

JALTHAL BIODIVERSITY APPROACH

Conservation of Plant Diversity with Emphasis on Rare and Threatened Trees in Jalthal Remnant Forest



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Conserving the last standing tree *in situ*: *Dillenia indica* is a very rare tree in Jalthal forest. Only three living trees exist in the forest.

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Cover photo: *Cycas pectinata*, a vulnerable species, growing from a lateral bud after its top was cut.

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Abstract

Biodiversity conservation efforts often prioritise the charismatic megafauna, top predators, threatened mammals and birds for conservation actions. Plant species have also faced unprecedented threats with many species at risk of extinction and are in need of immediate conservation action. However, conservation efforts are often inadequate for effective conservation of plant species, particularly in managed forests. This paper identifies plant species that are rare, threatened, locally prioritised and act as keystone species, and discusses their conservation in the biodiversity-rich but degraded remnant forest of Jalthal. The assessment of the conservation status of these species is based on ecological sampling, workshops with the local people, forest transect walks including onsite interviews with local people and literature review. Taking into account the rarity, threat, regeneration status and biogeographic significance of trees, we propose overall approach and species-specific strategies for the conservation of rare and threatened trees. These approaches and strategies, in turn, will be used as a guiding framework for conserving tree species through various interlinked field actions in Jalthal forest. These proposed approaches, fine-scale data coupled with regional biogeography, can be equally useful for other forest species as well.

1. Background

Jalthal is a 6100-hectare rectangular block of forest surrounded by settlements and agricultural fields. This forest island is the largest remnant of the once contiguous, lush and dense forest known as the *Charkoshe Jhadi*. The forest spans an elevation range of 60 to 120 meters above sea level and features the lowest altitudinal forest in Nepal. It is a moist tropical forest that largely consists of floristic elements from the Indo-Malayan Floristic Region (Thapa *et al.* 2003). Jalthal forest is primarily a sal (*Shorea robusta*) forest, with sal present in both pure and mixed stands. Sal dominance is increasing in successional stands. Similarly, heterogeneity in old-growth stand is decreasing with increased dominance of sal trees due to a higher protection of sal trees because of the high value of their timber. The forest also has elements typical of tropical evergreen forest, particularly in depressions and along moist gullies.

Jalthal forest is known for the richness of its flora and fauna. Recent studies have documented over 600 species of plants including ferns (Sharma *et al.* 2021, Poudel 2022, Sharma *et al.* 2024). The forest is also home to several threatened species of fauna, such as the endangered Asiatic elephant (*Elephas maximus*), critically endangered Chinese pangolin (*Manis pentadactyla*), and elongated tortoise (*Indotestudo elongata*). The forest features four species of plants (all trees) listed in the IUCN Red List of threatened species, including a notable population of *Cycas pectinata* (Sharma *et al.* 2021).

Although Jalthal forest is diverse it is also degraded. Past land use has caused degradation of the forest and this is ongoing. The most serious impacts on Jalthal occurred following the Tarai resettlement program, which began in the 1960s. First, the forest was fragmented and the remaining patches gradually degraded, a process which continues today. Degraded areas of the forest are heavily impacted by the biological invasion of species such as *Mikania micrantha* (Nep: Pyangri lahara, Lahare banmara), *Chromolaena odorata* (Nep: Seto banmara) and *Lantana camara* (Nep: Kande banmara) (Sharma *et al.* 2021).

Jalthal Forest has been managed as community forest since 2003, and has gained improvements in forest cover and tree density. However, community

forest management remains narrowly focused and prioritises the high-value timber species, sal. Unfortunately, due to the limited nature of the conservation activities in Jalthal, its rare and endangered plant species have not received the required attention.

This technical paper has been prepared to discuss the management interventions directed towards the conservation of the locally prioritised, rare and threatened trees of Jalthal. It first identifies locally prioritised, rare and threatened tree species for conservation. Following a brief overview of the current practices and the challenges to plant conservation in Nepal, it proposes actions that target the conservation of those species. This document, in turn, guides the field interventions for the conservation of plant resources in the Jalthal Biodiversity Project which is supported by the UK's Darwin Initiative. The lessons learned in this conservation programme, which is based on sound ecological principles and strong community engagement, have important implications for conservation far beyond Jalthal's boundaries.

2. Species prioritised for conservation action

We selected 30 species, 28 of which are trees, for conservation action. Multiple criteria were used to select these species. These included local conservation workshops (10 species), IUCN red list (3 species), rarity analysis (17 species), locally threatened and facing one or more impediments to regeneration (19 species). Three species that are neither threatened nor rare but crucial for maintaining forest biodiversity were also selected for conservation. Species may belong to more than one category.

2.1 Rarity of trees: Trees are a key component of every healthy forest ecosystem. They provide a myriad of ecosystem services from direct-use products to regulatory services (BGCI 2021). Trees are the sources of many products, ranging from timber to medicines used in traditional healing practices. The Global Tree Assessment (BGCI 2021) reported that one in every five tree species is directly used by people. They also contribute to regulating the global climate by sequestering carbon and acting as a carbon sink. Similarly, trees play a significant role in maintaining local and regional

hydrological cycles, impacting precipitation, humidity and temperature. They also act as buffers against climatic extremes and are vital biodiversity reservoirs, supporting the diversity of life from roots to canopy through bark and trunk. Trees are essential for resilient social and ecological systems in the face of the biodiversity and climate crisis.

However, industrialization, urbanization and agricultural development during the last six decades have threatened trees and forested habitats in Nepal's lowlands. Past land use has left a remarkable footprint on forest and tree diversity. Threats to trees are still high in the areas of congruence of high diversity and high poverty. According to the Global Tree Assessment (BGCI 2021), over one-third of tree species are threatened with extinction globally. However, all trees are not equally threatened and threats vary among species and localities.

