Shah Abdul Latif University, Khairpur

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ECOLOGY AND THREATS TO COMMIPHORA WIGHTII IN THAR DESERT OF PAKISTAN

Principal Investigator
Dr Muzafar H. Sirohi
Department of Botany, Shah Abdul Latif University Khairpur, Sindh Pakistan
Volunteers
Mr Shakeel A. Khaskheli, Mr Sajjad H. Sahito, Syed Fiaz H. Shah

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EXECUTIVE SUMMARY

Commiphora wightii, locally known as Guggul or Gugar, is a slow-growing medicinal shrub of the family Burseraceae, long valued in Ayurvedic and Unani medicine for its therapeutic gum resin, guggulu. The species is currently listed as Critically Endangered (CR-A2cd) on the IUCN Red List, reflecting a population decline exceeding 80% over the past three generations. Tharparkar District in Sindh Province represents one of the few last remaining natural habitats of this species in Pakistan, making it a site of urgent global conservation significance.

This study was conducted to fill a critical gap in scientific knowledge, as no systematic district wide ecological survey of *C. wightii* had previously been undertaken in the region. Surveys were carried out across 43 sites — 34 in open desert plains and 9 in the Karoonjhar Hills, using a grid-based sampling framework. At each site, ten 20 m × 20 m quadrats were established to record plant counts, height, canopy diameter, regeneration status, and associated vegetation. Community interviews were also conducted to document local threats and harvesting practices.

The species was recorded at only 11 of 43 surveyed sites (25.6%), with just 26 individuals documented within sampled quadrats, reflecting critically low population density. The highest concentrations were found in the rocky Karoonjhar Hills, where rugged terrain limits livestock access. Open sandy plains retained only isolated individuals, a marked contrast to historical accounts from local elders describing the species as once widespread. Population structure showed a predominance of mature plants with very few juveniles, indicating serious regeneration failure and uncertainty about long-term viability.

Five principal threats were identified: destructive gum extraction using deep incisions and chemical irritants; unsustainable livestock grazing by a herd exceeding 6.5 million animals; habitat conversion of rangelands to agricultural land; invasion by *Prosopis juliflora*; and the species' own biological limitations, including low seed viability and poor germination under arid conditions.

The study recommends a comprehensive conservation response encompassing formal protection of population hotspots in the Karoonjhar Hills, establishment of native plant nurseries for ex-situ propagation, creation of community bio-enclosures to facilitate regeneration, promotion of cultivated agroforestry as an alternative to wild harvesting, training of gum collectors in non-lethal tapping methods, and strengthened institutional coordination for legal enforcement. Without urgent intervention, the continued decline of *C. wightii* in one of its last remaining natural habitats appears increasingly inevitable. This study provides the ecological foundation and strategic direction necessary to guide its recovery in the Thar Desert of Pakistan.

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1. INTRODUCTION

The Thar Desert, located in the southeastern corner of Sindh Province in Pakistan and extending into the Indian subcontinent, represents one of the most ecologically distinct arid landscapes in Asia. Covering approximately 22,000 square kilometers within Pakistani territory, the Tharparkar District constitutes a significant component of this extensive desert ecosystem (Ghalib et al., 2013). Contrary to the stereotypical image of a barren, lifeless wasteland, the Thar Desert is characterized by a complex mosaic of sand dunes, vegetated corridors between dunes, rocky outcrops, seasonal wetlands, and grasslands, each supporting a remarkable diversity of flora and fauna uniquely adapted to survive under conditions of extreme heat, aridity, and unpredictable rainfall. This ecological richness, however, exists in increasing tension with the pressures of a rapidly expanding human population, unsustainable resource utilization, and the accelerating impacts of climate change, factors that jeopardize many of the desert's most valuable species, placing them at significant risk of both local and global extinction.

Among the ecologically and ethnobotanically significant plants found within the Tharparkar landscape is *Commiphora wightii* (Indian Bdellium), commonly referred to as Guggul, or Gugar in the local Sindhi language. This slow-growing, resiniferous shrub, belonging to the family Burseraceae, has historically occupied a central role in traditional medicine systems throughout the Indian subcontinent, including Ayurveda and Unani. The gum-resin extracted from its bark, commercially known as guggulu, has been documented for its therapeutic applications in treating a variety of ailments, including inflammation, arthritis, back pain, cardiovascular disease, and as a natural repellent against insects and snakes (Ved et al., 2015). The demand for this gum in both traditional and increasingly modern pharmaceutical markets has led to intensified harvesting pressure on wild populations. Market data indicate that 40 kilograms of raw guggul gum can command a price of approximately eighty thousand Pakistani rupees, underscoring both the economic value of the species and the incentive for its over-exploitation (personal communication).

