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Conservation paradox: strong cultural ties but poor regeneration of chiuri (*Diploknema butyracea*) in Nepal

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Abstract

Chiuri (*Diploknema butyracea*), a culturally and economically significant tree in the Nepal Himalayas, plays a vital role as a cultural keystone species. This study examined its regeneration across 90 plots along three elevational gradients: lower (500-800 m), middle (800-1100 m), and upper (1100-1400 m) in western, central, and eastern Nepal. The highest seedling densities occurred in the Upper Central (16 seedlings/ha) and Upper Western (14 seedlings/ha) regions. Regeneration was affected by factors such as disturbance, shade intolerance, thick litter layers, short seed viability, and grazing. Notably, areas with low disturbance and strong traditional conservation practices, especially among the *Chepang* community, showed better regeneration outcomes. The findings highlight the value of indigenous knowledge in promoting forest health. To ensure the long-term survival of *Chiuri*, the study recommends establishing seed orchards, promoting public awareness, and launching large-scale plantations. These efforts would enhance both the ecological sustainability and cultural significance of this important Himalayan species.

Keywords: Conservation practices, Ethnobotany, Population dynamics, Sustainable management

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Introduction

All trees provide many tangible and intangible benefits, though some species are important for indigenous people due to their high value in cultural and spiritual practices, as well as their key role in ecosystem maintenance, which is often referred to as cultural keystone species (Uprety *et al*., 2013; Benner *et al*., 2021; Hill *et al*., 2021). Indigenous peoples select and use these plants based on deliberate criteria rather than random choice, considering taxonomic affinities, ethnobotanical uses, ancestral wisdom (Farnsworth and Bingel, 1977; Cox, 2007), ecological traits (Kutal et al., 2021), phytogeographical distribution (Saslis-

Lagoudakis *et al.*, 2014), and socio-cultural influences (Kunwar *et al.*, 2022).

Diploknema butyracea (Roxb.) H. J. Lam, also known as Butter tree in English, and *Chiuri* in Nepali, is one of the most important tree species in terms of ecology, economy, and cultural values (Bhattarai *et al*., 2024). For generations, *Chiuri* has played a vital economic role by supporting various micro-enterprises, including soap making, butter and honey production, wine and juice processing, beekeeping, oilcake manufacturing, and insecticide production (Golay et al., 2021). The seed-derived butter is its primary product. Additionally, every part of the plant, such as bark, leaves, flowers, nectar, and fruit has diverse uses, highlighting its multipurpose value. Indeed, it is regarded as a cultural keystone species due to its important cultural value in Nepal, especially in the *Chepang* community where the *Chepang* ethnic group offer *Chiuri* trees as dowries to their daughters and feel the matter of pride to have *Chiuri* trees in their territory, indicating its crucial role in their culture (Dhakal, 2014; Chikanbanjar *et al*., 2021; Uprety and Asselin, 2023).

The *Chiuri* tree is native to the Sub-Himalayan regions of Nepal, India, China, and Bhutan, and is found across the entire Himalayan range between 200 and 1800 meters in altitude (Press *et al*. 2000; Joshi 2010; Majumdar *et al*. 2012, Bhattarai et al., 2024). In Nepal, it is reported in 58 out of 77 districts being abundant in central and western Siwalik and lower mid-hills and holds a significant social, cultural, economic, and ecological importance, particularly for communities in the lower Himalayan region (Bhattarai *et al*., 2021) due to its diverse uses in food, medicine, fodder, and industry. Its edible fruits are rich in sugar, carbohydrates, protein, fat, ash, sodium, potassium, phosphorus, iron, and calcium, and the juice is consumed to quench thirst (Sundriyal and Sundriyal, 2004). The flowers provide nectar for beekeeping and are also used to produce jaggery with high economic value in Uttarakhand, India (Khanka *et al*., 2009). The tree retains green leaves during dry months, making it a preferred cattle fodder. *Chiuri* products such as butter, seeds, honey, juice, soap, and wine are widely used in the confectionery, pharmaceutical, and cosmetic industries (Bist and Bhatta, 2014). *Chiuri* butter is employed in making vegetable ghee, candles, healing creams, and as an extender for cocoa butter when blended with Kokum or Sal fat. Its by-product cake is used as manure with pesticidal properties and has applications as a wormicide, nematicide, molluscicide, rodenticide, and insecticide. It can also serve as poultry feed after detoxification and as a crude fish poison. The butter has high economic demand estimated at 1080 MTs for soap companies, 120 MTs for monasteries and temples, 100 MTs for cosmetic industries, and 240 MTs for cosmetic exports (GIZ, 2013). However, key challenges include the need for improved technology for high-quality oil extraction and better market development for processed products (Acharya, 2014).