A forest ecosystem consists of many species and in a diverse forest, there can be several thousand species of varying abundances. The species abundance patterns of trees have been well-studied, and different models have been proposed to predict the distribution patterns. In tropical forests, many of the trees belong to only a few dominant or abundant species, while the majority of species are present at very low frequencies (Cooper *et al.* 2024), and the huge diversity in such forests is

due to the rare species (Hubbell 2013). Locating and identifying the rare species in such forests and determining the classes of rarity (Rabinowitz 1981) is crucial for conservation. Trees that have a small local population, a narrow distribution range and are habitat-specific tend to be rare in forests. The rarity of trees in forests could be an outcome of land use history or the biological traits of species or an interaction between them.

Area-based ecological sampling can provide important information about species richness, diversity, density and frequency of species, and is useful in analyzing forest structure and composition. These samples are also widely used to analyze the relationship between species diversity and productivity and relationship with environmental variables. However, this sampling may be ineffective for recording trees which occur at very low frequencies (Piers *et al.* 1953), and it needs to be combined with taxonomic inventories to adequately document rare tree species (Ellis and Coppins 2017).

2.2 Rare trees of Jalthal: Ecological sampling across the 228 plots recorded 3,982 individual stems of trees with a diameter at breast height (DBH) exceeding 5 cm, belonging to 114 tree species. Among these, 42 species were recorded only once (Fig. 1), and a further 12 species were only found

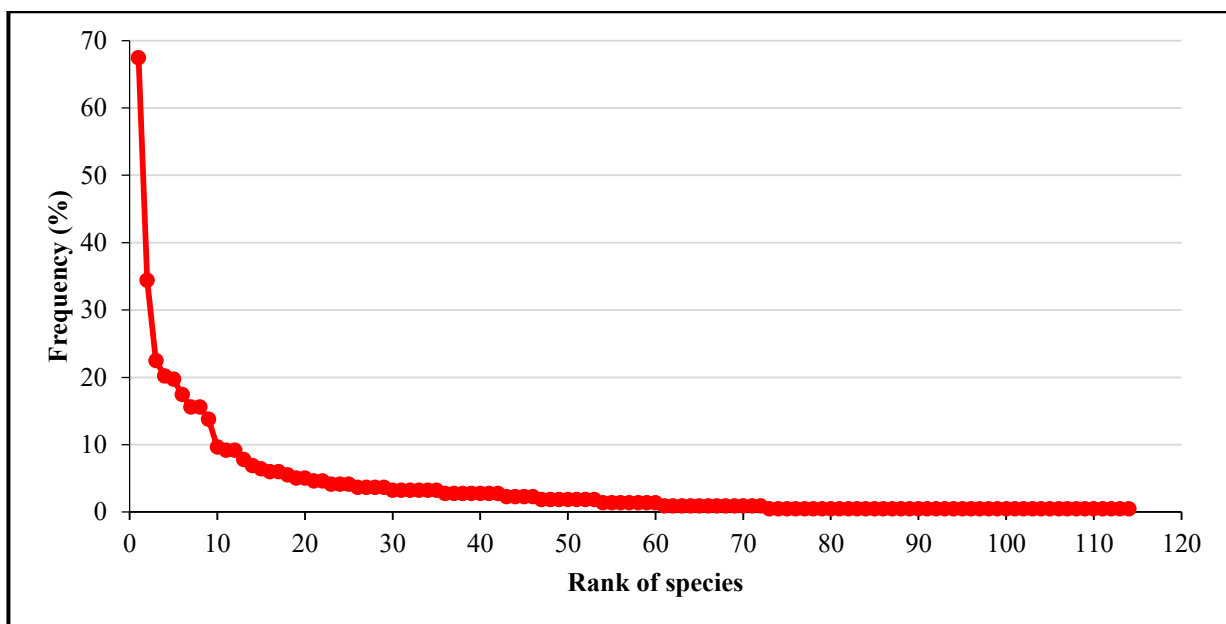


Fig. 1. Frequency rank of tree species of Jalthal, species ranked after 72 are singleton.

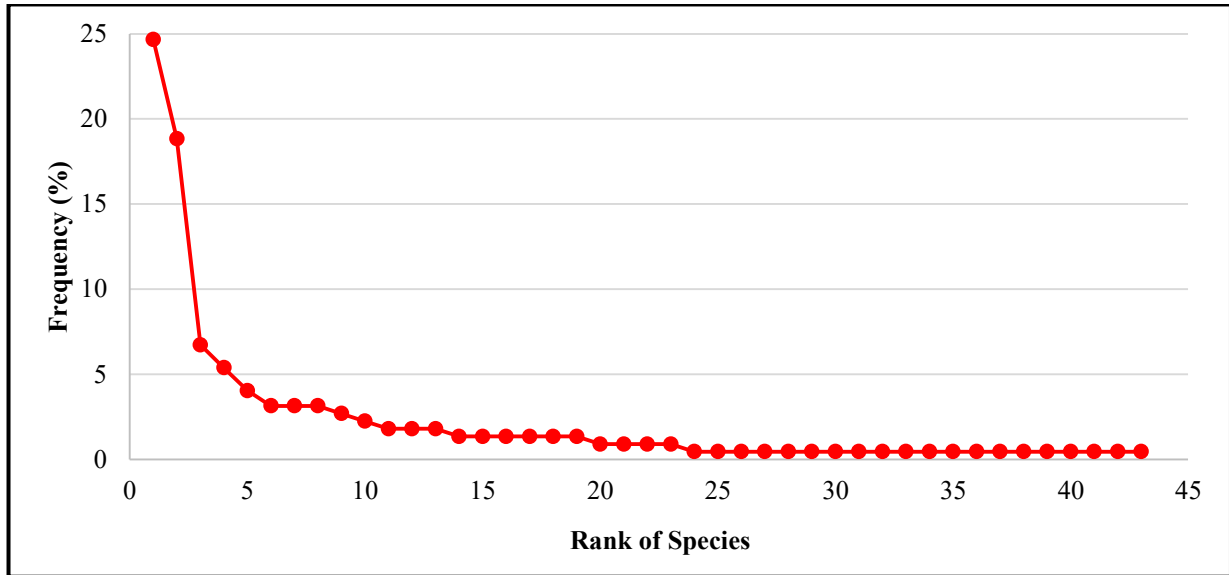


Fig. 2. Frequency rank of species in sapling layer.