The conservation status of *C. wightii* reflects the severity of these pressures. The species is currently classified as Critically Endangered (CR-A2cd) on the IUCN Red List of Threatened Species, a designation that indicates a documented rapid decline in population size of more than 80% over the past three generations, primarily due to over-harvesting and habitat degradation (Ved et al., 2015). The Tharparkar District represents one of the few remaining natural habitats where this species continues to grow in the wild, thereby making it a site of global conservation significance. Although the few studies conducted to date have confirmed the presence of the species at several localities across Tharparkar (Saand et al., 2019), systematic data regarding population size, age structure, spatial distribution, reproductive dynamics, and habitat associations are largely absent from the scientific literature.

The existing gap in knowledge is particularly concerning in light of the ecological vulnerabilities that currently affect the broader Tharparkar Desert landscape. This region is home to a dense and rapidly expanding human population, with the district's inhabitants increasing from 0.54 million in 1981 to over 1.64 million by 2017, which corresponds to an annual growth rate of 3.14% (PBS, 2021). A significant majority of this population, approximately 92%, resides in rural and remote desert areas, relying predominantly on rain-fed agriculture and free-range livestock rearing as their primary means of subsistence (PBS, 2021; Khuhawar et al., 2019). Livestock overgrazing represents one of the most pervasive threats to the desert's vegetation cover, resulting in the degradation of native plant communities and diminishing habitat quality for species such as *C. wightii*, which necessitates undisturbed sandy soil conditions for natural regeneration. Additionally, the absence of adequate family planning, limited access to formal education, and insufficient healthcare infrastructure collectively hinder the community's ability to adopt more sustainable land use practices.

2. OBJECTIVES

- To assess the ecology, distribution, and primary threats impacting the natural populations of *Commiphora wightii* in the Thar Desert of Pakistan.
- To propose effective conservation strategies aimed at mitigating anthropogenic pressures and ensuring the long-term viability of the species.

3. METHODOLOGY

The study was conducted in Tharparkar district, an arid to semi-arid region characterized by dispersed vegetation and variable accessibility due to scattered settlements and villages. A grid based sampling framework was overlaid on a map of the district to standardize spatial sampling across this sparsely vegetated area, consistent with grid based approaches commonly employed in arid landscapes to address spatial heterogeneity and logistical challenges (Lawley et al., 2016; Pias et al., 2019). This grid framework facilitates reproducibility and comparability of site level sampling across arid environments and aligns with the transition from systematic to directed sampling concepts in large-scale, resource-limited settings (Li et al., 2017).

Each grid cell covered an approximate area of about 400 square kilometers, with the center of each grid cell designated as the primary sampling point. If the required sampling location was inaccessible due to settlements or other obstructions, the nearest suitable alternative within the grid cell was selected as the sampling point to maintain spatial coverage (Pias et al., 2019; Li et al., 2017). Karonjhar hills is a relatively different microhabitat from the reset of the desert. The hilly area is stretched over about 19 kilometers. Also the nature of anthropogenic activities is different. Therefore we surveyed this area separately on nine site.

A total of 43 sites were sampled (34 desert and flats, 09 Hills), reflecting a deliberately scoped but spatially distributed design appropriate for preliminary vegetation surveys in deserts where

resource limitations necessitate pragmatic site selection (Quevedo & Frances, 2007; Lawley et al., 2016).

At each sampling site, ten 20 m x 20 m quadrats were established to characterize local woody vegetation structure and composition. The quadrats were positioned to ensure an inter quadrat distance of approximately 100 meters, ensuring spatial independence among quadrats within a site and enabling conversion to a total sampled area per site of 0.4 hectares. This spatial configuration is consistent with standard field plot sampling practices used in arid vegetation assessments to balance precision and logistical feasibility (Li et al., 2017; Virk et al., 2024).

Within each quadrat, the following measurements were recorded for *C. wightii* (guggul) individuals: (a) counts of plants, (b) height, and canopy (c) ecological observations (growth form, regeneration status, associated micro-habitat features). Additionally, co-occurring plant species within quadrats were identified to characterize community composition and potential competitive interactions. This approach aligns with established field protocols for vegetation censuses in arid ecosystems (Chen et al., 2023; Virk et al., 2024).

To assess threats to *C. wightii*, semi-structured interviews were conducted with members of the local communities. Given the social dynamics, the interviews were designed as informal conversations rather than formal structured questionnaires.

