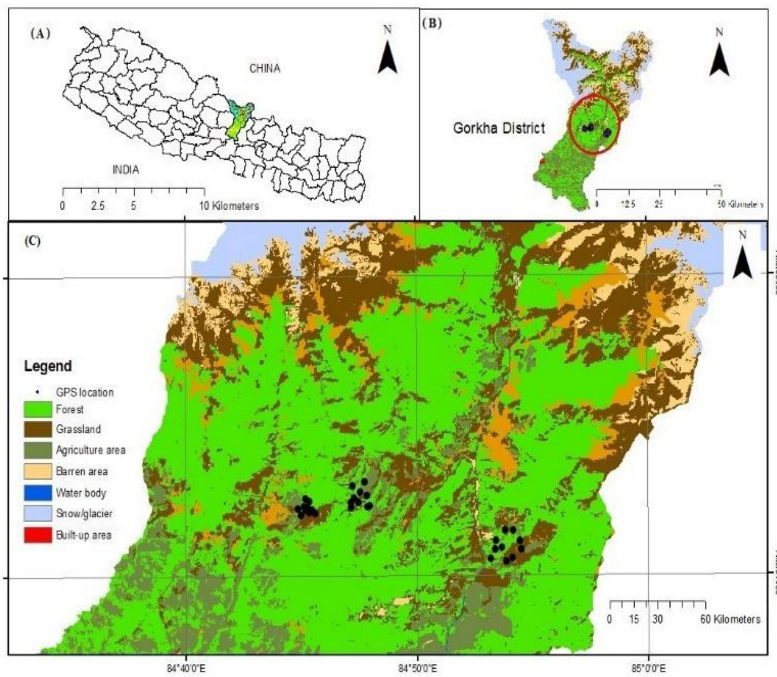

Figure 1. Map of the study area (A=Map of Nepal showing Gorkha district, B= Map of Gorkha district with the vegetation and coverage, C= Zoom out the map of the study area showing study plots)

***Correspondence:** Mr. Bishal Subedi, Department of Botany, Amrit Science College, Kathmandu, Nepal, email: bishalsubedi143@gmail.com

Survey Design and Data Collection

An initial survey was conducted in June 2019 to map the distribution of Swertia chirayita across different locations. Systematic sampling was then carried out in August 2019, following a resource selection process to identify the structure of various populations of S. chirayita. Thirty sampling plots measuring 10×10 m² were established, spaced at least 200 meters apart. To assess population status, each 10×10 m² plot was further divided into subplots of 1×1 m², arranged with a 2-meter gap between each subplot.

For population studies, every Swertia chirayita plant within the quadrats was observed and categorized into three life stages: rosette, vegetative aerial, and reproductive aerial (following Lyngdoh [8]). Plants emerging as seedlings were classified as rosettes, larger plants without inflorescence as vegetative aerials, and those with inflorescence as reproductive aerials. Associated species (whether herbs, shrubs, or trees) within each quadrat were also recorded. The collected samples were identified by referring to standard literature, seeking scientific consultation, visiting herbaria (TUCH and KATH), and comparing them with high-resolution herbarium images from the University Herbarium at the University of Tokyo (TI) [9-11]. The slope angle of each study site was measured using a clinometer.

Soil samples were collected following the methodology of Sherif et al. [12]. The Soil and Fertilizer Testing Laboratory in Hetauda, Nepal examined air-dried soil samples from each location to determine the total nitrogen content (using the Kjeldahl method), total organic matter (OM) (using the Walkley-Black method), phosphorus content (P_2O_5) (using Olsen's method), and soil moisture (using the oven-drying method). The soil pH at the study sites was measured using a digital pH meter.

The spatial distribution of S. chirayita was determined according to Whitford [13].

The data was analyzed using both parametric and non-parametric statistical tests. Non-parametric correlation analysis was used to identify the general relationships between population parameters and soil factors. Additional data analysis was done using tools like SPSS version 25, R, and Microsoft Excel. Methods such as non-parametric tests, analysis of variance (ANOVA), and pairwise comparisons were utilized to identify variations across populations. One-way ANOVA was utilized to assess variations in plant population density and composition. The distribution pattern of the species was analyzed using the ratio of abundance and frequency.

Results and Discussion

Population structure of S. chirayita in gorkha

The study revealed that S. chirayita populations were most abundant in Laprak, followed by Barpak and Kashigaun. While there was a significant difference in the population between Laprak and Kashigaun, no significant differences were observed between Barpak and Laprak or between Barpak and Kashigaun (Table 1). However, the density of the rosette form of S. chirayita showed significant variation across the study sites, with a notable difference between Laprak and Kashigaun.