twice. *Shorea robusta* was the most frequent and abundant species, and was present in 64% of plots. At the Sapling (height more than 1.5 m and DBH between 2.5 to 5 cm) strata, we found 43 species, of these, 20 were found once only (Fig. 2).

Our taxonomic survey and on-site transect walk with local people significantly added to the species list derived from ecological sampling, with an additional 41 species, bringing the total number of tree species to 155.

We have selected 30 species for conservation and propagation management within Jalthal forest

(Appendix 1). The rarity and commonness of these species has been evaluated using the Rabinowitz (1981) scheme, as detailed in Table 1. Global/regional/national distribution data for these species was obtained from secondary sources (Shrestha *et al.* 2022, GBIF 2023, POWO 2023) and our own ecological data was used to estimate local populations and their habitat specificities. Species with distribution in two or less floristic regions (following Welk 2015) were considered to have a smaller geographical range.

As expected, we found more rare species (class

Table 1: Classes of rarity after Rabinowitz (1981) provided with rarity ranks following Yu and Dobson (2000).

GEOGRAPHIC RANGE		Large		Small	
HABITAT SPECIFICITY		Wide	Narrow	Wide	Narrow
LOCAL POPULATION SIZE	Large, dominant somewhere	A (4) <i>Emblica officinalis</i> <i>Ficus racemosa</i> <i>Schima wallichii</i> <i>Syzygium cumini</i>	B (3) <i>Artocarpus chama</i>	E (3)	F (2)
	Small, non-dominant	C (3) <i>Bhesa robusta</i> <i>Canthiumera glabra</i> <i>Dalbergia latifolia</i> <i>Ficus semicordata</i> <i>Homalium ceylanicum</i> <i>Ougeinia oojeinensis</i> <i>Phanera scandens</i> <i>Phoenix loureiroi</i> <i>Prunus ceylanica</i> <i>Tamilnadia uliginosa</i> <i>Terminalia chebula</i>	D (2) <i>Baccaurea ramiflora</i> <i>Bombax ceiba</i> <i>Canarium strictum</i> <i>Dillenia indica</i> <i>Garcinia cowa</i> <i>Garcinia xanthochymus</i> <i>Gynocardia odorata</i> <i>Magnolia champaca</i> <i>Pinanga gracilis</i> <i>Pterygota alata</i>	G (2) <i>Cycas pectinata</i>	H (1) <i>Cinnamomum tenuipile</i> <i>Horsfieldia kingii</i> <i>Sarcosperma arboreum</i>

*Rank of 1 indicates the highest degree of rarity.

B-H) than common ones (Class A), among the selected species. The majority of these rare species found in Jalthal tend to have a larger geographic range with non-dominant small local populations (C3 and D2). Thus, local rarity does not mean that species is rare in the global context.

2.3 Local prioritisation of species for conservation: Local people have long interacted with forest biodiversity and their observations of changes in plant populations can provide important insights for conservation priorities. Four workshops were organized for a total of 60 local people, and recognized 35 species of plants as priorities for conservation. Locals prioritised species on various criteria- abundance, changes in abundance over three decades, local usefulness and threats. Among locally prioritised 35 species, ten tree species were selected for propagation management and conservation actions at Jalthal.

2.4 Regeneration problems of trees: Problem with the regeneration of a tree species may apply at various stages of the life cycle. The regeneration process can be considered to begin with flowering, including pollination, fertilization and seed set, dispersal and germination of the seed, seedling establishment, maturation to mature trees, and the repeating of this cycle (Grubb 1977). Many of the tree species in Jalthal have problems at one or more stages of the regeneration process (Table 2). It should be noted that the problems we have identified predominantly rely on observation and ecological sampling, rather than the experimental data.

Jalthal forest has been subjected to low-intensity anthropogenic disturbances for centuries. However, pressure on the forest for biomass increased abruptly over the last five decades with the increase in migration from the Midhills to the Tarai and the population surge in lowland Nepal. This pressure has caused significant problems for tree regeneration. The impact of biomass pressure often leads to the gradual, barely perceptible, degradation of forests, resulting in a chronic disturbance (Singh 1998) rather than a discrete event of tree felling or deforestation.

Trees which have evident regeneration problems and are subject to biomass pressures are considered as locally threatened species.

2.5 Species supporting other species: We identified forest biomass extraction, mainly lopping and the cutting of saplings for fodder, as an immediate threat to rare species in Jalthal forest. Therefore, we have identified key fodder species whose proper management in forest and in private land can play a positive role for forest biodiversity. *Ficus racemosa* and *Ficus semicordata* fall into this category. Similarly, we have also considered keystone species which are important for the survival of other species of plants, pollinators and seed disperser fauna. *Bombax ceiba* is an example of this category.

3. Conservation of rare trees in Nepal

Nepal has taken diverse approaches, both *in situ* and *ex situ*, for biodiversity conservation and made

Table 2: Problems associated with natural regeneration of trees in Jalthal, some examples here may not be covered in 30 species of Appendix 1.