4. RESULTS AND DISCUSSION

4.1 *Distribution of C. wightii across Tharparkar*

The distribution analysis indicated that *C. wightii* currently exhibits a restricted and fragmented distribution across the Thar Desert of Pakistan (Figure1). Out of the 43 surveyed sites, the species was recorded at only 11 sites, constituting approximately 25.6% of the total sampled localities. A total of 26 individuals were documented within the random quadrats during this study, reflecting an overall low abundance and sparse population density in the region. The highest abundance was observed in the Karoonjhar Hill range and adjacent habitats around the Run of Kuch and Kotlo Lake, where six individuals were recorded from Run of Kuch alone, and four individuals were noted at one of the hilly sites. Additional populations were identified in other rocky hill habitats, albeit with comparatively lower abundances ranging from one to three individuals per site.

Scattered individuals were also observed near Mithi in open sandy desert habitats outside the sampled quadrats, suggesting that the species persists in isolated pockets within the desert plains. However, the low frequency of occurrence and poor abundance in sandy habitats suggest that the species has undergone a significant decline in these areas. According to personal communications with local elders, *C. wightii* was once relatively common in both sandy desert plains and the Karoonjhar Hills of Tharparkar. In contrast, the current survey illustrates that the

major surviving populations are now predominantly confined to rocky hilly terrain, with only sparse and scattered individuals remaining in open desert habitats.

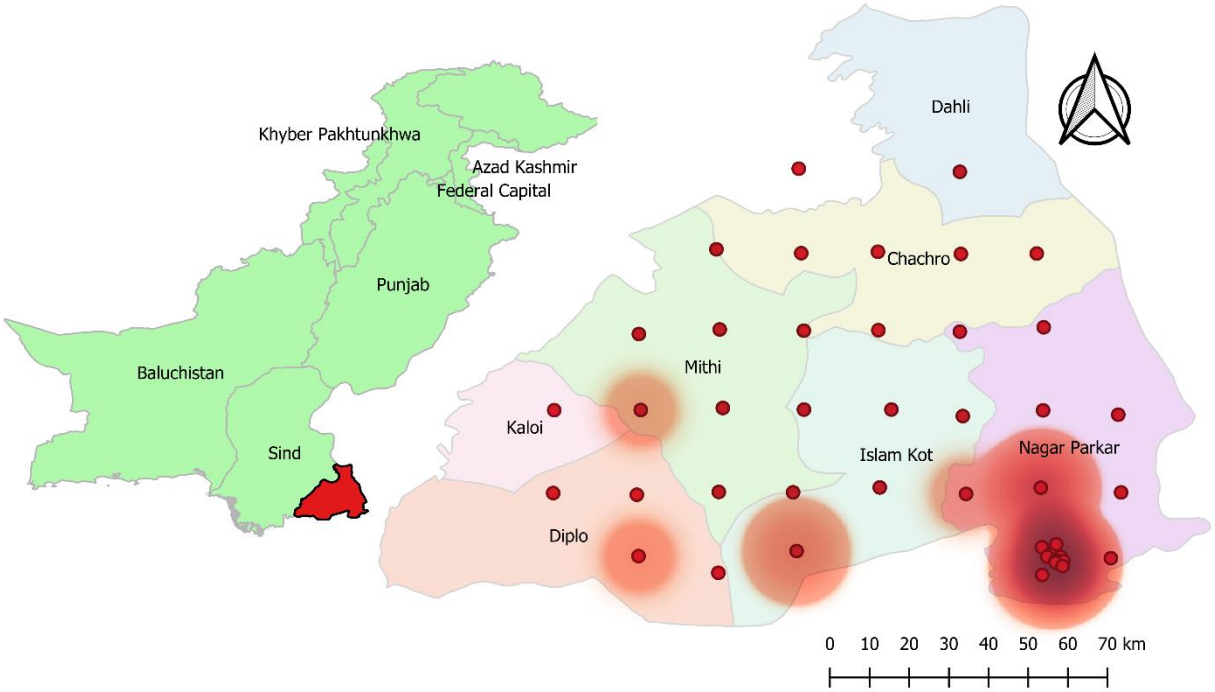

Figure 1. Map of Pakistan (left) showing the location of Tharparkar District (Thar Desert) in Sindh Province, and a detailed map of Tharparkar District (right) divided into seven subdivisions. Red points indicate the sampling sites, while the heat map illustrates the distribution of *Commiphora wightii*, with darker colors representing higher abundance per unit area.

