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ARTICLE

Status of floristic diversity and impact of development on two sacred groves from Maval Tehsil (Maharashtra, India) after a century

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Abstract: Global urbanisation and anthropogenic activities are leading to a decline in religious beliefs and adversely affecting the biodiversity, ecology, and environmental sustainability of sacred groves, particularly in Lonavala (Rye Wood Park) and Karla Grove in Maval Tehsil, Pune district, Maharashtra, India. The Lonavala Grove, situated at 18.749° N, 73.403° E, and 622 m, and the Karla Grove, located at 18.760° N, 73.478° E, with an elevation of 621 m, both within the Western Ghats, are undergoing transformations due to landscape gardens and urban developments despite their historical significance. Gammie Alexander's 1903 floristic research identified 84 species across both groves, but our present study reveals a significant decline. Lonavala and Karla groves now host 46 genera and 42 species and 25 genera and 29 species, respectively, totaling 120 species from 49 families and 110 genera. This decline is attributed to the introduction of alien and invasive species, resulting in the disappearance of six indigenous species over the past century. The research aims to explore and document changes in floristic diversity, utilising remote sensing methods like NDVI for growth and deterioration assessment, measuring tree and liana girth, and analysing the impact on native flora due to the spread of alien species.

Keywords: Biodiversity heritage site, garden development, girth measurement, global urbanization, impact on biodiversity and native flora, introduction of alien and invasive species, normalized difference vegetation index, remote sensing, sacred forest, urban sacred natural sites.

Abbreviations: C—Common | CIT—Common in thickets | CL—Climber | EC—Enormous climber | EH—Epiphytic Herb | E—Exotic | F—Few | G—Girth | HB—Herb | H—Height | I—Invasive | K—Karla | L—Lonavala | LAK—Lonavala and Karla | OOCAL—Only one climber at Lonavala | OOT—Only one tree | OOTIL—Only one tree in Lonavala | OSAK—Only seen at Karla | OTIAL—Only Two individuals at Lonavala | R—Rare | SIBG | SOTT—Seen only two trees | SSOMST—Small shrub or moderately size tree | T—Tree | TOTP—Two or three plants | TT—Tall tree | TTILW—Tall tree in Lonavala wood | VCC—Very common climber | VCIT—Very common in thickets | VLC—Very large climber.

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Author details: Mr Kishor Himmat Saste is presently working on 'Status of floristic Diversity of Maval Tehsil: A part of Northern Western Ghats and its Impact Assessment' as part of PhD research. Rani Babanrao Bhagat is an assistant professor and has published many papers in reputed journals. She has expertise in angiosperm taxonomy, ethnobotany, biodiversity conservation, antioxidants, antimicrobials and essential oils.

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INTRODUCTION

Sacred groves are forest patches protected and managed by various indigenous communities on religious beliefs. In the modern era religious beliefs, cultural values, and socio-economic aspects have undergone significant changes. These changes have led to a decline in the motivation to protect and conserve sacred groves, resulting in their degradation (Khan et al. 2008; Palmeirim et al. 2023). The issues of degradation of sacred groves have been discussed by different researchers from Maharashtra, India, and worldwide (Gadgil & Chandran 1992; Chandran 1997; Bhagwat & Rutte 2006)

In Ethiopia, due to changes in land use patterns, there is a 36.6% decrease in sacred forest areas after a time change period of 15 years (Daye & Healey 2015). Mahabaleshwarkar et al. (2023) reported that there is a high risk of losing an important taxa *Canarium strictum* Roxb. due to degradation of the surrounding grove from Bhor, Thesil due to the developmental activities**.** The degradation of sacred groves in the Western Ghats is mainly caused by conflicts such as forest fires, encroachment for coffee plantations, deforestation for charcoal production, and the use of swamp groves for areca nut and paddy cultivation (Gadgil & Chandran 1992; Chandran 1997).

Land use for tourism, roads, mines, dams, and neo-urbanization has also resulted in the degradation of sacred groves (Pandey 1999; Bhagwat & Rutte 2006). According to Unnikrishnan (1995) and Patwardhan (2021), the newly constructed temple is a major threat to the deterioration of sacred groves. Tatay & Merino (2023) reviewed numerous sacred natural sites and showed how different cultures and religions have contributed to their preservation across the globe. Developmental activities within and surrounding groves, deforestation, land conversion, forest fragmentation, encroachment, and planned or accidental changes in the species composition are the most common anthropogenic disturbances in groves (Ray 2014).

Rutte (2011) highlighted various conflicts, policies, and potential solutions to maintain ecological reliability to avoid degradation of sacred groves. Management of protected areas like sacred groves is often unsuccessful in preventing human encroachment (Bhagwat & Rutte 2006). So, important sacred groves should be included in the ‚Protected Area Network' to ensure adequate conservation (Khan et al. 2008). Kulkarni et al. (2013) worked on the diversity of two monotypic sacred groves from the Pune district to evaluate the impact of development for 15 years interval and its comparative floristic account, which showed the reduction in the number of endemic herbs, shrubs, and climbers. The studies on floristic uniqueness and the effect of degradation on plant diversity of 15 sacred groves have been reported from the northern Western Ghats of Pune district, Maharashtra (Kulkarni et al. 2018). Godbole (1980) studied eight sacred groves from Maval Tehsil and documented the dominant species to understand the impact of development on the area and floristic diversity.

Historical and floristic importance of two sacred groves

Lonavala grove has been extensively explored by various British botanists, contributing valuable insights into its botanical richness. Notable reports include Graham (1839), Voigt (1845), Gammie (1903), Cooke (1908), and Santapau (1967), showcasing a range of genera and species (Table 1). Despite its historical fame, Santapau (1967) noted the challenge of fully documenting the grove's diversity.