S.N.	Nature of the problem	Details of the problem	Species in the categories
1	Seed germination	Mature trees are present and sufficient seeds are produced, but seeds fail to germinate in the wild	<i>Prunus ceylanica</i> , <i>Cinnamomum tenuipile</i> , <i>Bhesa robusta</i> , <i>Castanopsis indica</i> , <i>C. lanceifolia</i> , <i>Terminalia chebula</i> , <i>Zanthoxylum rhetsa</i>
2	Seedling establishment	Seeds germinate into seedlings, but they fail to grow into saplings	<i>Artocarpus chama</i> , <i>Garcinia xanthochymus</i> , <i>Horsfieldia kingii</i>
3	Fruit set and maturity	Fruits are formed, but they do not reach maturity or do not produce viable seeds	<i>Magnolia champaca</i> , <i>Baccaurea ramiflora</i> , <i>Canthiumera glabra</i>
4	Lack of fruiting (mature) individuals	There are few individuals that do not reach maturity, and are unable to regenerate	<i>Garcinia cowa</i> , <i>Phoenix loureiroi</i> , <i>Dalbergia latifolia</i> , <i>Dillenia indica</i> , <i>Ougenia oojensis</i>
5	Pollination or fertilization problems	In dioecious trees, genetic, phenological or physical barriers limit pollination	<i>Cycas pectinata</i>

legal and institutional arrangements to promote it (Dhakal *et al.* 2018, MoFSC 2014). Area-based conservation approach is one of the priority strategies of Nepal's biodiversity conservation. The National Parks and Wildlife Conservation Act (1973) provides a legal foundation for establishing protected areas and conservation of species. So far, Nepal has established a network of protected area systems extending from lowland Tarai to the high mountains, covering 23.39% of the country's total land (DNPWC 2022).

Nepal is also party to several multilateral environmental agreements (MEAs) like CBD (Convention on Biological Diversity) and CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), which shows the Nepal government's commitment to biodiversity conservation (MoFSC 2014, MoFE 2018). The CITES Act 2017 prevents the trade of threatened fauna and flora and regulates the international trade of CITES-listed species.

The Community Forestry Program is a priority program of the Nepal government, and covers one-third (2.65 million hectares) of the national forests, engaging over 22 thousand CFUGs (FECOFUN

2023). This is an important program for biodiversity conservation outside protected areas. Similarly, there are areas where local communities and indigenous communities have played a role in conserving biological diversity (Jana and Paudel 2010).

Furthermore, the government of Nepal initiated the National Tree Seed Project (NTSP) in 1982, under the Tree Improvement Section of the Department of Forest to increase the diversity of tree species. Within this programme the establishment of Seed Orchards, Seedling Seed Orchards (SSO), Breeding Seed Orchards (BSO) and Tree Improvement Stands (TIS) in different places supports the genetic improvement and safeguarding of tree species diversity. BSO of *Choerospondias axillaris* and *Dalbergia sissoo* have now been established at various locations across Nepal (Amatya and Shrestha 2022).

3.1 Conservation through nurseries and plantation:

Nepal has an extensive network of plant nurseries, but there is a lack of coordination in their activities and the plantation programmes they support, with no systematic review of their status and the seedling species grown. Nurseries vary widely in terms of their ownership and objectives (Pandit

Table 3: Major types of nurseries operating in Nepal.

S.N.	Nurseries categories and major objectives	Ownership	Remarks
1	Floriculture nurseries/ For ornamental species	Private	Commercial nurseries that produce flowers for garden and domestic decoration. Such nurseries are in cities and produce many exotic flowers.
2	Forest nurseries/ For forest extension services	Government (DoF, DPR), Community forests	Produce seedlings of trees, mainly of timber, some fodder and horticultural species; primary for forest plantation commonly using exotic species like <i>Pinus patula</i> , <i>Tectona grandis</i> and <i>Eucalyptus</i> spp. <i>Cinnamomum tamala</i> and native fodder trees like <i>Artocarpus lacucha</i> are also grown. Have relatively little interest in conservation; rare and threatened trees are rarely grown. Has been a recent increase in the production of fodder species.
3	Botanical nurseries/ For conservation, education, research and ornamental plants	Botanical gardens (Department of Plant Resources-DPR)	Mostly native plants for conservation, education and plantation; focus on medicinal plants and NTFPs; rare and threatened species are planted throughout Nepal via 12 Botanical Gardens ranging from Tarai to the Mountains; a rare species- <i>Gnetum montanum</i> and some tree ferns are propagated in DPR garden facilities; rare plants of lowland Nepal are not well covered.
4	Horticulture nurseries/ For extension of fruit trees and other common horticulture species	Government, Private	Mainly for commercial and horticulture extension purpose (various species of citrus, mango, litchi, etc.).
5	Farmer's nurseries/ For common horticulture species, forest trees and fodder	Farmers and enthusiasts	Mainly produce forest trees, fodder and horticultural species; such nurseries are relatively few, though one such exists in Jalthal.

et al. 2020), with the five main types have been summarized (Table 3). These nurseries produce millions of seedlings annually. In the year 2019, the Government of Nepal organized campaign for the plantation of fifty million seedlings in a year. An assessment has estimated that over 1.36 billion seedlings were produced and distributed between 1978 to 2017 (Lamsal *et al.* 2020).

Although these diverse nurseries produce and distribute young plants of various kinds throughout the year (Tamrakar 2004), they primarily focus on commercial trees, selected high-value non-timber species, and some horticultural trees. Many, including the government nurseries, produce seedlings of exotic species, mainly Teak (*Tectona grandis*) and *Eucalyptus* spp. An assessment of nurseries reported that over half of the planted species are exotic (Acharya 2018). Based on the available literature and data from species in plantations, it is evident that nurseries focused on commercial timber and high-value non-timber species, while rare and threatened trees are rarely grown.