The population dynamics of a species' seedlings, saplings, and adult plants illustrate its regeneration profile, which is crucial in determining its regeneration status and is a pivotal process ensuring the continual existence of a species within a community (Saikia and Khan, 2013). A population boasting a substantial number of seedlings and saplings signifies satisfactory regeneration behavior, while a scarcity of these developmental stages within a forest indicates inadequate regeneration (Khan et al., 1987; Tripathi and Khan, 2007). The regeneration profile of a species, reflected through the dynamics of its seedlings, saplings, and adult plants, plays a vital role in assessing its regeneration status and ensuring its long-term survival within a community (Saikia and Khan, 2013). A healthy population, characterized by an abundance of seedlings and saplings, indicates robust regenerative capacity, whereas a shortage of these younger growth stages signals poor regeneration (Tripathi and Khan, 2007). Successful regeneration depends on the species' ability to produce new seedlings, support their survival, and promote their growth (Good and Good, 1972). Evaluating the likelihood of regeneration success requires an understanding of the current population structure, growth patterns, and reproductive capacity (Guedje *et al*., 2003).

Approximately 10 million naturally growing *Chiuri* trees are estimated to cover around 1,900 hectares of land in Nepal (Joshi, 2010). However, ongoing degradation, deforestation, overexploitation, and the spread of invasive alien species have significantly impacted local biodiversity, cultural practices, and valuable species, including *Chiuri* (MoFSC, 2014). The decline of culturally significant tree species can disrupt the cultural heritage, livelihoods of dependent communities, and traditional conservation values (Uprety and Asselin, 2023). Documentation of traditional knowledge developed by local communities through experiences of adapting to the constrained environment is paramount in the era of climate change (Karki *et al.* 2022). Evaluating this knowledge and its patterns holds promise for formulating specific strategies for traditional knowledge preservation and building resilience while acknowledging the unique characteristics of each community, geography, culture, and biodiversity (Chaudhary *et al.* 2017, Singh *et al.* 2019). As climate change has adversely impacted ecosystems leading to altered biodiversity, habitat fragmentation (Atwood et al., 2015; Dejene, 2018), it is an utmost requirement to explore the present status of such valuable plant species and promote sustainable utilization in the future to make an effective plan and sustainable management. Understanding population demography is vital for interpreting current species distribution and forecasting future trends (Normand *et al*., 2014). The regeneration status of a species is best assessed through the abundance of seedlings, saplings, and adults, as well as by analyzing the frequency distribution across different size classes in the population structure (Pokhriyal *et al*., 2010; Iralu *et al*., 2018). Therefore, this study focuses on evaluating the regeneration patterns of *Chiuri* along elevational gradients in western, central, and eastern Nepal to support sustainable management and conservation initiatives.

Materials and Methods

Study sites

Nepal, situated between longitudes 80°33’ to 88°12' E and latitudes 26°8’ to 30°27’ N (Banerji, 1963; Stainton, 1972), is administratively divided into seven provinces, 77 districts, and 753 local bodies (Figure 1). Its topography comprises three major vertical physiographic regions: the southern Tarai plains, the mid-hills, and the northern mountains, with the Siwalik range lying between the Tarai and the hills (Chhetri and Easterling, 2010). These diverse landscapes are shaped by unique historical, cultural, and socio-economic contexts. For this study, three transect surveys were conducted across lower (500–800 m), middle (500–1100 m), and upper (1100–1400 m) elevational gradients in the western, central, and eastern regions of Nepal. These areas reflect rich cultural diversity and varying ethnic compositions. Western Nepal is primarily inhabited by Kshetri, Brahman-Hill, and Dalit communities; Central Nepal includes Kshetri, Brahman-Hill, Tamang, and *Chepang*; and Eastern Nepal is home to Limbu, Sherpa, Kshetri, Brahman-Hill, Rai, Tamang, and Dalit groups. Dominant caste groups like Kshetri (16%) and Brahman-Hill (12%) mostly reside in the mid-hills, while Dalits, making up about 13% of the population, are more concentrated in the west. Ethnic groups such as Tamang (5%) and *Chepang* (0.2%) belong to the Tibeto-Nepalese category, contributing to the country’s rich tapestry of traditional knowledge and cultural heritage (CBS, 2021).