The present distribution pattern implies that the Karoonjhar Hills may serve as critical refugial habitats for *C. wightii* (Figure 1). The rocky and rugged terrain likely provides ecological protection by reducing accessibility to livestock grazing and anthropogenic disturbance. In comparison to open sandy plains, hilly habitats experience relatively lower grazing pressure, potentially facilitating the survival and regeneration of seedlings and mature plants. Conversely, the sandy desert plains of Tharparkar are extensively subjected to continuous grazing, browsing, fuelwood collection, and habitat degradation, which may have contributed to the decline of the species from its former range.

The concentration of populations within rocky habitats further suggests the ecological preference of *C. wightii* for xerophytic environments characterized by shallow soils, rocky substrata, and low moisture availability. These habitats also support associated drought-adapted shrub communities that may provide favorable microhabitats for the persistence of the species

under extreme desert conditions. The patchy distribution and low abundance observed in the present study additionally indicate habitat fragmentation and insufficient natural regeneration across much of the Thar Desert landscape.

4.2 *Height and Diameter of Plants*

The analysis of plant height and canopy diameter of *C. wightii* populations recorded from various localities in Tharparkar revealed significant variation in plant size and growth structure. Plant height ranged from 21 cm to 195 cm, with a mean height of 123 ± 70.29 cm (1.23 ± 0.70 m), indicating substantial variability among individuals within the population (Figure 2). The frequency distribution demonstrated that approximately 42% of the recorded individuals were stunted, measuring less than 90 cm in height, while approximately 57.6% exceeded 160 cm. The predominance of taller individuals suggests that the current populations are largely composed of mature plants, with comparatively fewer intermediate-sized individuals observed.

Similarly, plant canopy diameter varied from 24 cm to 102 cm, with a mean diameter of 72.69 ± 27.9 cm (0.72 ± 0.27 m). Most mature individuals exhibited a broader canopy spread, reflecting well-established growth under relatively stable habitat conditions (Figure 2). In contrast, smaller diameter classes were represented by fewer individuals, indicating limited recruitment and poor establishment of younger plants in natural habitats.

The observed variation in height and diameter reflects differences in habitat conditions, grazing intensity, moisture availability, and plant age across the surveyed sites. Larger individuals were primarily recorded from the Karoonjhar Hills and associated rocky habitats, where reduced grazing pressure and lower anthropogenic disturbance may favor plant survival and growth. Conversely, stunted individuals were more prevalent in open sandy plains subjected to continuous browsing, drought stress, and habitat degradation.

The predominance of mature plants, coupled with the relatively lower proportion of young and intermediate-sized individuals, may indicate poor natural regeneration within the populations of *C. wightii* in Tharparkar. Continuous grazing pressure, fuelwood collection, and environmental stress under arid climatic conditions may inhibit seedling establishment and juvenile survival. These findings suggest that although some mature populations persist, the long-term sustainability of the species may be jeopardized if regeneration remains constrained.