Originally referred to as 'Lanowlee Woods' (Graham 1839) or 'Lanoli' (Mahan 1878), Lonavala grove featured broad belts of tall trees and massive climbers (Gammie 1903). The Lonavala Municipal Corporation has transformed it into 'Rye Wood Park' or 'Udyan,' a name reflective of the remaining large trees (Image 2F). The grove hosts the 'Mahashivratri' celebration, attracting a crowd (Images 2H & I).

Stuart (2019) and Hegewald (2022) suggest it as a Buddhist garden due to a water tank, while Hindus consider it a 'Mahadev grove' with a temple dedicated to Lord Shiva. Encroachments have impacted the temple of the god 'Waghoba' (Image 1A). Lonavala, a former British hill station, served as a rest and recreation area, altering the grove's face and disrupting biodiversity.

Voigt (1845) mentions saplings raised from grove seeds planted at the Calcutta Botanical Garden. Noteworthy trees include *Semecarpus anacardium* L.f., a source of creosote (Balfour 1870), and *Ficus drupacea* Thunb., creating natural topiary (Robert 1896) work (Image 1E). John Graham cited Lonavala Grove in the protologue of Alpinia neesiana Graham (Patil et al. 2021).

During the Mahashivaratri festival, thousands of pilgrims visit the 40-acre grove, which once extended to the Lonavala railway station. Development activities altered its appearance, underscoring the urgent need for conservation efforts and a thorough examination of

its floristic diversity.

The Karla grove, known for 'Karlyachi Rai' and housing the deity Mahalaxmi (Image 1B), was historically associated with a mango tree-filled Karla village (as of 1825). Situated in the Western Ghats biodiversity hotspot, both groves are rapidly deteriorating due to road widening, garden development, and encroachment. Remote sensing techniques, including NDVI, were employed to assess the grove degradation. This study emphasises a comparative analysis of floristic diversity, current status, the impact of degradation, changes in tree girth, and outlines measures for future conservation.

Study Area

The sacred groves under study are situated in Maval Tehsil of the Pune district in Maharashtra, India. Lonavala Grove also recognized as Ryewood Park, is positioned at 18.749°N, 73.402°E, with an elevation of 622 m. It is situated 1 km south of the city. Karla Sacred Grove is located at 18.760°N, 73.478°E, with an elevation of 621 m, and is positioned near the renowned 'Ekvira temple,' 5 km from Khandala. Lonavala and Karla sacred groves cover an approximate area of 19.06 and 7.63 acres, respectively.

MATERIAL AND METHODS

This study aimed to achieve the following objectives:

Floristic Survey: Conducted thorough field investigations from 1 January 2022, to 24 December 2022, to comprehend the floristic composition and current status of the area. Collected, pressed, and identified specimens using standard procedures and regional flora. Utilised documented data for comparative analysis with Gammie's (1903) floristic work, establishing an inventory of species for assessing the impact of development on the floristic diversity of Lonavala and Karla Groves.

Conducted a comparative analysis of old and new statistical data.

Photo documentation of diversity: Captured photographs of each flowering plant species, accompanied by essential field data.

Measurement of the girth of trees and lianas: Measured the girth of trees and lianas using a measuring tape to assess their growth and development. Compared the obtained data with previously reported measurements.

Table 1. Floristic diversity of Lonavala grove by different researchers.

Works on sacred groves	Genus	Species
Graham, 1839	12	14
Voigt, 1845	6	6
Gammie, 1903	68	74
Cooke, 1908	7	8
Santapau, 1967	1	1
Present study	42	46

Impact assessment studies and interpretation: Assessed the impact of development on Lonavala and Karla groves using remote sensing techniques and NDVI analysis. Examined geographical changes over 40 years (1980–2020) at 20-year intervals. Utilised Landsat 8 satellite imagery data to observe the degradation of the sacred grove. Calculated NDVI using QGIS software for a comprehensive analysis.

RESULT AND DISCUSSION

As a result of development activities, the floristic diversity and size of many sacred groves have declined (Mishra et al. 2004; Khan et al. 2008; Ray 2014; Kulkarni et al. 2018).

The sacred grove of Lonavala has been transformed into a garden by the Lonavala Municipal Corporation. To enhance aesthetics, various amenities have been introduced, including a rockery (Image 3C), a water tank adorned with water lilies, and renovations to the lawn (Image 2C–E). The incorporation of boulder construction and tree boulders further contributes to the visual appeal. The addition of more attractive plants compared to the previous composition has implications for the ephemeral and epiphytic flora within the sacred grove.

Despite the developmental activities such as lawn grass installation, weeding, ecotourism initiatives, and tile paving, there is still a presence of ephemeral flora on the tree trunks within the grove, as depicted in Image 2E.

Gammie (1903) mentioned *Alpinia neesiana* Graham (= *Zingiber neesanum* (J.Graham) Ramamoorthy), which was found on the grove's periphery, but now has been invaded by garden ornamental plants, and very few plants remain there. Additionally, the Western Ghats endemic taxon *Curcuma pseudomontana* J.Graham was discovered in the current investigation. The endemic species are on the verge of extinction from the grove

Image 1. A—Shrine of deity Waghoba in Lonavala grove | B—Mahalaxmi deity of Karla grove | C—Colony of Bats on Mango tree in Karla grove| D—Giant Lianas of *Combretum albidum* G. Don | E—Measuring girth of *Ficus drupacea* Thunb. | F—Giant liana of *Entada phaseoloides* (L.) Merr. | G—Topiary work of parasitic *Ficus drupacea* Thunb. © © Kishor Saste.