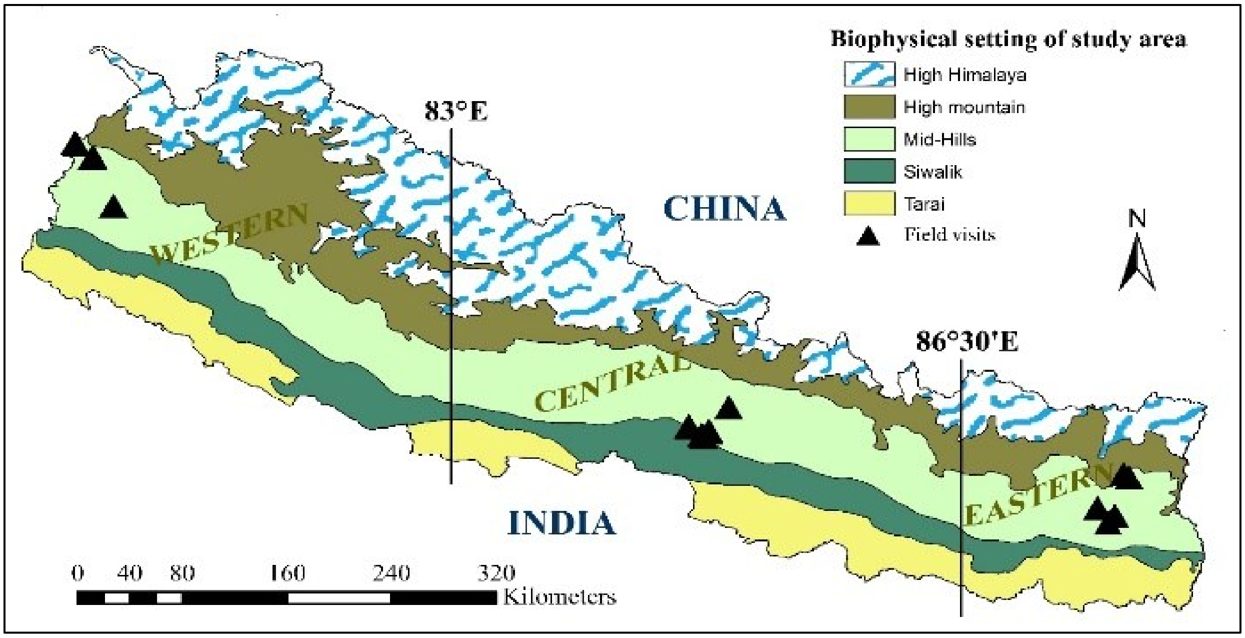

Figure 1. Map of the study sites

Data collection and analysis

Prior to initiating our fieldwork, we conducted a thorough literature review on Chiuri, focusing on its ecology, ethnobotnaical uses, conservation status, and economic potential using relevant sources such as books, journal articles, online databases, and grey literature to gather comprehensive information, following the methodology outlined by Pullin et al. (2009). We established 90 circular sample plots, with 30 plots placed along each transect in the western, central, and eastern regions of Nepal. Each plot covered an area of 500 m² and was spaced at least 100 meters apart. Using the total count method, we carefully recorded and measured all individuals within each plot. The height of adult individuals was measured with a range finder, while diameter measurements were taken using diameter tape. Additionally, composite soil samples and disturbance types were collected following the guidelines of FRTC (2019). We evaluated the density of adult and regenerating population by classifying individuals into seedlings (H<1m), saplings (H=1-5 m and DBH<10 cm), adults (DBH>10cm). Regeneration status was determined based on the population size of seedlings and saplings following criteria outlined by Saha *et al*. (2016), Sarkar and Devi (2014) (Table 1). Disturbance attributes were categorized into various types including landslide, livestock grazing, lopping, litter collection, bush cutting, forest fires, encroachment, latex tapping, sapling cutting, tree cutting, insect attacks, plant parasites, plant diseases, wind & storm, and others (FRTC, 2019) and analyzed the frequency of each type. We applied a one-way ANOVA to compare adult and regeneration densities along the study sites.