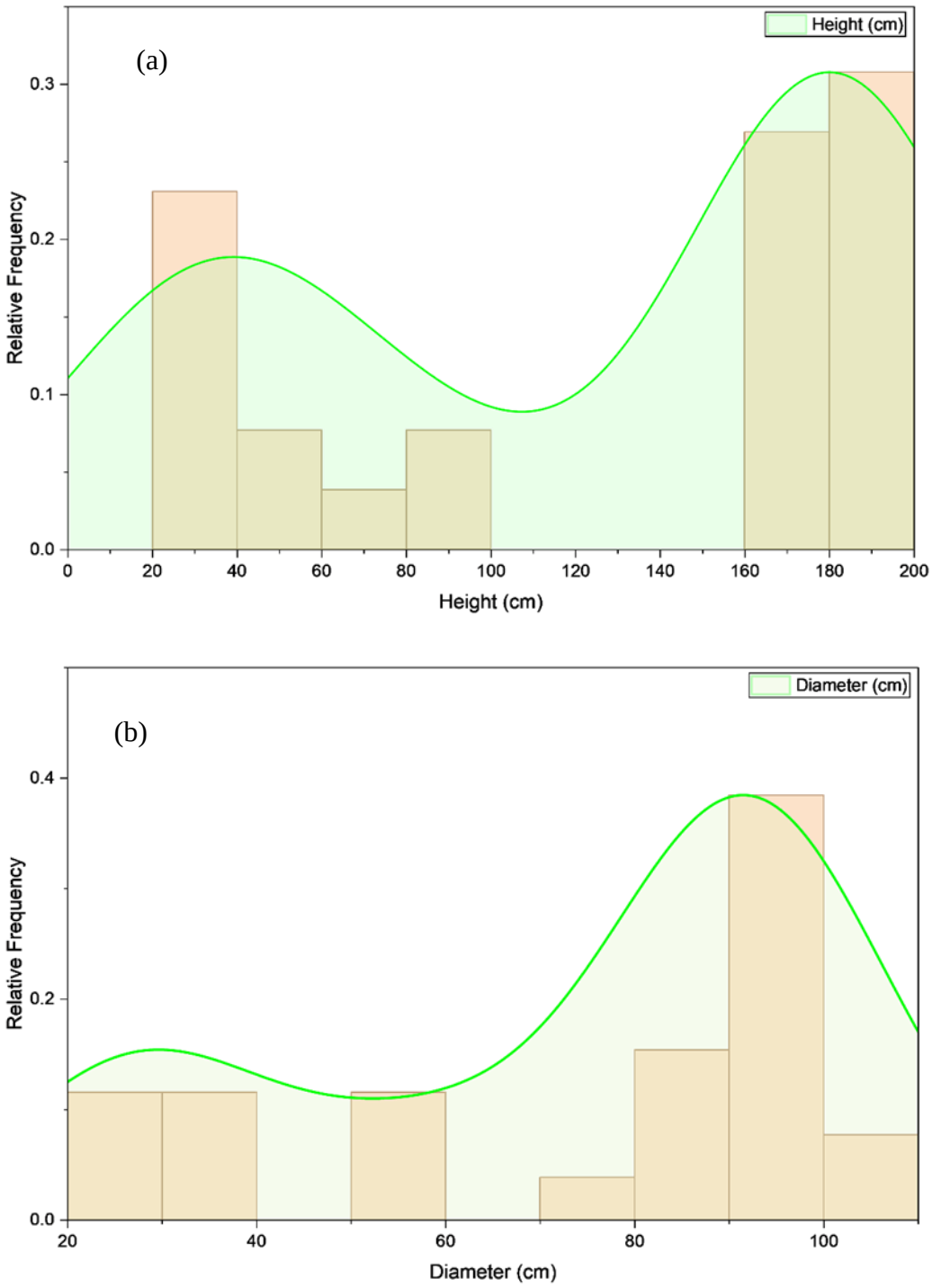

Figure 2 Structural parameters of *C. wightii* individuals documented during the study in Tharparkar District: (a) height and (b) canopy spread.

4.3 *Major Co-occurring Species*

The co-occurrence analysis revealed that *C. wightii* is intricately associated with the characteristic xerophytic vegetation of Tharparkar, frequently occurring within desert shrub communities that are specifically adapted to the harsh arid conditions of the region. The species demonstrated a recurrent association with several drought-tolerant shrubs, trees, and herbs, including *Prosopis juliflora, Euphorbia caducifolia, Crotalaria burhia, Aerva javanica, Grewia tenax, Citrullus colocynthis, Acacia senegal, Salvadora oleoides,* and *Leptadenia pyrotechnica* (Table 1) Collectively, these associated species represent a variety of habitats, including rocky hills, sandy plains, stabilized dunes, and dry thorn scrub, which dominate the desert ecosystem of Tharparkar.

Among the associated species, *Prosopis juliflora* (Mesquite) exhibited the highest frequency of co-occurrence with *C. wightii*, co-occurring at eight distinct sites. However, this association appears to be predominantly influenced by the invasive spread of *P. juliflora* throughout Tharparkar District, rather than indicating a natural ecological preference. As an invasive species, *P. juliflora* has rapidly proliferated across nearly all habitat types in the region, encompassing dunes, plains, agricultural lands, grazing areas, and rocky habitats where *C. wightii* is naturally found. Consequently, this invasion has led to extensive overlap with native vegetation communities and frequent co-occurrence with numerous desert plants. The invasion of *P. juliflora* may adversely impact native species through competition for water, nutrients, and spatial resources, thereby altering the natural structure of desert ecosystems.

A more robust ecological relationship was observed between *C. wightii* and *Euphorbia caducifolia,* which exhibited the highest Jaccard similarity value among all associated species (Table 1). Both species are integral components of rocky xerophytic scrub vegetation and are highly adapted to shallow soils, extreme temperatures, and prolonged drought conditions. Their recurrent co-occurrence suggests a strong habitat similarity, indicating that rocky hill ecosystems serve as critical refuges for native desert flora in Tharparkar.