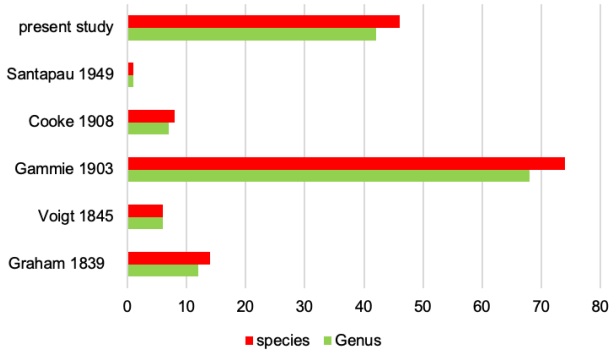

Figure 1. Floristic diversity of Lonavala grove by different researchers.

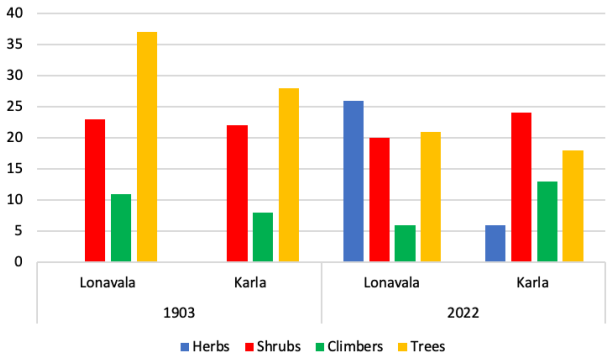

Figure 2. Bar diagram showing the number of herbs, shrubs, trees, and climbers.

as a result of construction, weeding, and the planting of ornamental plants like *Duranta* L. and *Bougainvillea*. comm. ex Juss. (Figure 3E–G)

Some groves are better suited for the occurrence of more sensitive, hygrophilous endemic species due to the water retention capacity of groves (Ray 2014). The abundance of the endemic taxon *Hedychium scaposum* Nimmo (= *Curcuma scaposa* (Nimmo) Skornick. & M.Sabu) on the west side of the lake boulders of the grove was noted in the Bombay Catalogue (Graham 1839). Unfortunately, because of waste-filled and polluted marshy habitat, this endemic taxon has now completely vanished. In addition to an embankment of the invasive ornamental weed *Sphagneticola calendulacea* (L.) Pruski, swampy waste areas are said to be home to a large population of the exotic taxon *Alocasia macrorrhizos* (L.) G. Don. (Image 3A & B). Most sacred groves are experiencing an ecological problem caused by the invasion of exotic weeds (Ramsankar 2010).

Due to the Britishers' lack of knowledge about traditional sacred grove practices and conservation, they planted ornamental plants in Lonavala Grove, which disrupted the grove's ecology. Instead, they believed that the sacred grove was a scheme by the Indian people to prevent the British government from claiming the land (Gadgil & Chandran 1992).

The tree trunks that were previously covered with climbers like *Piper nigrum* L., and epiphytes such as *Dendrophthoe longiflora* (Desr.) Ettingsh, are now entirely replaced with exotics like *Philodendron* and decorative climbers (Image 3D). The invasion of such decorative climbers has had a negative impact on populations of endemic flora such as grasses, orchids, and *Begonias*, leading them to grow on the boulders and damp walls of the grove.

Capparis moonii Wight was previously found in dense thickets at Lonavala grove. However, due to the clearing of the ground, only two individuals have been located. Unfortunately, several previously reported evergreen plant species by Gammie (1903) from the Lonavala grove have completely vanished. These species include *Dysoxylum binectariferum* (Roxb.) Hook.f. ex Bedd., *Zanthoxylum rhetsa* (Roxb.) DC., *Catunaregam spinosa* (Thunb.) Tirveng, and *Xantolis tomentosa* (Roxb.) Raf. The reduction in evergreen tree cover in sacred groves adversely affects the ecology (Gadgil & Chandran 1992; Unnikrishnan 1995; Ray 2014). It has also been revealed that certain taxa, which were reported one in number, are now extinct. However, *Machilus glaucescens* (Nees) Wight and *Mangifera indica* L. currently dominate the area. Unfortunately, due to garden expansion, the sacred groves of Lonavala are now home to more exotic weeds, escaped flora, and attractive species.

Critical note on girth measurement of giant lianas and other trees

A unique characteristic of both groves is the presence of the enormous lianas *Entada phaseoloides* (L.) Merr., *Combretum latifolium* Blume, and *Premna coriacea* C.B.Clarke. In a study conducted in the Pune district, the circumference of *Entada phaseoloides* (L.) Merr. from various sacred groves was reported. Bhise et al. (2013) found that the largest liana, measuring 1.22 m in circumference, was from Kalbhairavnath sacred grove. However, our current work shows that the same plant, previously measured at Lonavala grove with a circumference of 0.48 m, actually has a circumference of 1.83 m. This makes *Entada phaseoloides* (L.) Merr. not only the largest liana plant in Lonavala but possibly even in Maharashtra.

Most of the ancient trees that Gammie had mentioned and measured have disappeared from groves. The absence of plant girth measurements

Table 2. List of taxa reported in 1903 and present study.