Table 1. The criteria used for assigning the regeneration status

Description	Regeneration status
If the number of seedlings>saplings>adults	Good
If the number of seedlings>or<saplings<adults	Fair
If the species occupied only as saplings, and adults and number of saplings>=<adults	Poor
If individuals of species were present only in adult form	No
If individuals of species had no adults only occupy in seedlings or saplings	New regeneration

Results and Discussion

Population density of Chiuri along study sites

The population density of *Chiuri* varied significantly (p=0.000) across the study sites (Figure 2). The Upper Central site had the highest adult density (104/ha) and a regeneration density (16/ha), indicating a strong population with moderate regeneration potential. The Upper Western site followed with adult density (82/ha) and 14/ha in regeneration, suggesting stability. In contrast, the Middle and Lower Western sites showed lower adult densities and minimal or no regeneration, particularly in Lower Western, where no regeneration was recorded. The Upper Eastern site had adults and regeneration 52/ha and 8/ha respectively, while the Middle and Lower Eastern sites exhibited the lowest densities, with a critical lack of regeneration, especially in Lower Eastern thus facing challenges in population renewal.

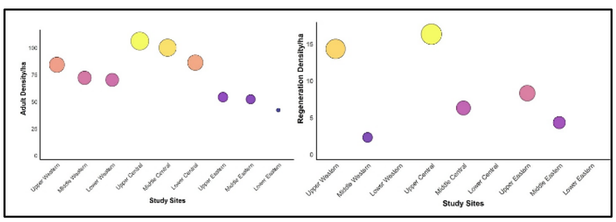

Figure 2. Adult and regeneration density along study sites

The higher population density in the central region is likely attributed to effective conservation practices in the region, driven by customary laws upheld by local communities such as the *Chepang*. The *Chepang* people not only rely on and revere the *Chiuri* tree but also actively participate in its management and conservation across various tenure systems, including state forest lands, unregistered private lands (locally known as *Khoriya*), and registered private lands. These practices play a crucial role in preventing deforestation and promoting sustainable harvesting as studies have highlighted a strong positive relationship between ecological health and ethnobotanical practices (Sharma, 2011; Sherpa, 2015; Bhattarai *et al*., 2024).

Factors shaping the population density of Chiuri along study sites

The principal component analysis (PCA) biplot illustrates that the topographic factors such as slope and elevation, showed a strong positive association with population density followed by soil nutrients, particularly nitrogen (N) and organic matter (OM) (Figure 3). In contrast, disturbance showed a clear negative association with tree density, as evidenced by the opposing direction of their vectors reducing population density by disrupting regeneration processes and damaging existing vegetation thus shaping the distribution pattern of the species whereas, pH and potassium displayed no strong association, indicating its limited impact on density compared to the other factors.

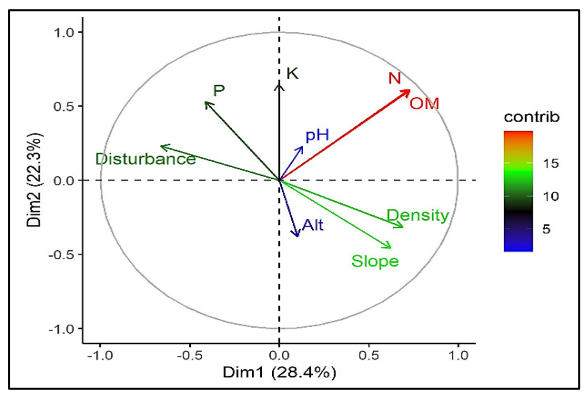

Figure 3. PCA biplot showing the influence of determinant variables on population density