Botanical Gardens under the Department of Plant Resources (DPR) have conserved several endemic species and IUCN red-listed and CITES-listed tree species. DPR also maintains a collection of seeds of various tree species (NBG 2023). DPR nursery facilities, however, have not assessed the regeneration status or initiated conservation actions for threatened trees. A few selected threatened species, e.g. *Taxus wallichiana* and *Pterocarpus marsupium*, are used in extension plantations, but these are primarily for economic reasons and any conservation interest is secondary.

4. Conservation of rare trees: Jalthal approach

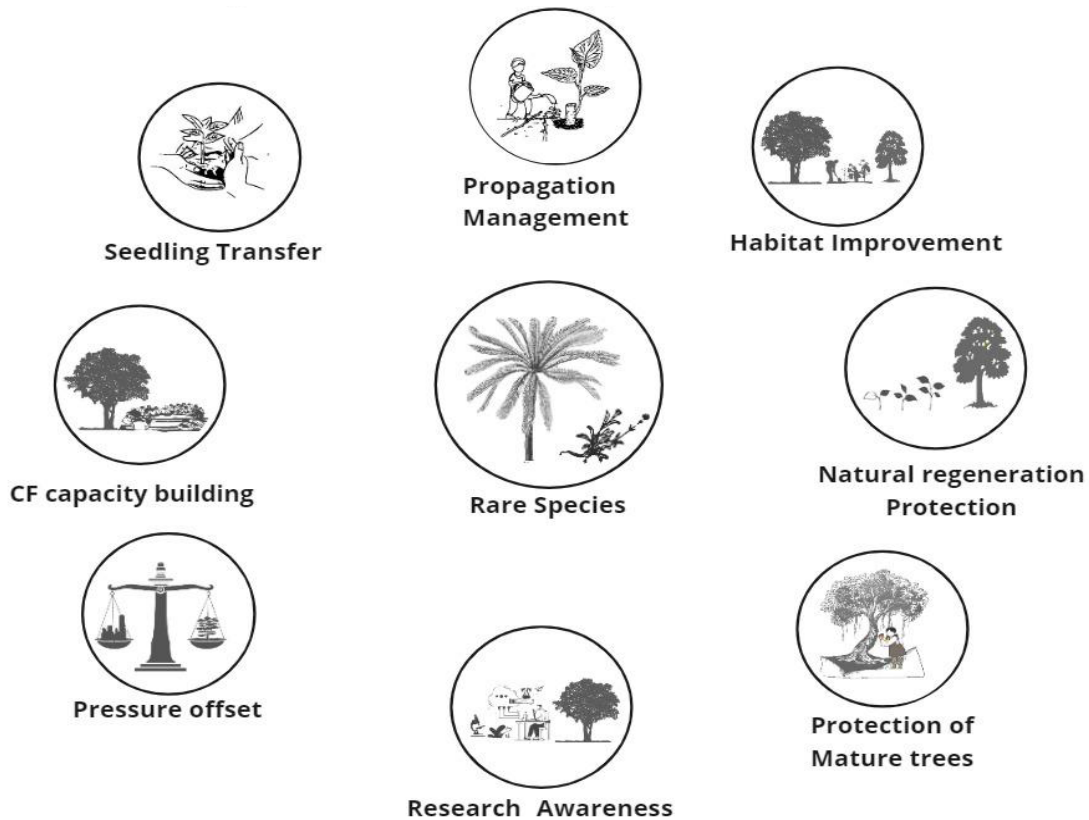
The current management of Jalthal forest by CFUGs have done much to protect the forest through the prevention of encroachment, regulation of the collection and distribution of forest products, grazing bans, regulation of forest use, plantation of tree seedlings, proactive and reactive responses to fire, and control of tree felling and illegal hunting. As a result of these activities forest canopy and tree density has increased. However, management is heavily focused on timber production and prioritises the dominant structural species, sal. Despite the protection of the forest and its key

structural features, tree diversity and rare and threatened trees are not adequately protected (Sharma *et al.* 2021, Sharma 2022). In addition, there lacks cooperation among CFUGs in regard to biodiversity conservation. Drawing from existing practices and building on our ecological data and taxonomic surveys, we have identified the urgent need for targeted conservation of plant diversity in Jalthal forest.

We will consider, promote and support for overall biodiversity conservation in Jalthal through various actions like forest restoration, invasive species management, plant propagation, habitat conservation and management, biomass pressure offset, awareness and education, etc. We will consider following guidelines for rare trees and overall biodiversity conservation in Jalthal. These guidelines, in turn, are aligned with broader conservation and restoration guidelines (Di Sacco *et al.* 2021, Pascaul *et al.* 2021).

- a) Retain and protect existing old growth trees, habitat trees and old growth forest patches
- b) Prioritize natural regeneration over plantation, in case of plantation promote local seed provenance
- c) Species are best protected in their natural habitats
- d) Restoration of natural habitat supports species conservation
- e) A good population of a species is required for its long-term conservation
- f) Pluralistic approaches contribute to achieving wider conservation goals
- g) Engage with local people and acknowledge them as stewards of biodiversity conservation
- h) Collaboration among diverse stakeholders enhances the sustainability of conservation
- i) Invasive species have negative effects on forest biodiversity

For the conservation of rare and threatened trees of Jalthal, we identify such trees and trees that require special attention, strengthen existing good practices, and propose diverse strategies appropriate for our target species. These strategies are not isolated, but rather framed within the broader objective of forest restoration and biodiversity conservation. These strategies, in turn, should be an integral part of CF management plans.



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Fig. 3. Diverse activities contributing towards conservation of rare and threatened plants in Jalthal forest.