Significant variations in the density of vegetative and reproductive aerials were observed across the different study areas, such as Laprak, Barpak, and Kashigaun. Laprak had the highest A/F ratio at 0.066, followed by Barpak at 0.059, and Kashigaun at 0.049. Kashigaun has an even distribution with a ratio below 0.050, while Barpak and Laprak have a clustered distribution with a ratio above 0.050.

The study unveiled that S. chirayita populations thrived most abundantly in Laprak, followed by Barpak and Kashigaun. While a significant variance in population was noted between Laprak and Kashigaun, no substantial disparities were observed between Barpak and Laprak or between Barpak and Kashigaun (Table 1). Nevertheless, the density of the rosette form of S. chirayita exhibited notable variation across the study sites, particularly discernible between Laprak and Kashigaun.

The abundance of vegetative and reproductive aerials also displayed significant discrepancies among the study areas, encompassing Laprak, Barpak, and Kashigaun. Laprak recorded the highest abundance-to-frequency (A/F) ratio at 0.066, trailed by Barpak at 0.059 and Kashigaun at 0.049. This ratio implies that Kashigaun showcases a systematic distribution ($A/F < 0.050$), while Barpak and Laprak manifest a contagious distribution pattern ($A/F > 0.050$).

Table 1. Comparison of life stages and total population of S. chirayita across study sites, along with the abundance-to-frequency ratio

Place	Rosette (Mean Popn ± S.D.)	Vegetative aerials (Mean Popn ± S.D.)	Reproductive aerials (Mean Popn ± S.D.)	Total Popn (Mean Popn ± S.D.)	A/F ratio
Barpak	2.78± 2.05	2.37 ± 1.66yz	1.75 ± 0.82yz	5.55 ± 3.91	0.059
Kashigaun	2.05±0.87x	2.07 ± 0.74xy	1.39 ± 0.92xy	4.59 ± 1.48x	0.049
Laprak	2.55 ± 1.58z	2.95 ± 2.14xz	2.09 ± 1.09xz	6.07 ± 4.05z	0.066
F value	4.178	5.963	8.29	4.244	
P value	0.017	0.003	0	0.015	

Note: x = significant difference from Barpak, y = significant difference from Laprak, and z = significant difference from Kashigaun, at p = 0.05 with df = 2 and n = 90 in a one-way ANOVA followed by LSD

In this research, quadrats were set up according to resource preference, leading to high occurrences (>90%) of S. chirayita. The species' adaptability across a wide range of habitats is reflected in its high frequency. However, the average density of S. chirayita (4.59–6.07 individuals/m²) suggests that the species does not grow densely, similar to findings by Bhatt et al. [14] in the western and northwestern Himalayas of India. The low population density could result from excessive harvesting of

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wild populations, since the whole plant holds significant medicinal properties [4,15,16]. The practice of uprooting the plant before seed development diminishes the likelihood of seed production, reducing the chances of future rejuvenation. The higher density of S. chirayita in Laprak, which is at a higher altitude, supports the observation that the species thrives better at higher elevations, consistent with Bhatt et al. [14].

Naturalized populations commonly comprise different groups, with the initial groups having greater fertility and survival rates. Nevertheless, certain research has shown a decrease in initial survival rates among new groups [18]. In this research, the rosette form had a lower density compared to vegetative and reproductive aerials. The varying distribution of S. chirayita is influenced by factors like altitude and slope degree, as reported by Joshi and Dhawan, Phoboo and Jha, and Sharma et al. [18,19]. Consistent with prior studies, S. chirayita showed significant and non-random distribution patterns [14]. This phenomenon is frequently seen in natural environments as a result of the wide range of environmental conditions [20].

Physiographic and Soil Characteristics of S. chirayita

Swertia chirayita was observed in open grasslands, slopes, and old landslide areas at elevations between 1860 and 2825 meters above sea level (masl) in the Gorkha district. Laprak (2360-2825 masl), Barpak (2080-2790 masl), and Kashigaun (1860-2036 masl) were the locations mentioned. The species favors acidic soils, with pH levels between 4.29 and 5.1. The total nitrogen content in the soil was very low (0.032% to 0.061%), while phosphorus content varied from 62.68 to 76.02 kg/hectare. The total organic carbon ranged from 1.15% to 2.49%. Slope angles varied from 27.27° to 29.3°. Despite similar soil nitrogen content and slope degree across the study sites, other soil and environmental factors such as pH, organic carbon content, phosphorus content, moisture content, and altitude varied significantly (Table 2).