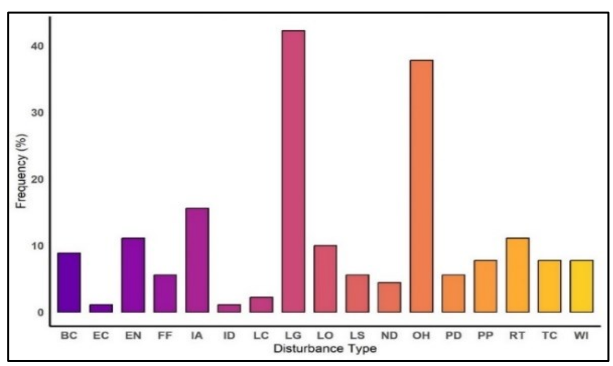

Figure 4. Dominant disturbance types observed in the field

(ND – No disturbance; LS – Landslide; LG – Livestock grazing; LO – Lopping; LP – Litter collection; BC – Bush cutting; FF – Forest fire; EN – Encroachment; RT – Resing tapping; LC – Lathra cutting; TC – Tree cutting; OH – Other human-induced; IA – Insect attack; PP – Plant parasites; PD – Plant disease; WI – Wind, storm)

The frequency of various disturbance types observed in the study sites revealed varying levels of influence (Figure 4). Livestock grazing (LG) was the most prevalent disturbance, accounting for 42.22% of occurrences, highlighting its significant effect on the forest structure. This was followed by other human-induced disturbances such as removing the bark, foot trails, forest roads, etc.) at 37.78%. Insect attack (IA) contributed 15.56%, showing the impact of biological disturbances. Both encroachment (EN) and resin tapping (RT) accounted for 11.11%, suggesting the impacts of land use changes and resource extraction. Lopping (LO) at 10% reflected the effects of foliage harvesting on tree health. Overall, the dominance of human-induced disturbances, particularly livestock grazing, underscored the need for sustainable management practices to mitigate further ecological degradation.

Regeneration status

The regeneration status of the *Chiuri* population was fair in Upper Central, Middle Central, and Upper Eastern. However, poor regeneration status was observed in Upper Western, Middle Western, Lower Central, and Middle Eastern whereas it was absent from Lower Western, and Lower Eastern (Table 2).

Table 2. Regeneration status of *Chiuri* along the study sites

Study sites	Seedlings/ha	Saplings/ha	Adults/ha	Compare to adults	Regeneration status
Upper Western	0	14	82	Sa>or≤ adult	Poor
Middle Western	0	2	70	Sa>or≤ adult	Poor
Lower Western	0	0	68	Only adult	None
Upper Central	2	14	104	Se>or≤Sa≤Adult	Fair
Middle Central	2	4	98	Se>or≤Sa≤Adult	Fair
Lower Central	0	2	82	Only adult	Poor
Upper Eastern	2	4	54	Se>or≤Sa≤Adult	Fair
Middle Eastern	0	4	46	Sa>or≤ adult	Poor
Lower Eastern	0	0	44	Only adult	None

Determinant factors influencing regeneration

The limited regeneration density of the *Chiuri* tree in natural habitats results from multiple ecological constraints compounded by anthropogenic disturbances such as excessive grazing, as cattle feed on its fruits, seeds, seedlings, saplings, and even mature leaves, often eliminating seedlings that survive initial challenges (Uprety and Asselin, 2023). Despite seed germination rates exceeding 99% in controlled nursery conditions, natural regeneration remains poor, highlighting the species' struggle in its native environment. The *Chiuri* tree, known for its dense canopy and thick, leathery leaves, follows a unique ecological cycle, shedding leaves and fruit synchronously. However, this coordinated dispersal is hindered by ecological barriers such as shade intolerance and a 2-3 days short seed viability (Jackson *et al*., 1994; Acharya *et al*., 2023). The extensive canopy creates heavy shade, restricting sunlight vital for seedling growth, while thick leaf litter beneath the tree prevents seed-to-soil contact, further impeding germination. These factors collectively pose significant challenges to the natural regeneration of the *Chiuri* tree.