The association of *C. wightii* with species such as *Crotalaria burhia, Aerva javanica*, and *Leptadenia pyrotechnica* further underscores its adaptation to sandy and dune-based habitats. These species are typically found on stabilized sand dunes and dry sandy plains, where moisture availability is severely limited. Their co-occurrence reflects ecological adaptation to desert environments characterized by nutrient-poor soils, elevated temperatures, and wind erosion. Furthermore, the presence of *Citrullus colocynthis* within these habitats reinforces the drought resistant nature of the associated vegetation community.

The co-occurrence with woody species, including *Acacia senegal, Salvadora oleoides,* and *Grewia tenax,* indicates that *C. wightii* is also linked to dry thorn forests and semi-arid scrub vegetation. Together, these species constitute an essential xerophytic woodland assemblage that stabilizes fragile desert ecosystems and supports biodiversity under arid climatic conditions.

The presence of these associated species suggests that *C. wightii* occupies ecotonal habitats situated between rocky scrublands and sandy desert plains.

Table 1. Joint occurrence sites and Jaccard similarity indices of plant species associated with *Commiphora wightii* in the study area.

Species	**Joint Occurrence Sites**	**Jaccard Similarity**
Prosopis juliflora	8	0.31
Euphorbia caducifolia	7	0.44
Crotalaria burhia	5	0.17
Aerva javanica	5	0.14
Grewia tenax	4	0.21
Citrullus colocynthis	4	0.19
Acacia senegal	4	0.15
Salvadora oleoides	4	0.13
Leptadenia pyrotechnica	4	0.11
Cressa cretica	3	0.23
Digitaria ciliaris	3	0.20
Aristida funiculata	3	0.17
Aristida adscensionis	3	0.13
Dactyloctenium aegyptium	3	0.13
Panicum turgidum	3	0.13

4.4 *Threats to the population of C. wightii*

Among the identified threats, destructive **gum extraction** is regarded as the most significant factor contributing to the decline of *C. wightii* populations. This species produces an economically valuable oleo-gum resin known as "guggul," which is extensively utilized in traditional medicine and herbal industries. Local collectors extract the resin by making deep incisions in the stems and branches of mature plants, often employing chemical methods to enhance gum exudation. Mature plants, typically around 5–6 years of age, are frequently subjected to repeated tapping, which compromises their health and often results in stem infections, desiccation, and eventual mortality. The harvested gum is sold through local intermediaries and subsequently transported to markets in Mithi before being distributed to

larger cities (i.e. Karachi). Prior research has similarly identified unscientific and destructive tapping practices as a principal cause of the decline in natural populations of *C. wightii*. Literature indicates that improper harvesting techniques, overexploitation for medicinal resin, and non-scientific tapping methods have significantly diminished wild populations across its natural range in India and Pakistan.

Heavy grazing pressure constitutes another major threat to the regeneration and survival of *C. wightii* in Tharparkar. According to estimates from the National Disaster Management Authority (NDMA), the livestock population in the region exceeds 6.5 million animals, while the carrying capacity of the desert rangelands remains exceedingly low, thereby exerting severe grazing pressure on local vegetation. During periods of drought, herders frequently relocate with their livestock to neighboring districts due to forage shortages. Continuous browsing by goats, sheep, camels, and other livestock inflicts direct damage on young seedlings and regenerating shoots of *C. wightii*. Field observations from the present study revealed a significantly lower presence of juvenile and intermediate sized individuals in comparison to mature plants, suggesting inadequate natural regeneration. Open sandy habitats subjected to intense grazing contained only sporadic individuals, whereas more intact populations persisted primarily in the rocky terrain of the Karoonjhar Hills, where livestock access is relatively restricted. Excessive grazing pressure may thus be a primary factor contributing to the species' decline in extensive areas of its former range in the sandy desert plains.

Habitat conversion and land-use change also significantly contribute to the decline of *C. wightii*. Natural rangelands and desert scrub habitats are increasingly encroached upon and transformed into agricultural land to accommodate the growing human population in Tharparkar. The expansion of cultivation into previously uncultivated desert areas has led to the removal of native vegetation, habitat fragmentation, and a reduction in suitable habitats essential for the species' survival. Such habitat degradation not only diminishes population size but also isolates remnant populations, thereby restricting natural regeneration and gene flow among populations.