While we work for overall biodiversity conservation, the conservation actions proposed below are expected to contribute to taking targeted and species-specific actions based on ecological and biological needs (Fig. 3). The Jalthal biodiversity project will collaborate with key actors in organizing and implementing these activities in the forest. DFO Jhapa and CFUGs are key stakeholders in the management of this unique forest island.

4.1 *In situ* conservation: *In situ* conservation is the conservation of species in their natural habitats. To conserve rare and threatened species of Jalthal, we will prioritise *in situ* conservation to reverse population declines. Three key activities have been proposed and are being organized to support *in situ* conservation.

4.1.1 Protection of key habitats, species and structures: *In situ* conservation involves the protection of key habitats that host unique and rare species of plants. In Jalthal, wet gullies are key habitats that harbor tropical evergreen forest species. Wet gullies and riparian habitats will be protected from biological invasion especially by *Mikania micrantha*. Similarly, Jalthal forest

has some attributes of old growth and primary forest. Large trees, large lianas, habitat trees and mixed forest stands are key structural aspects of Jalthal forest biodiversity. These structures will be protected. Special care will be provided for the very rare species like *Cinnamomum tenuipile* and *Prunus ceylanica* which are found in small populations. Jalthal forest's interior has been designated the core area; it is rich and diverse, and conservation-oriented management will be promoted there. Regulation of forest products collection is an important activity for *in situ* conservation of rare and threatened species.

4.1.2 Seed collection and dispersal: Seeding, a comparatively inexpensive technique to regenerate, has the potential to quickly reforest large areas. Direct seeding is more flexible, faster and cost-effective. Naturally germinated seedlings are better adapted to their environment than planted seedlings. We may adopt this strategy to increase the density of rare and threatened species if their seeds are not dispersed sufficiently by natural means. For example, *Garcinia cowa* occurs in a limited area in Jalthal. We could collect the seeds of such species and disperse them within other

suitable parts of the forest. Species with larger seeds and low dispersibility will benefit from this strategy.

4.1.3 Natural regeneration protection:

Promotion and protection of natural regeneration results in better outcomes than plantation. *Mikania micrantha* cover has adversely affected the natural regeneration process of many tree species, particularly in degraded areas. Some species, e.g., *Artocarpus chama*, naturally produce large numbers of seedlings, but despite this, there are very few individuals in the sapling layer. This is mainly due to the extensive lopping of seedlings for fodder. Efforts will be made to protect and promote natural regeneration through invasive species management and biomass pressure reduction activities.

4.2 Conservation through reintroductions:

Intermediate approaches between *ex situ* and *in situ* have been proposed to complement these two conventional methods of species conservation (Volis 2017). We will consider introducing plant species in Jalthal forest which are known to have recently been eliminated from Jalthal due to over-exploitation. *Ougeinia oojeinensis* is a candidate species for reintroduction. The last mature trees of this species were felled about two decades ago and no living trees (except a single seedling from root sucker) have been observed in recent years. This species can be reintroduced into the forest using seeds from nearby natural populations.

4.2.1 Nursery management: Local nurseries owned by farmers and enthusiasts play a pivotal role in the conservation of rare and threatened species. In Jalthal, our project initiated a forest nursery in 2022, and basic propagation experiments are now underway. We harvest mature seeds, primarily from rare and threatened species whenever they are available in the forest, and nurture them in the nursery until they mature enough to thrive in their natural habitat. Continual observations and experiments involving selected species are carried out with active local participation. In addition, vegetative propagation tools like cutting and layering methods are being experimented with for those species that have difficulty propagating from seeds. The seedlings will later be handed over to the CFUGs to be planted in their forests. Some of the seedlings will also be distributed to individual

farmers and local people to be planted on private lands. Small-scale nurseries owned by some CFs will be promoted and strengthened to conserve rare and threatened species.

4.3 Strengthen capacity of local institutions:

Conservation programs are more likely to succeed when local communities have the capacity to understand the problems, monitor changes in forest biodiversity and make decisions on adaptive management for specific habitats and species. In the context of Jalthal, the stewardship of the forest is entrusted to the Community Forest User Groups (CFUGs) and local institutions. Hence, capacity-building through trainings, workshops, and campaigns is imperative, targeting CFUG members and other forest users. Hands-on training sessions focused on the management of rare and endangered plant species will be conducted regularly. Local champions in conservation will be identified and supported.

4.4 Collaboration and participation:

Indigenous communities of the Eastern Tarai, *Meche*, *Santhal* and *Rajbanshi*, and other ethnic/caste groups like Brahman, Kshetri, Limbu, Rai, Magar and Tamang living around Jalthal forest have a long tradition of using forest resources and have accumulated rich ecological knowledge about species, habitats and ecosystems. Our rare tree conservation approach acknowledges the need for participatory and collaborative approach for forest biodiversity conservation and it will prioritise participation of indigenous people, youths and women in conservation. CFUGs will be key driver to implement the conservation of rare and threatened plants. This conservation approach will engage elderly people, youths and women in field activities. Co-learning will be adopted, and local people's meaningful participation will be ensured in all stages of conservation planning and field implementation. Inter-generational knowledge sharing will be facilitated by organizing joint program between youths and elderly people. Dialogue among diverse actors/stakeholders-Division Forest Office (DFO), Local governments, CFUGs, local youths, political parties and environmental defenders will be promoted to build collaboration towards the conservation of Jalthal forest biodiversity.

4.5 Biomass pressure offset activities: Jalthal Forest serves as a direct or indirect source for a range of forest products utilized by the local community. The forest is under considerable pressure for firewood and fodder. On a typical day in winter, as many as 2000 people enter the forest from surrounding settlements to collect fodder and firewood. Excessive fodder collection has negatively affected the regeneration of tree species. The populations of many trees have declined due to branch lopping for fodder. Examples include *Garcinia cowa*, *Baccaurea ramiflora* and *Ficus semicordata*. The project will promote cultivation of fodder trees and shrubs on private lands to reduce pressure on the forest. Similarly, parts of some degraded areas of forest can be developed into fodder orchards. CFs can manage such orchards and regulate the harvest of fodder.