Scientific name	Family	Habit	Status in 1903		Present Status	
			Lonavala	Karla	Lonavala	Karla
Clematis hedysarifolia DC.	Ranunculaceae	CL	–	CIT	–	R
Capparis moonii Wight	Capparaceae	CL	C	C	'2 nos.'	–
Sterculia guttata Roxb.	Malvaceae	T	+	+	–	+
Hiptage benghalensis (L.) Kurz	Malpighiaceae	CL	+	–	–	–
Grewia tiliifolia Vahl	Malvaceae	T	–	SSOMST	–	+
Firmiana colorata (Roxb.) R.Br.	Malvaceae	T	+	–	–	–
Zanthoxylum rhetsa (Roxb.) DC.	Rutaceae	T	+	–	–	–
Glycosmis pentaphylla (Retz.) DC.	Rutaceae	S	+	–	–	–
Atalantia racemosa Wight ex Hook.	Rutaceae	S	+	+	–	–
Dysoxylum binectariferum (Roxb.) Hook.f. ex Bedd.	Meliaceae	T	+	–	–	–
Celastrus paniculatus Willd.	Celastraceae	CL	VCC	VCC	–	+
Gymnosporia emarginata (Willd.) Thwaites	Celastraceae	S	+	+	–	+
Ventilago madraspatana Gaertn.	Rhamnaceae	S	C	C	–	–
Ziziphus rugosa Lam.	Rhamnaceae	S	+	+	+	+
Allophylus cobbe (L.) Forsyth f.	Sapindaceae	S	–	+	–	–
Schleichera oleosa (Lour.) Oken	Sapindaceae	T	+	–	–	–
Mangifera indica L.	Anacardiaceae	T	H: 15.24–21.34 m) (G: 3.05–3.97 m)	+	(G: 3.96 m)	+
Holigarna grahamii (Wight) Kurz	Anacardiaceae	T	C, (H :15.24 m) (G: 0.91–8.13 m)	–	2 nos (G: 2.35 m)	–
Semecarpus anacardium L.f.	Anacardiaceae	T	2 or 3 nos	2 or 3 nos	–	–
Butea monosperma (Lam.) Kuntze	Fabaceae	T	VC	VC	–	(G: 1.83 m)
Crotalaria retusa L.	Fabaceae	S	+	+	–	+
Dalbergia horrida var. horrida	Fabaceae	CL	–	+	–	(G: 1.07 m)
Mezoneuron cucullatum (Roxb.) Wight & Arn.	Fabaceae	CL	EC, (G: 0.46 m)	–	–	(G: 0.17–0.34 m)
Saraca asoca (Roxb.) W.J.de Wilde	Fabaceae	T	+	–	(G: 0.91 m)	–
Tamarindus indica L.	Fabaceae	T	–	+	–	–
Entada phaseoloides (L.) Merr.	Fabaceae	CL	+	(G: 0.91 m)	(G: 1.83 m)	+
Senegalia rugata (Lam.) Britton & Rose	Fabaceae	S	+	+	–	–
Albizia chinensis (Osbeck) Merr.	Fabaceae	T	(H: 21.37 m) (G: 3.05 m)	+	–	–
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	T	(H:15.24–21.37 m) (G: 1.52–4.57 m)	–	(G: 2.44 m)	–
Terminalia chebula Retz.	Combretaceae	T	+	–	–	–
Getonia floribunda Roxb.	Combretaceae	CL	+	+	–	(G: 0.91 m)
Combretum albidum G.Don	Combretaceae	CL	+	+	(G: 1.49–4.90 m)	–
Syzygium cumini (L.) Skeels	Myrtaceae	T	(G: 1.52–3.05 m)	+	+	(G: 2.44–3.17 m)
Memecylon edule Roxb.	Melastomataceae	T	VCIT (G: 0.31–0.61 m)	–	–	–
Memecylon umbellatum Burm.f.	Melastomataceae	T	+	+	+	+
Opuntia elatior Mill.	Cactaceae	S	–	+	–	–
Neolamarckia cadamba (Roxb.) Bosser	Rubiaceae	T	R	–	–	–
Catunaregam spinosa (Thunb.) Tirveng.	Rubiaceae	T	C	C	+	+
Psydrax umbellatus (Wight) Bridson	Rubiaceae	T	+	+	–	+
Ixora brachiata Roxb.	Rubiaceae	S	+	+	–	+
Ixora nigricans R.Br. ex Wight & Arn.	Rubiaceae	S	+	–	–	–