The proliferation of **invasive species**, particularly *P. juliflora*, presents an additional ecological threat to native populations of *C. wightii*. During the present study, *P. juliflora* exhibited the highest co-occurrence with *C. wightii*, primarily due to its aggressive colonization of nearly all habitats in Tharparkar, including rocky hills, sandy plains, grazing lands, and disturbed environments. The dense growth of *P. juliflora* may alter the structure of native vegetation and intensify competition for water, nutrients, and space under already moisture stressed desert conditions. Literature similarly recognizes the invasion by non-native species as a contributing factor to habitat degradation and the population decline of *C. wightii*.

In addition to anthropogenic disturbances, several **ecological and biological limitations** further jeopardize the survival of the species. *C. wightii* exhibits slow growth rates, low seed viability, poor germination rates, and weak natural regeneration in arid conditions. Environmental

stresses such as prolonged drought, low rainfall, soil erosion, and climatic variability further hinder regeneration success and the survival of young plants. The present study also observed an aging population structure characterized by a predominance of mature individuals, with relatively few juvenile plants, indicating ongoing regeneration failure in natural habitats.

5. CONSERVATION INTERVENTIONS AND STRATEGIC RECOMMENDATIONS

The wild populations of *C. wightii* in Tharparkar have historically experienced a continuous decline toward extinction. In recognition of its increasing vulnerability, the species was classified as Vulnerable in 1998 and subsequently elevated to Critically Endangered (CR) on the global IUCN Red List of Threatened Species in 2015 (Ved et al., 2015). To halt this decline and secure the recovery of this economically and ecologically significant medicinal plant, an urgent and comprehensive conservation strategy that integrates in-situ protection, ex-situ propagation, sustainable utilization, and communityled governance must be implemented.

The following is a detailed elaboration of the strategic conservation actions required to ensure the survival and long-term viability of *C. wightii* in Tharparkar.

5.1 *Establishment of Protected Areas and Species-Specific Recovery Plans*

To safeguard remaining wild populations from localized extinction, it is essential to establish micro-habitats and conservation zones within known biodiversity hotspots in Tharparkar. Areas exhibiting surviving clusters of the species, such as the rocky terrains of the Karoonjhar Hills in Nagarparkar and specialized hyper-arid sand dunes, must be mapped using Geographic Information Systems (GIS) and formally designated as protected areas under the existing Forest Act.

Furthermore, a legally backed, dedicated recovery plan tailored for *C. wightii* must be developed. This plan may establish specific, measurable targets for population recovery over a 10-year period, coordinate actions across multiple departments, prohibit unauthorized wild harvesting, and restrict heavy infrastructural development or mining activities within these ecologically sensitive zones.

5.2 *Ex-Situ Conservation: Native Plant Nurseries and Seedling Propagation*

Given that *C. wightii* exhibits poor natural seed germination and high sapling mortality under hyper-arid conditions, systematic ex-situ propagation is essential for habitat restoration.

Decentralized, state-of-the-art native plant nurseries should be established across key talukas in Tharparkar (Mithi, Nagarparkar, Islamkot, Chachro). These nurseries will specifically focus on preserving the local germplasm of indigenous desert flora.

Due to low seed viability (15%–18%), propagation protocols should primarily rely on vegetative stem cuttings. Utilizing healthy, semi-hardwood cuttings treated with root-inducing growth hormones (such as Indole-3-Butyric Acid, or IBA) can significantly enhance rooting success. Concurrently, academic research should be employed to break seed coat dormancy through mechanical scarification and hormonal soaking, thereby gradually diversifying the genetic pool of nursery-raised stocks.

5.3 *In-Situ Habitat Management: Bio-Enclosures and Rangeland Restoration*

The considerable pressure from livestock in Tharparkar poses a significant challenge to seedling establishment. Passive restoration through localized exclusion zones presents the most viable solution.

Strategic plots within communal rangelands should be cordoned off using bio-fencing. The construction of community bio-enclosures can be achieved using thorny native species such as *Euphorbia caducifolia, Acacia senegal, Ziziphus numularia,* and *Prosopis cineraria* (Kandi) around the perimeter.

These bio-enclosures will function as livestock-free sanctuaries for a minimum of 5 to 7 years. By eliminating grazing and trampling pressures within the enclosures, the natural soil seed bank will be allowed to recover, and nursery reared *C. wightii* saplings can be reintroduced through enrichment planting, ensuring they reach maturity without being browsed

5.4 *Cultivation and Commercialization of Priority Medicinal Plants*

To address the unsustainable exploitation of wild forest resources, *C. wightii* must transition from a species reliant on wild foraging to one that is cultivated within agroforestry systems.