4.6 Awareness and knowledge management: We will also promote mutual learning, where local people serve as citizen scientists and contribute to biodiversity monitoring. Forest transect walks with local people and experts will be important training and awareness-raising activities to improve understanding of forest biodiversity, its threats and conservation. Through these activities, we will familiarize people with species identification, their ecological significance, and their current status within the forest ecosystem. This awareness will, in turn, play a pivotal role in promoting the conservation of the entire forest and its diversity. Similarly, we will share information about the status of species gained from our research including experiments in the nursery. In addition, awareness rising workshops, meetings and training will be organised. Diverse knowledge products targeting local people will be published and disseminated.

5. Further research

Long-term population studies of rare and threatened species are key to understanding the drivers of plant population status and regeneration. A temporal study of the reproductive phenology of species is crucial to understanding the variation in flowering and fruiting periods within and between the species and the consequences of these variations. It further helps us to understand the irregularity of flowering in tree species and the underlying reasons. Studies of plant-pollinator interactions and pollination mechanisms can yield information that can guide

strategies for maintaining the viable population of the species in the forest. Such studies are particularly important in species with unisexual (dioecious and monoecious) systems. Similarly, experimental studies, both lab and field-based, on species with low capacities for natural seed germination are needed to develop appropriate strategies to enhance their germination and establishment. The role of anthropogenic disturbances and climate change impacts on the population dynamics of rare and threatened species should also be a research priority to support the conservation of plant genetic resources in Jalthal and other forests.

Given the current status of threatened biodiversity, biogeographic significance of the forest, emerging threats and the dependence of local people on the forest for diverse environmental services, Jalthal forest also offers an important research area for forest management (Sharma et al 2021). An obvious question could be what is the best strategy to integrate conservation and sustainable utilization of forest resources. The forest is currently being managed as 22 CFs and there lacks cooperation among CFUGs in regards to threatened biodiversity. There is also a need for meaningful cooperation among CFUGs to safeguard the forests biodiversity.

6. Conclusion

Globally nearly 45% of flowering plants face a risk of extinction (Antonelli *et al.* 2023). Likewise, a global assessment of trees has shown that over 30% of trees are at risk of extinction and many species have very small populations in the wild (BGCI 2021). The situation in Jalthal is similar to the global picture. One-third of tree species in Jalthal are impacted by a lack of sustainable regeneration. Several rare species have only a handful (less than 10) of mature individuals, while some are already in the process of local extinction. The need for serious action toward the conservation of trees and other flowering plants in Jalthal forest is evident.

Selecting species for conservation needs data from diverse sources, ranging from local plant communities to global biogeographic studies, and takes considerable effort. We have identified species for conservation action by employing multiple criteria. Population and regeneration data were used to identify rare and threatened trees in

Jalthal forest, and combining this with information on threats and local people's priorities we have selected species and proposed strategies for conservation actions. The conservation strategies we have suggested are tailored to suit the needs of the species assessed based on ecological data from Jalthal. Further research and experimentation will be used to improve the strategies we have proposed. In some cases, the regeneration problem might be genetic, but this is beyond the scope of this study and our approach.

Although our approach prioritises selected species for focused action, we also stress the need for the maintenance of all aspects of a healthy forest ecosystem. We believe that the conservation measures proposed in this paper will be effective in protecting plant species in Jalthal, and also will be applicable to other forests elsewhere in Nepal.

Acknowledging the biodiversity significance of forest and gaps in management, we urge for better integration of biodiversity in CF management plans and routine activities. CFUGs in Jalthal and elsewhere should better cooperate to conserve threatened biodiversity and address the pertinent threats to forest biodiversity.

7. References

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Appendix 1: Species selected for conservation action and their threats and status in Jalthal forest.