Table 1. Relationship of factors determining the habitat of S. chirayita.

Variables	Barpak (Mean±S.E.)	Kashigaun (Mean±S.E.)	Laprak (Mean±S.E.)	P-value	F-value
Altitude (masl)	2278.7 ± 75.35^{yz}	1956.3 ± 20.015^{xy}	2496 ± 56.49^{xz}	0	23.867
Moisture content (%)	41.35 ± 10.274^{z}	20.53 ± 2.85^{xy}	41.59 ± 5.005^{z}	0.012	3.16
N^a (%)	0.061±0.0156	0.032±0.0071	0.040±0.0096	0.193	1.748
P^b (kg/hector)	62.68±3.044	76.02±2.499	66.522±4.098	0.039	
pH^b	4.72±0.305	5.1±0.159	4.29±0.126	0.034	
$Slope^b$ (0)	28.53±1.33	26.27±1.65	29.3±1.73	0.309	
Total org. C^a (%)	1.48 ± 0.387^{y}	1.15 ± 0.112^{y}	2.49 ± 0.342^{xz}	0.012	5.227

Note: a = One-way ANOVA followed by LSD; b = Kruskal-Wallis test; x= significant difference with Barpak, y = significant difference with Laprak, and z = significant difference with Kashigaun, at p = 0.05 with df = 2 and n = 10.

S. chirayita is found in the temperate Himalayas, from Kashmir to Bhutan and the Khasia hills of Meghalaya [21]. It is distributed across Nepal at altitudes between 1500 and 3000 masl, with a preference for elevations around 2000 masl [22].

However, in this research, Laprak had a greater abundance of S. chirayita at elevations of 2360-2825 masl, in contrast to Barpak and Kashigaun. Bhatt and colleagues also found that S. chirayita performed better at increased altitudes [14]. The species prefers acidic soils, and the total carbon, nitrogen, and phosphorous content in the soil observed in this study is consistent with findings by Barakoti [23]. Similar to Bhatt et al., S. chirayita was found growing on open grassy slopes [14]. The species does well in open areas like grassy slopes, landslide debris, and moss-covered slopes, potentially because there is less competition from other species for sunlight, moisture, and nutrients.

Relationship Between S. chirayita Density and Various Soil and Environmental Factors

Spearman's correlation was employed to assess the relationship between the density of S. chirayita and various soil and environmental factors (Table 3). The study revealed a significant positive correlation between the presence of Swertia chirayita in different plant phases and the soil's total organic carbon, nitrogen, and phosphorous levels. However, a noticeable negative correlation was observed between the plant density and the phosphorous levels in the soil. Significantly, the density of S. chirayita did not display any notable correlation with soil pH, moisture levels, or altitude.

A strong inverse relationship was found between the density of S. chirayita and phosphorous content (p=0.001, -0.613), while a strong positive correlation was observed with total soil organic carbon and nitrogen content (p=0.001). The weakest correlations were seen with slope (0.006), while soil pH (0.076), elevation (0.136), and soil moisture (0.224) came after. Aerial stage densities, both vegetative and reproductive, had a small negative correlation with soil pH, while rosette density and total plant density had a slight positive correlation with soil pH.

Additionally, the soil's phosphorous content had a significant negative relationship (0.619) with total nitrogen. Altitude was positively correlated with soil moisture (0.530) and slope angle (0.372) and was negatively correlated with soil pH (-0.367).

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Table 3. Spearman Correlation was calculated for 30 samples to assess the relationship between Swertia chirayita population density and various soil parameters (n=30).

Variables	1	2	3	4	5	6	7	8	9	10	11
1. Rosette plant density (m-2)	1										
2. Vegetative aerial density (m-2)	0.60**	1									
3. Reproductive aerial density (m-2)											
4. Total density (m-2)	0.83**	0.84**	0.68**	1							
5. Total nitrogen (%)	0.58**	0.42*	0.60**	0.57**	1						
6. Phosphorous content (kg/hector)	-0.510**	-0.463*	-0.52**	-0.61**	0.62**	1					
7. Soil pH	0.12	0	-0.01	0.08	-0.2	0	1				
8. Total organic carbon (%)	0.37*	0.63**	0.53**	0.61**	0.3	0	-0.2	1			
9. Altitude (masl)	0.02	0	0.21	0.14	0.2	0	-0.37*	0.18	1		
10. Moisture content (%)	0.143	0.2	0.16	0.2	0.3	0	-0.3	0.33	0.53**	1	
11. Slope Angle (0)	-0.36	0	-0.15	-0.2	0	0	-0.1	-0.1	0.37*	0.2	1

Note: **= Correlation is significant at the 0.01 level and *= Correlation is significant at the 0.05 level

Figure 2 shows how Swertia chirayita population density, altitude, and different soil properties are connected in a scatter plot using PCA. The PCA biplot shows a strong correlation between the density of S. chirayita and the levels of total soil organic carbon and total nitrogen. Nevertheless, it demonstrates minimal correlation with elevation or other soil factors.