- ***Agroforestry Integration*:** It is essential to incentivize farmers to incorporate *C. wightii* as a priority medicinal crop along the peripheries of their traditional agricultural fields (bunds) or within mixed-cropping arid farming systems.

- ***Market Integration and Economic Incentives:*** Establishing transparent buy-back agreements between local farmers and certified pharmaceutical or herbal industries will enhance the economic viability of cultivation. Cultivating this plant on private lands will create a legal, traceable supply chain that directly addresses the economic incentives for the illegal harvesting of wild populations.

5.5 *Capacity Building: Sustainable Gum Tapping Techniques and Harvester Training*

The elimination of destructive, chemically-assisted tapping methods that lead to high plant mortality is critical for the immediate survival of mature wild populations.

- ***Development of Non-Lethal Tapping Protocols***: It is necessary to establish standardized, non-destructive tapping guidelines grounded in scientific forestry practices. These guidelines should include limitations on cuts to shallow incisions confined strictly to the bark (without penetrating the inner cambium layer), regulation of the number of cuts per plant based on stem girth, and an absolute prohibition on lethal chemical irritants, such as copper sulfate.

- ***Grassroots Training Workshops***: Field-based training programs must be implemented for traditional gum collectors. Harvesters will be instructed in the use of specialized, standardized tapping tools and educated on the importance of mandatory rest periods (e.g., harvesting only once every two years per plant during optimal seasonal windows) to facilitate the natural healing of the plant's secretory ducts.

5.6 *Public Awareness Campaigns and Community Engagement*

Successful conservation efforts necessitate the active participation and stewardship of the indigenous communities residing in the Thar Desert.

- ***Cultivating Environmental Stewardship:*** Comprehensive awareness campaigns should be launched across villages, schools, and local community gatherings (Oataks). These initiatives must emphasize the critical ecological role of *C. wightii*, its endangered status, and its long-term economic value when managed sustainably.

- ***Revitalization of Traditional Ecological Knowledge (TEK***): The integration of modern scientific methodologies with the traditional conservation ethics of local communities (such as historical reverence for sacred groves and communally protected rangelands) will establish a culturally resonant conservation framework that fosters community pride and self-regulation.

5.7 *Institutional Synergy: Collaboration among Local Authorities*

A fragmented approach cannot adequately address the scale of the threats facing this species. A coordinated institutional framework is required to bridge policy and field execution. It is essential to facilitate seamless operational coordination among various departments, including the Local District Government, the Sindh Wildlife Department, the Sindh Forest Department, and law enforcement agencies. This alliance is crucial for the strict enforcement of the protective provisions of provincial and national laws and for monitoring transit checkpoints to intercept illegal smuggling routes originating from Mithi.

OUTPUTS OF THE PROJECT

1. ***Research Publication***: The findings generated through this project have been compiled into a scientific manuscript and submitted to a peer-reviewed journal for publication. The publication will contribute to the global body of knowledge on the ecology, conservation status, and management of *Commiphora wightii*, while increasing the international visibility of conservation challenges facing the species in Pakistan.

2. ***Communication of Conservation Recommendations to Relevant Authorities***: A detailed report outlining the current status of *Commiphora wightii*, major threats to its survival, and priority conservation measures has been shared with local government authorities and relevant departments. The recommendations are intended to facilitate evidence-based decision-making and encourage immediate conservation actions for the protection and recovery of remaining populations.

3. ***Production of Awareness Video***: A short educational video highlighting the conservation status, ecological importance, and current threats facing *Commiphora wightii* will be disseminated through online platforms, including YouTube. The video will serves as an accessible outreach tool to raise public awareness and promote community participation in species conservation.

4. ***Dissemination of Photographic Documentation*****:** Photographs documenting natural habitats, field surveys, and populations of *Commiphora wightii* have been shared through internet-based platforms and social media channels. These visual materials have contributed to broader public awareness and have helped showcase the ecological significance and conservation concerns associated with the species.

5. ***Community Awareness and Environmental Education Activities***: Awareness sessions were conducted with local communities, resource users, and school students during field visits throughout the project period. These engagements enhanced understanding of the ecological value of *Commiphora wightii*, promoted responsible resource use, and encouraged local stewardship for the conservation of biodiversity in the Thar Desert.

6. ***Establishment of a Baseline Dataset for Future Conservation Efforts***: The project generated the first systematic dataset on the distribution, population structure, habitat associations, and threats affecting *Commiphora wightii* in Tharparkar. This information provides a scientific baseline for future monitoring, habitat restoration initiatives, and species recovery programmes.

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Pictures during filed study