Scientific name	Family	Habit	Status in 1903		Present Status	
			Lonavala	Karla	Lonavala	Karla
Meyna spinosa Roxb. ex Link	Rubiaceae	S	(H: 6.10 m, G: 1.52 m)	+	–	(G: 4.5 m)
Pavetta indica L.	Rubiaceae	S	+	+	–	+
Acilepis dendigulensis (DC.) H.Rob.	Asteraceae	S	+	+	+	–
Xantolis tomentosa (Roxb.) Raf.	Spatotaceae	T	Vc	vc	–	+
Mimusops elengi L.	Spatotaceae	T	TTILW	+	–	–
Diospyros montana Roxb.	Ebenaceae	T	+	–	–	–
Jasminum malabaricum Wight	Oleaceae	CL	+	–	–	–
Chionanthus ramiflorus Roxb.	Oleaceae	T	C	C	R	R
Tetrapilus dioicus (Roxb.) L.A.S.Johnson	Oleaceae	T	+	(G: 0.76 m)	(G: 2.68–4.27 m)	+
Carissa carandas L.	Apocynaceae	S	+	+	–	+
Carissa spinarum L.	Apocynaceae	S	+	+	–	–
Anodendron parviflorum (Roxb.) I.M.Turner	Apocynaceae	CL	C	–	'1 nos.'	–
Cordia myxa L.	Boraginaceae	T	F	–	–	–
Heterophragma quadriloculare (Roxb.) K.Schum.	Bignoniaceae	T	–	'1 nos.'	–	+
Stereospermum chelonoides (L.f.) DC.	Bignoniaceae	T	TT	–	–	–
Strobilanthes ixiocephala Benth.	Acanthaceae	S	C	C	–	–
Lantana camara L.	Verbenaceae	S	+	+	+	+
Callicarpa tomentosa (L.) L.	Lamiaceae	S	+	(H: 7.62 m)	–	–
Premna coriacea C.B.Clarke	Lamiaceae	CL	+	–	+	–
Vitex negundo L.	Lamiaceae	S	C	–	R	R
Colebrookea oppositifolia Sm.	Lamiaceae	S	C	C		
Machilus glaucescens (Nees) Wight	Lauraceae	T	(G: 3.81 m)	+	(G: 1.83–2.74 m)	+
Lasiosiphon glaucus Fresen.	Thymelaeaceae	S	+	+	–	–
Elaeagnus latifolia Lour.	Elaeagnaceae	S	+	+	–	+
Dendrophthoe longiflora (Desr.) Ettingsh.	Loranthaceae	S	VCC	VCC	R	R
Macrosolen parasiticus (L.) Danser	Loranthaceae	S	C	C	–	–
Viscum capitellatum Sm.	Santalaceae	S	+	+	–	–
Osyris lanceolata Hochst. & Steud.	Santalaceae	T	+	+	–	–
Euphorbia neriifolia L.	Euphorbiaceae	S	+	+	–	–
Bridelia retusa (L.) A.Juss.	Phyllanthaceae	T	+	+	+	+
Holoptelea integrifolia (Roxb.) Planch.	Ulmaceae	T	–	+	–	–
Celtis tetrandra Roxb.	Cannabaceae	T	F	F	'1 nos.'	–
Ficus tinctoria ssp. *gibbosa* (Blume) Corner	Moraceae	T	–	+	+	+
Ficus drupacea Thunb.	Moraceae	T	+	–	(G: 5.27)	–
Ficus religiosa L.	Moraceae	T	+	+	–	–
Ficus amplissima Sm.	Moraceae	T	+	+	+	–
Ficus exasperata Vahl	Moraceae	T	+	+	+	–
Ficus racemosa L.	Moraceae	T	C	C	–	–
Artocarpus integrifolia L.f	Moraceae	T	+	+	–	(G: 0.76 - 2.50 m)
Gnetum edule (Willd.) Blume	Gnetaceae	CL	VLC, (G: 0.91 m)	+	–	–
Caryota urens L.	Arecaceae	T	+	+	+	+
Bambusa arundinacea Willd.	Poaceae	S	+	+	–	+
Pseudoxytenanthera ritchiei (Munro) H.B.Naithani	Poaceae	S	–	+	–	–

reported in 1903 suggests that old trees are no longer alive, or new ones are growing. However, the increase in girth measurements previously recorded indicates that the former trees and lianas are growing and recovering (as shown in Table 2). For instance, *Entada phaseoloides* (L.) Merr. grows 3 feet (0.914 m) in girth every 120 years.

In the Karla and Lonavala groves, the tallest trees, *Albizia chinensis* (Osbeck) Merr. (21.37 m) and *Mangifera* (21.34 m), have completely vanished. The two tallest trees in Lonavala grove, *Terminalia bellirica* (*Gaertn*.) Roxb. and *Holigarna grahamii* (Wight) Kurz, measuring 15.24 m and 21.37 m high, have also disappeared entirely.

In Karla Grove, the *Meyna spinosa* Roxb. ex Link has the largest girth, measuring 4.2 m, while the *Mezoneuron cucullatum* (Roxb.) Wight & Arn has the smallest girth, measuring only 0.17 m. On the other hand, in Lonavala grove, the *Ficus drupacea* Thunb and *Saraca asoca* (Roxb.) W.J.deWilde have the largest and smallest girths, measuring 5.27 m and 0.91 m, respectively.

In Karla Grove, the species with the thickest lianas is *Getonia floribunda* Roxb. It measures 0.91 m. On the other hand, *Mezoneuron cucullatum* (Roxb.) Wight & Arn has the thinnest lianas with a measurement of 0.17 m. In Lonavala Grove, the species with the thickest and thinnest lianas are *Combretum albidum* G.Don and *Entada phaseoloides* (L.) Merr. respectively. *Combretum albidum* G.Don has a measurement of 4.90 m while *Entada phaseoloides* (L.) Merr. measures 1.83 m.

Impact of development activities on the floristic of Karla Grove

Acacia auriculiformis A.Cunn. ex Benth. planted in social forestry and forest fire programs disturb the grove biota and hurt the area's ecological function (Gokhale 2005; Ray 2014). The floristic diversity of the sacred grove was degraded by the social forestry plantation program and invasive weeds (Burman 1996; Bhagwat & Rutte 2006). In 1903, *Clematis hedysarifolia* DC. was the most abundant species in both groves, but it has since disappeared from the Lonavala grove, with only a few individuals remaining in the Karla grove. The dominant species throughout the entire grove is *Trichosanthes tricuspidata* Lour climber, which covers every tree. Cucurbitaceae climbers like *Trichosanthes tricuspidata* Lour have invaded and dominated sacred groves due to various reasons, including climate changes, forest disturbances, and the formation of tree gaps caused by grove deforestation (Rai et al. 2016).

The Karla sacred grove is facing a major issue as *Asystasia gangetica* (L.) T.Anderson and *Trichosanthes tricuspidata* Lour are invading and spreading rapidly over the area as shown in Image (Image 2A & B). This has made it difficult for the locals and forest rangers to move around the grove. Moreover, social forestry and forest fires have severely damaged the floristic diversity of the grove (See Image 2B).