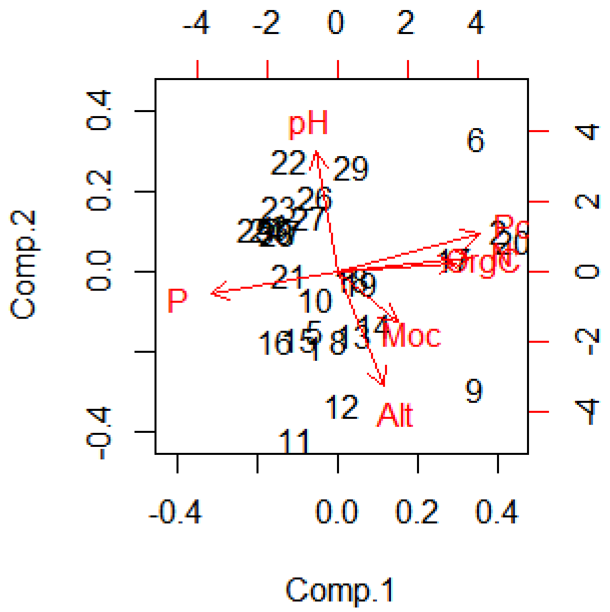

Figure 2. PCA analysis of Swertia chirayita density about various soil properties (Moc = Moisture Content, N = Total Nitrogen Content of the Soil, OrgC = Total Organic Carbon in the Soil, PdT = S. chirayita Population Density, pH = Soil pH, P = Soil Phosphorus Content).

The density of Swertia chirayita was significantly correlated with the total nitrogen content, phosphorus content, and total organic soil carbon in all plant forms - rosette, vegetative aerials, and reproductive aerials. The relationship between the density of S. chirayita and the levels of soil phosphorus, total nitrogen, soil pH, soil organic carbon, altitude, soil moisture, and slope angle is equally significant across all stages of life. This might be due to the fact that the soil sample came from one plot with all stages of life, without specifically collecting data for each stage in different seasons. To induce flowering, the right soil pH and adequate phosphorous levels are necessary [24]. This could explain why there is a strong connection between phosphorous levels and plant density, since the research took place during the flowering season. There was a strong positive correlation between the amount of nitrogen in the soil and the density of S. chirayita, suggesting that Swertia chirayita thrives in nitrogen-rich soil.

There was no association found between S. chirayita's population density across various life stages and soil pH, altitude, moisture content, or slope. This might explain why the plant has the ability to thrive in a wider range of habitats than other forest plants.

At the current altitude, there was a notable direct relationship between soil moisture content and altitude. In his 1979 study, Smith found that higher altitudes in mountain areas are associated with more precipitation, possibly explaining the strong connection between altitude and soil moisture content in the current research. In the current study, it was also found that there is a strong inverse relationship between altitude and total soil organic carbon. This could be because higher altitudes receive more rainfall, which leads to the washing away of above-ground organic matter in the soil, consequently reducing soil microbial activities. Bangroo et al. also documented a decline in soil microbial activities as altitude rose [25].

Conclusions

The research found that the Gorkha region has ample opportunities for growing Swertia chirayita because of its varied and appropriate environments. S. chirayita populations show flexibility in different light, moisture levels, and soil conditions, flourishing mainly in regions with acidic soil and high organic matter content. Plant density was discovered to be the greatest when compared to Barpak and Kashigaun because of the

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favorable climate, good soil quality, and optimal microhabitat characteristics in those areas.

In Barpak and Kashigaun, there was a significant difference in density between reproductive aerials and rosette and vegetative aerials. The decline could be due to the plant being harvested before it can reproduce. Moreover, S. chirayita demonstrates a liking for soil abundant in nitrogen, suggesting that it flourishes in areas with high nitrogen levels.

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Disclosure Statement

No potential conflict of interest was reported by the author.