S.N.	Botanical name*	Status in the forest	Driver	Suggested action
1	<i>Artocarpus chama</i> Buch.-Ham. [P, LT]	Dominant in wet areas, habitat specialist, common, plenty of seeds and good germination but a lack of saplings and pole-sized trees	Fire, lopping for fodder, mainly anthropogenic pressure	Protection of natural regeneration, habitat protection, transferred seedling in suitable habitats
2	<i>Baccaurea ramiflora</i> Lour. [LT, R]	Habitat specialist, decreasing in wild, fast and good germination but seedlings rarely get a chance to be mature	Firewood and fodder pressure, fruits destroyed by wildlife and humans	Stem cutting could be a viable option for propagation, mother tree protection, seedling transfer to suitable habitat
3	<i>Bhesa robusta</i> (Roxb.) Ding Hou [R]	Rare in Jalthal, no seedlings and saplings observed	Unknown; plant is neither a fodder nor a preferred firewood	Seed propagation experiment
4	<i>Bombax ceiba</i> L. [LT, R, K]	Rare in forest but grows in river banks and in the agricultural field, good regeneration in open areas	Felled for soft wood	Protection of existing old trees and natural regeneration
5	<i>Canarium strictum</i> Roxb. [LT]	Very rare in Jalthal, represented by only a handful mature individuals	No information; trees might have felled for resin in the past	Natural regeneration protection, seed germination in nurseries
6	<i>Canthiumera glabra</i> (Blume) K.M.Wong & Mahyuni [LT, R]	Very rare in Jalthal, only a handful of trees were observed, enormous seed production but very low germination around mature trees	May be intrinsic, seeds are degraded soon after falling on soil surface	Further research on seed germination, experiment on stem cutting and layering
7	<i>Cinnamomum tenuipile</i> Kosterm. [LT, R]	Rare tree in Jalthal, no natural regeneration in spite of enormous seed production	Past exploitation, poor seed germination	Seed propagation experimentation, stem cutting experimentation and seed collection from other places
8	<i>Cycas pectinata</i> Buch.-Ham. [IUCN, P, R]	Rare, ca. 100 mature trees in Jalthal, good germination of seeds, seedling are slow-growing, population declining	Fodder collection, forest fire, and use of tender shoot for vegetable	Translocation of seedlings/nursery practice, protection of mature trees and habitat protection
9	<i>Dalbergia latifolia</i> Roxb. [LT, IUCN]	Rare in Jalthal, with few scattered small trees, declined abruptly	Past exploitation, forest fire	Reintroduction, protection of existing trees
10	<i>Dillenia indica</i> L. [LT, R]	Rare in Jalthal, planted trees occur in settlements	Past exploitation	Seed collection from nearby forest and grow in nursery
11	<i>Embllica officinalis</i> Gaertn. [P]	Declining population in wild	Past exploitation	Plantation and protection of existing trees
12	<i>Ficus racemosa</i> L. [P, K]	Not rare, considered here for fodder pressure offset	Fodder collection	Propagation in nursery, natural regeneration protection
13	<i>Ficus semicordata</i> Buch.-Ham. ex Sm. [LT, K]	Rare in forest, used to be common in the past	Lopped for fodder and collection for firewood	Stem cutting and other nursery practices to grow and plant in forest
14	<i>Garcinia cowa</i> Roxb. ex Choisy [LT, R]	Rare tree, no fruiting individual observed	Past exploitation and fodder collection	Stem cutting/vegetative propagation
15	<i>Garcinia xanthochymus</i> Hook.f. ex T.Anderson [LT, R]	Rare trees, good first year regeneration, plenty of seeds produced but saplings do not survive	May be intrinsic driver	Translocation of seedlings/nursery practice

16	<i>Gynocardia odorata</i> R.Br. [P, R]	Rare in Jalthal, species more common in mid-hills and poor germination	Unknown	Germination in nurseries and dissemination
17	<i>Homalium ceylanicum</i> (Gardner) Benth. [R]	A rare species	Exploitation as timber	Natural regeneration protection, nursery practices
18	<i>Horsfieldia kingii</i> (Hook.f.) Warb. [LT, P, R]	A very rare tree, low regeneration	Low germination, tree felling, and fruit collection for food	Seed germination/stem cutting/natural regeneration protection/nursery practices
19	<i>Magnolia champaca</i> (L.) Baill. ex Pierre [LT, R]	Rare in Jalthal, represented by only a handful of mature individuals, no seedlings were observed	Past exploitation for timber and fodder	Nursery practices/seeds collection from other places
20	<i>Ougeinia oojeimensis</i> (Roxb.) Hochr. [LT]	Very rare, at the stage of local extinction, used to be common in dry locations	Past exploitation for firewood and utensils	Reintroduction from nearby population
21	<i>Phanera scandens</i> (L.) Lour. ex Raf.# [LT]	Rare in Jalthal, represented by only a handful individuals	Past exploitation	Seed collection and expansion through nursery propagation, protection of existing lianas
22	<i>Phoenix loureiroidi</i> Kunth [LT]	Very rare in the wild in Jalthal, used to be common in dry locations	Past exploitation	Reintroduction from nearby population
23	<i>Pinanga gracilis</i> Blume## [LT, R]	Rare in Jalthal, seen in only two locations	Fodder collection	Nursery practice and habitat protection
24	<i>Prunus ceylanica</i> (Wight) Miq. [IUCN, LT, R]	Rare tree represented by a handful of individuals, plenty of seed production, but poor regeneration	May be some intrinsic drivers, problem in seed germination	Experiment on seed germination/stem cutting
25	<i>Pterygota alata</i> (Roxb.) R.Br. [R]	Few mature trees, there is natural regeneration but it is not protected	Lopped for fodder	Protecting natural regeneration, Germination in nurseries
26	<i>Sarcosperma arboreum</i> Hook.f. [R]	Rare tree, habitat specific, occurs only a handful trees	UNKNOWN	Protection of mature trees and their habitat
27	<i>Schima wallichii</i> (DC.) Korth. [P]	Old grown trees are decreasing, not so rare but could be an important germplasm in lowland Nepal	Habitat degradation, felling of mature trees	Natural regeneration protection, protection of old-growth trees
28	<i>Syzygium cumini</i> (L.) Skeels [P]	Population decline, good regeneration	Tree felling	Natural regeneration protection
29	<i>Tamilnadia uliginosa</i> (Retz.) Tirveng. & Sastre [P]	Rare in the forest	Fodder collection, and fruits are collected before maturity for food	Natural regeneration protection, cultivation in private lands
30	<i>Terminalia chebula</i> Retz. [P, LT]	Very rare, handful of mature trees in forest, no saplings and middle-sized trees	Past exploitation, poor seed germination, tree felling and lopping	Protecting existing saplings/nursery practices/ plantation

* Unless specified trees, # Woody climber, ##Palm, letters in square brackets [P-Prioritised by locals, R-Rare, LT- Locally threatened, K-Key for conservation of other trees, IUCN-IUCN red listed].



Two rare species of Jalthal (*Dillenia indica* & *Baccaurea ramiflora*) growing in community nursery in Jalthal.

Kusum seedling growing in community nursery

Baccaurea ramiflora, locally known as Kusum, is an important wild edible fruit. It was once a common species in wet gullies of eastern and central Nepal but its population has been declined in the wild and regeneration has been impaired, mainly due to lopping and habitat destruction.



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