The regression analysis, combined with species-specific ecological traits, highlights key factors influencing the regeneration of *Chiuri* in the Nepal Himalaya. The significant negative effect of adult tree density on regeneration is likely due to competition for resources and the dense canopy, which limits light availability, despite *Chiuri* being a light-demanding species. The significant positive influence of slope may indicate reduced soil compaction and lower grazing pressure, promoting seedling survival. However, the negative impact of disturbance aligns with the species' vulnerability to grazing, as its highly palatable seeds, seedlings, and saplings are frequently destroyed. These findings indicate that both biotic interactions, such as competition and grazing, and physical site conditions, like slope and canopy cover, are crucial drivers of *Chiuri* tree regeneration. Additionally, the paradigm shift in the subsistence utilization of *Chiuri* might be a supporting cause for decline the in population density and regeneration. Historically, *Chiuri* played a central role in local livelihoods, with its products being used for cooking (ghee), skincare, lighting lamps, and even in fishing and agriculture (oilcake as fertilizer). However, the advent of modern alternatives, such as packaged oils, candles, chemical fertilizers, and commercial skin care products, has reduced the reliance on *Chiuri* products (Poudel *et al*., 2024). This shift has diminished the tree's cultural and practical importance within communities, leading to less attention and care towards its conservation and regeneration coupled with ecological challenges such as the species' short seed viability, high light requirements, and vulnerability to grazing.

Phytochemical composition and economic prospective

The most widely used product of the plant is the butter extracted from the seeds. The major chemical constituents of the seed includes alkaloid, tannin, fats, glycosides, flavonoids, phenol, terpenoids, saponins, sterols etc. (Tyagi and Tyagi, 2015) whereas palmitic acid, stearic acid, oleic acid, and linoleic acid are the chief components of the *Chiuri* butter. Various researchers reported similar major chemical constituents from different areas slightly differing in their proportion of the composition like palmitic acid (55-61%), stearic acid (1.6-3.8), oleic acid (6-39%), and linoleic acid (0.2-5.7%) from different locations of Nepal and India (Bushell and Hilditch, 1938; Agarwal *et al*., 1963; Sengupta and Roy Choudhary, 1978; Reddy and Prabhakar, 1994; Devkota *et al*., 2012; Bandyopadhyay *et al*., 2017) (Table 3). *Chiuri* ghee is the main source of edible oil widely used for cooking purposes. In Nepal, it is distributed from east to west in Tarai and mid-hills and has the potential to produce 37,245 metric tons of *Chiuri* butter with a market value of about NPR 5 billion (US$ 41.4 million) (Joshi, 2010), thus showing huge potentiality of production.

Table 3. Variations of chemical concentration of *Chiuri* seeds

Fatty acids	Relative composition (%)				
Palmitic acid	55.86	55.6	61	58.4-66	56.8-64.1
Stearic acid	1.63	5.2	3.8	2.4-2.9	2.4-3.5
Oleic acid	38.55	35.9	30	28.9-35.2	28-31.3
Linoleic acid	3.69	3.3	0.2	2.6-3.7	4.3-5.7
Sample origin	India	India	India	Nepal	India
Reference	(Agarwal *et al*., 1963)	(Sengupta and Roy Choudhary, 1978)	(Reddy and Prabhakar, 1994)	(Devkota *et al*., 2012)	(Bandyopadhyay *et al*., 2017)

Global demand for cocoa butter for producing chocolate, candies, and coating in increasing and different vegetable fats and oils have their unique properties, however, can be blended to produce cocoa butter equivalents (Salas *et al*., 2013). The butter obtained from *D. butyracea* can be used as cocoa butter equivalent when combined with certain proportions of some other fats to obtain confectionery fats or cocoa butter extenders (Reddy and Prabhakar, 1994) (Table 4) and produced cocoa butter extenders by blending *Chiuri* butter (33-50%) and Sal fat (50-67%). However, the extraction is only practiced for small scale (Reddy and Prabhakar, 1994; Vidhate and Singhal, 2013), which indeed, can be industrialized to optimize the economic implication through this multipurpose tree.

Table 4. Fatty acid and triacylglyceride composition of hard butter obtained from blending *Chiuri* butter and kokum fat

Compositions	***Chiuri* butter middle fraction**	**Blend 1 (*Chiuri* butter 60% and Kokum fat 40%)**	**Blend 2 (*Chiuri* butter and Sal fat)**	**Cocoa butter**
		Fatty acid (%)		
Palmitic acid	66.3	34.4	16	31
Stearic acid	3.9	35.3	45.6	34
Oleic acid	27.7	30	32.2	35
Linoleic acid	0.6	0.2	-	-
		Triacylglycerols (%)		
Tristaurated (GS3)	2.5	2	-	-
Monounsaturated disaturated (GS2U)	18	89	90	90
Diunsaturated monosaturated (GSU2)	12	7.8	8	10
Reference		Reddy and Prabhakar (1994)	Reddy and Prabhakar (1989)	