Big old trees play a vital ecological role in sacred groves. They provide nesting or sheltering cavities for 30% of vertebrate species (Lindenmayer et al. 2012; Lindenmayer & Laurance 2016) and also store large quantities of carbon. Loss of such species has considerable consequences on both biodiversity and

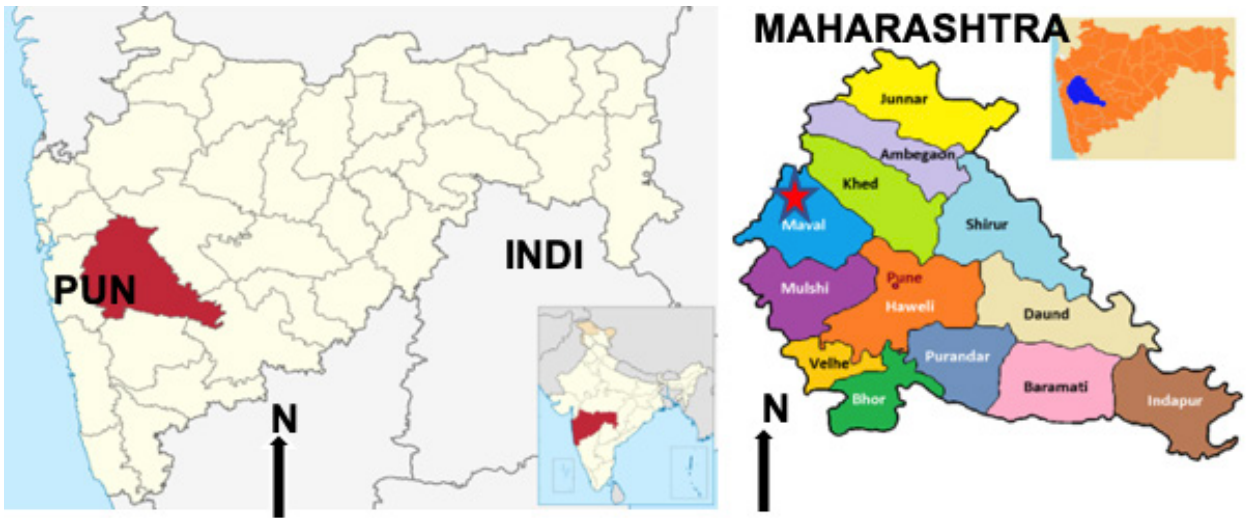

Figure 3. A—Map of India showing Maharashtra state and Pune district | B—Marked asterisk indicates Maval Tehsil.

Image 2. A—Invasion of Trichosanthes tricuspidata Lour in Karla grove | B—Social forestry and forest fire in Karla Grove | C—Development of garden | D— Introduction of water garden for water Lily | E—Paving of floor tiles | F—Sacred grove used as park | G—Use of sacred grove for enjoyment | H—Mahashivratri celebration in grove | I—Use of park as amusement for children during Mahashivratri festival | J—Use of grove for municipal worker housing. © Kishor Saste.

Table 3. List of newly reported taxa from Lonavala and Karla groves.

Botanical name	Family	Habit	Status (Wild/ exotic)	Lonavala	Karla
Achyranthes coynei Santapau	Amaranthaceae	HB	W	–	+
Aerides maculosa Lindl.	Orchidaceae	EH	W	+	–
Allamanda cathartica L.	Apocynaceae	CL	E	+	–
Alocasia macrorrhizos (L.) G.Don	Araceae	HB	E	+	–
Alternanthera sessilis (L.) DC.	Amaranthaceae	HB	I	–	+
Argyreia elliptica (Roth) Choisy	Convolvulaceae	CL	W	–	+
Aspidopterys cordata (B.Heyne ex Wall.) A.Juss.	Malpighiaceae	CL	W	–	+
Begonia crenata Dryand.	Begoniaceae	HB	W	+	–
Bougainvillea spectabilis Willd.	Nyctaginaceae	S	E	+	–
Caladium bicolor (Aiton) Vent.	Araceae	HB	E	+	–
Calliandra haematocephala Hassk.	Mimosaceae	S	E	+	
Carica papaya L.	Caricaceae	S	E	–	+
Chromolaena corymbosa (Aubl.) R.M.King & H.Rob.	Asteraceae	S	E	+	+
Clerodendrum infortunatum L.	Verbenaceae	S	E	+	–
Clerodendrum thomsoniae Balf.f.	Verbenaceae	S	E	+	–
Coccinia grandis (L.) Voigt	Cucurbitaceae	CL	W	–	+
Codiaeum variegatum (L.) Rumph. ex A.Juss.	Euphorbiaceae	S	E	+	–
Coleus scutellarioides (L.) Benth.	Lamiaceae	HB	E	+	–
Curcuma pseudomontana J.Graham	Zingiberaceae	HB	W	+	–
Cynarospermum asperrimum (Nees) Vollesen	Acanthaceae	HB	W	–	+
Cyrtococcum oxyphyllum (Hochst. ex Steud.) Stapf	Poaceae	HB	W	+	–
Cyrtococcum oxyphyllum (Hochst. ex Steud.) Stapf	Poaceae	HB	W		+
Dendrobium barbatulum Lindl.	Orchidaceae	EH	W	+	–
Dendrobium microbulbon A.Rich.	Orchidaceae	EH	W	+	–
Dracaena fragrans (L.) Ker Gawl.	Asparagaceae	S	E	+	–
Duranta erecta L.	Verbenaceae	S	E	+	–
Embelia ribes Burm.f.	Primulaceae	S	W		+
Eranthemum roseum (Vahl) R.Br. ex Roem. & Schult.	Acanthaceae	HB	W	+	–
Ficus hispida L.f.	Moraceae	T	W	+	–
Ficus retusa L.	Moraceae	T	W	–	+
Flemingia bracteata (Roxb.) Wight	Fabaceae	S	W	–	+
Garnotia arborum Stapf ex Woodrow	Poaceae	EH	W	+	–
Garnotia courtallensis (Arn. & Nees) Thwaites	Poaceae	EH	W	+	–
Gymnosporia rothiana (Walp.) M.A.Lawson	Celastraceae	S	W	–	+
Heliconia rostrata Ruiz & Pav.	Heliconiaceae	HB	E	+	–
Hydrangea macrophylla (Thunb.) Ser.	Hydrangeaceae	S	E	+	–
Ipomoea hederifolia L.	Convolvulaceae	CL	W	–	+
Justicia adhatoda L.	Acanthaceae	S	W	+	–
Kopsia fruticosa (Roxb.) A.DC.	Apocynaceae	T	E	+	–
Lantana *camara L.*	Verbenaceae	S	I	+	+
Lepidagathis fasciculata (Retz.) Nees	Acanthaceae	HB	W	+	–
Litsea ghatica Saldanha	Lauraceae	S	W	+	–
Livistona chinensis (Jacq.) R.Br. ex Mart.	Arecaceae	T	E	+	–
Macaranga peltata (Roxb.) Müll.Arg.	Euphorbiaceae	T	W	+	–
Nymphaea nouchali Burm.f.	Nymphaeaceae	HB	E	+	–
Oplismenus burmanni (Retz.) P.Beauv.	Poaceae	HB	W	–	+
Paspalum vaginatum Sw.	Poaceae	HB	E	+	–