References

1. GoN/MoFSC. Nepal Biodiversity Strategy and Action Plan 2014-2020. Gov Nepal Ministry for Soil Conservation. 2014.
2. Ghimie SK, Sah JP, Shrestha KK, Bajracharya D. Ecological study of some high altitude medicinal and aromatic plants in the Gyasunda Valley. Ecoprint. 1999;6(1):17-25.
3. Ghimire SK, Sapkota IB, Oli BR, Parajuli RR. Non-timber forest products of Nepal Himalaya: database of some important species found in the mountain protected areas and surrounding regions. WWF Nepal. 2008:74-76.
4. Joshi P, Dhawan V. Swertia chirayita- An Overview. Curr Sci. 2005;89(4):635-640.
5. Badola HK, Pal M. Endangered medicinal plants in Himachal Pradesh. Curr Sci. 2002;83(7):797-798.
6. Dutta PK. Study of a market chain of Swertia chirayita trade in the west Kameng district of Arunachal Pradesh. WWF-India. 2004.
7. Olsen CS. Valuation of commercial central Himalayan medicinal plants. Ambio. 2005;34(8):607-610. https://doi.org/10.1579/0044-7447-34.8.607
8. Lyngdoh M. Population ecology of threatened ethnomedicinal plant species about forest fragmentation in Kanchendzonga Biosphere Reserve, Sikkim. Shillong: North-Eastern Hill University; 2011.
9. Polunin O, Stainton A. Flowers of the Himalaya. Oxford University Press; 1984,79.
10. Raven JA. Putting the C in phycology. Eur J Phycol. 1997;32(4):319-333.
11. Ohba T, Hirabayashi JI, Nogami K, Kusakabe M, Yoshida M. Magma degassing process during the eruption of Mt. Unzen, Japan in 1991 to 1995: Modeling with the chemical composition of volcanic gas. J Volcanol Geotherm Res. 2008;175(1-2):120-132. https://doi.org/10.1016/j.jvolgeores.2008.03.040
12. Al Sherif EA. Melilotus indicus (L.) All., a salt-tolerant wild leguminous herb with high potential for use as a forage crop in salt-affected soils. Flora. 2009;204(10):737-746. https://doi.org/10.1016/j.flora.2008.10.004
13. Whitford PB. Distribution of woodland plants in relation to succession and clonal growth. Ecology. 1949;30(2):199-208. https://doi.org/10.2307/1931186
14. Bhatt A, Rawal RS, Dhar U. Ecological features of a critically rare medicinal plant, Swertia chirayita, in Himalaya. Plant Species Biol. 2006;21(1).
15. Kirtikar KR, Basu BD. Indian medicinal plants. International Book Distributors; 1999;3.
16. Nadkarni KM. Indian Plants and Drugs with Their Medicinal Properties and Uses. Delhi: Asiatic Publishing House; 2006.
17. Baskin JM, Baskin CC. Influence of germination date on survival and seed production in a natural population of Leavertworthia stylosa. Am Midl Nat. 1972;88:318-332.
18. Phoboo S, Jha PK. Trade and sustainable conservation of Swertia chirayita (Roxb. ex Fleming) h. Karst in Nepal. Nepal J Sci Technol. 2010;11:125-132.
19. Sharma N, Singh NK, Bhadwal MS. Relationship of somatic cell count and mastitis: An overview. Asian-Australas J Anim Sci. 2011;24(3):429-438.
20. Odum EP. Fundamentals of ecology. Printing Company Ltd; 1971.
21. Chanda SK, Bhattacharyya A, Sarkar S. Early diagenetic chert nodules in Bhander Limestone, Maihar, Satna District, Madhya Pradesh, India. J Geol. 1976;84(2):213-224.
22. Bhattarai KR, Shrestha S. Ecological Study on Chiraito (Swertia chirayita, Roxb.ex Fleming (Karsten) in Northern Gorkha. J Nat Hist Mus. 1996;15:13-16.
23. Barakoti TP. ARS Pakhribas, Nepal Agricultural Research Council, Nepal; 2002.
24. Erel R. Flowering and fruit set of olive trees in response to nitrogen, phosphorus, and potassium. J Am Soc Hortic Sci. 2008;133: 639-647.
25. Bangroo SA, Najar GR, Rasool A. Effect of altitude and aspect on soil organic carbon and nitrogen stocks in the Himalayan Mawer Forest Range. Catena. 2017;158:63-68. https://doi.org/10.1016/j.catena.2017.06.017

https://doi.org/10.61577/jec.2024.100012