Implications for sustainable management and conservation

Sustainable management and conservation of the *Chiuri* tree require a multifaceted approach that integrates traditional knowledge, community involvement, and scientific practices as there exists a strong association between ethnobotany and ecology (Bhattarai *et al*., 2024) indicating that the rich ethnobotanical linkage necessitates conservation thus being abundant population in that area. The low disturbance index, for instance, observed in central Nepal highlights the effectiveness of customary laws practiced by the *Chepang* ethnic groups, where cultural taboos on tree cutting and branch lopping have contributed significantly to *Chiuri* conservation. Recognizing *Chiuri* as a cultural keystone species underscores the importance of involving local communities in conservation efforts. Although The ethnobotanical use reports of *Chiuri* showed that there are 26 ethnic groups from 22 districts using *Chiuri* as a botanical (Bhattarai *et al*., 2024), promoting strict protection measures, such as regulating grazing and preventing other disturbances, can further support natural regeneration. Additionally, initiatives such as establishing *Chiuri* nurseries, forming *Chiuri* clubs, and conducting awareness programs are vital for enhancing conservation outcomes and disseminating knowledge about the tree's ecological and economic benefits. Combining traditional practices with modern conservation strategies will ensure the long-term sustainability of *Chiuri* populations while supporting local livelihoods and preserving cultural heritage.

Being a cultural keystone species, the plant has unique relationship with the *Chepang* ethnic community in Nepal and equally they are sincere to manage and conserve in different tenure systems viz. state forest lands, unregistered private land (locally called *Khoriya*), and registered private land (Paudel and Wiersum, 2002). Before 1990 the *Chiuri* tree growing on the state forest were officially state property, however, the government did allow ethnic *Chepang* people to use them according to customary rights which grants permission to claim individual tree for private use. Under different tenure conditions, various management practices have been applied following the customary rules and people generally do not fall the tree for timber, instead, branches or older trees are used for handles of tools, furniture, sheds for animals, and constructing fences (Paudel and Wiersum, 2002).

However, though the species is multipurpose and has the huge potential to contribute to the production system and economic generation, these plants are found to grow mostly in the natural condition and its cultivation practices with the aim of orchard establishment is still not familiar (Thapa, 2019). The usual planting material for *Chiuri* plantation is seed-based which requires about 6-10 years for flowering and fruiting (Chikanbanjar *et al*., 2021). However, in recent days, it has been made a successful cleft grafting technique to be the effective tool for the propagation of *Chiuri* (Wayo type) (Subedi *et al*., 2022). Similarly, cuttings taken from juvenile donors also showed more profuse rooting with higher percent survival though the cuttings taken from mature donors were not much effective comparatively (Zargar and Kumar, 2018). Though the government has prioritized for cultivation in massive scale (Joshi, 2010), enforcing Forest act (GoN, 2019), forest regulation (GoN, 2022) Herbs and Non-timber forest products development policy (DPR, 2004), poor regeneration in the natural strands, highly habitat specific, long time frame for the production, large sized, tedious traditional methodology of extraction and processing for butter etc. are other major challenges present in the field level. Thus, there is an immediate need to make a clear consensus about the diversity, distribution and ethnobotanical values of *Chiuri* for species level planning to maintain the sustainable biodiversity, empower the production to the commercial level, and conserve cultural heritage linked with this multipurpose tree species.

Conclusion

Chiuri represents a culturally significant and ecologically important species with substantial economic potential in Nepal. The observed spatial variation in population density and regeneration status across study sites reflects the complex interplay between ecological factors and anthropogenic disturbances. The central region, characterized by stronger community stewardship and customary conservation practices, notably among the *Chepang* ethnic group, demonstrates higher population densities and better regeneration status, underscoring the effectiveness of traditional ecological knowledge in species management. Despite the species' high germination potential under controlled conditions, natural regeneration remains poor due to short seed viability, shade intolerance, and grazing pressure. To promote sustainable management, conservation, and commercialization of *Chiuri*, integrated strategies that combine scientific research, community-based management, and supportive policy frameworks are urgently required. Such an approach would not only enhance biodiversity conservation but also strengthen rural livelihoods and safeguard the ethnobotanical heritage associated with this multipurpose species.

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