Botanical name	Family	Habit	Status (Wild/ exotic)	Lonavala	Karla
Pavetta indica L.	Rubiaceae	S	W	–	+
Philodendron erubescens K.Koch & Augustin	Araceae	HB	E	+	–
Phoenix sylvestris (L.) Roxb.	Arecaceae	T	W	–	+
Phyllanthus reticulatus Poir.	Euphorbiaceae	S	W	–	+
Pogostemon parviflorus Benth.	Lamiaceae	S	W	–	+
Porpax filiformis (Wight) Schuit., Y.P.Ng & H.A.Pedersen	Orchidaceae	EH	W	+	–
Porpax reticulata Lindl.	Orchidaceae	EH	W	+	–
Rhaphidophora tetrasperma Hook.f.	Araceae	HB	E	+	–
Rhynchoglossum obliquum Blume	Gesneriaceae	HB	W	+	–
Smilax zeylanica L.	Smilacaceae	CL	W	–	+
Solanum diphyllum L.	Solanaceae	S	E	+	+
Solanum indicum Roxb.	Solanaceae	S	W	–	+
Solanum nigrum L.	Solanaceae	HB	W	–	+
Solanum torvum Sw.	Solanaceae	S	E	+	+
Sphagneticola calendulacea (L.) Pruski	Asteraceae	HB	I	+	–
Synedrella nodiflora (L.) Gaertn.	Asteraceae	HB	I	–	+
Teramnus labialis (L.f.) Spreng.	Fabaceae	HB	W	+	
Trichosanthes tricuspidata Lour.	Cucurbitaceae	CL	W	–	+
Turnera ulmifolia L.	Turneraceae	HB	W	+	
Urena lobata L.	Malvaceae	S	I		+
Vigna vexillata (L.) A.Rich.	Fabaceae	CL	W	+	–
Vincetoxicum indicum (Burm.f.) Mabb.	Apocynaceae	CL	W	–	+
Woodfordia fruticosa (L.) Kurz	Lythraceae	S	W	–	+
Zingiber neesanum (J.Graham) Ramamoorthy	Zingiberaceae	HB	W	+	–

ecosystems worldwide (Lindenmayer et al. 2012; Lindenmayer & Laurance 2016). Several *Ficus* species were reported in 1903 but are now completely extinct. The presence of *Ficus tinctoria* ssp. *gibbosa* (Blume) Corner and *F. microcarpa* L.f. surroundings of the forest near the temple indicates the former extent of the grove. According to Gammie (1903), Karla Grove once had a colony of bats that fed on the fruits of various *Ficus* species. However, due to development activities, only one taxon - *F. tinctoria* ssp. *gibbosa* (Blume) remains. Other species such as *Ficus tinctoria* ssp. *gibbosa* (Blume) Corner and *F. retusa* L. can be found about 200 m away from the main grove, indicating the original size and extent of the previous grove around the temple. The *Ficus* species has completely disappeared from the grove, and as a result, these bats have been discovered to be feeding on mango trees (Image 1C) and the leaves of other plants. *Ficus* is therefore a crucial keystone species for bat conservation in such sacred forests. Therefore, it is crucial to stress the significance of sacred groves for both the preservation of other animals as well as the protection of plants. Bats play a significant role in seed dispersal, which is crucial for overall forest regeneration (Blicharska et al. 2013).

Impact of development activities on endemic plants

The number of endemic species and all species in the sacred woods in the Pune district of the Western Ghats declines as disturbance levels rise (Kulkarni et al. 2013).

The endemic plant species from the grove, which were once reported as being common, are now becoming rare, and some have even completely disappeared from the grove, as a result of the impact of development. These endemic species include *Gnetum edule* (Willd.) Blume, *Clematis hedysarifolia* DC, *Curcuma scaposa* (Nimmo) Skolnick & M.Sabu, *Holigarna grahamii* (Wight) Kurz, *Jasminum malabaricum* Wight, and *Pseudoxytenanthera ritchiei* (Munro) H.B.Naithani. Out of the total species documented from the groves, 19 are found to be endemic to the Western Ghats (Table 4).

Degradation of sacred groves

Over the last four decades, the vegetation landscape in both Lonavala grove and Karla grove has undergone

Image 3. A—Invasion of water tank by exotic weeds | B—Waste place in the grove occupied by weeds | C—Rockery in grove | D—Ornamental climbers on tree trunk | E – *Amorphophallus* along with ornamental plant | F—Endemic plant with ornamental *Duranta erecta* L. | G—Removal of *Zingiber neesanum* (J.Graham) Ramamoorthy, an endemic species as weed.

Table 4. List of endemic plant species reported from both groves.

Family	Botanical Name	Location
Ranunculaceae	*Clematis hedysarifolia* DC	K
Anacardiaceae	*Holigarna grahamii* (Wight) Kurz	L
Begoniaceae	*Begonia crenata* Dryand.	L
Rubiaceae	*Ixora brachiata* Roxb.	L and K
Amaranthaceae	*Achyranthes coynei Santapau*	K
Oleaceae	*Jasminum malabaricum* Wight	L
Lauraceae	*Litsea ghatica* Saldanha	L
Gnetaceae	*Gnetum edule* (Willd.) Blume	L and k
Orchidaceae	*Dendrobium microbulbon* A.Rich.	L
Orchidaceae	*Porpax filiformis* (Wight) Schuit., Y.P.Ng & H.A.Pedersen	L
Orchidaceae	*Dendrobium barbatulum* Lindl.	L
Orchidaceae	*Aerides maculosa* Lindl.	L
Orchidaceae	*Curcuma pseudomontana* J.Graham	L
Orchidaceae	*Zingiber neesanum* (J.Graham) Ramamoorthy	L
Zingiberaceae	*Curcuma scaposa* (Nimmo) Skornick. & M.Sabu	L
Poaceae	*Pseudoxytenanthera ritchiei* (Munro) H.B.Naithani	L
Poaceae	*Garnotia arborum* Stapf ex Woodrow	L
Malpighiaceae	*Aspidopterys cordata* (B.Heyne ex Wall.) A.Juss.	K
Celastraceae	*Gymnosporia rothiana* (Walp.) M.A.Lawson	K

notable changes, as indicated by the NDVI calculated at 20-year intervals from 1980 to 2020.

In 1980, Lonavala grove exhibited dense vegetation surrounded by limited greenery. However, by 2000, the grove had experienced degradation, attributed to activities such as garden construction. By 2020, Lonavala grove would have displayed a moderate level of vegetation compared to its previously reported dense state.

In contrast, Karla grove remained largely unaffected in 1980 and 2000, surrounded by moderate vegetation. In 2020, there was evidence of degradation with a change in NDVI values, likely due to encroachment and building construction. Nevertheless, a notable increase in dense vegetation in Karla grove in 2020 suggests the initiation of a social forestry initiative (Image 4G).

Vegetation analysis

The natural sacred groves at Lonavala and Karla underwent extensive transformation into gardens and urban areas, respectively. Gammie (1903) listed 84 species and 74 genera in 1903. However, during the current investigation, only 45 genera and 48 species could be listed, resulting in a loss of 35 genera and

Table 5. The total number of genera and species reported from both groves.

Location	Genera	Species
L and K (1903)	74	84
L and K (2022)	45	48
L (2022)	42	46
K (2022)	23	26
Total	**110**	**120**

Table 6. Total number of herbs, shrubs, climbers, and trees reported from both the groves in 1903 and 2022.

Habit	1903		2022	
	Lonavala	Karla	Lonavala	Karla
Herbs	0	0	26	6
Shrubs	26	26	20	27
Climbers	11	8	6	13
Trees	37	28	21	18

36 species (Table 2). there is an addition of 42 genera and 46 species from Lonavala alone due to garden development and new additions of herbaceous plant species, 57% of species have been lost from both groves. There is an addition of 25 genera and 29 species to Karla Grove. Invasive plant species such as *Solanum diphyllum* L., *Chromolaena corymbosa* (Aubl.) R.M.King & H.Rob., and *Solanum torvum* Sw. were found in both groves during the current study. In total, both groves now contain 120 species belonging to 110 genera (Table 5).

Out of the 46 species reported from the Lonavala grove, 22 species (47.86%) of the flora, are reported to be ornamental. In 1903 there were 42 trees, 12 climbers, and 30 shrubs from both groves. As per a recent study, it includes 26 herbs, 15 shrubs, one climber, and four tree species respectively (Table 3). However, this grove has lost several tree species such as *Cordia myxa* L., *Diospyros montana* Roxb., *Dysoxylum binectariferum* (Roxb.) Hook.f. ex Bedd., *Ficus racemosa* L., *Ficus religiosa* L., *Firmiana colorata* (Roxb.) R.Br., *Schleichera oleosa* (Lour.) Oken., *Terminalia chebula* Retz., *Memecylon edule* Roxb., *Neolamarckia cadamba* (Roxb.) Bosser., *Mimusops elengi* L., *Stereospermum chelonoides* (L.f.) DC., *Semecarpus anacardium* L.f., and *Zanthoxylum rhetsa* (Roxb.) DC. Whereas in Karla Grove there is the inclusion of six herbs, 14 shrubs, seven climbers, and two trees respectively (Table 3). There were 42 trees, 12 climbers, and 30 shrubs reported in

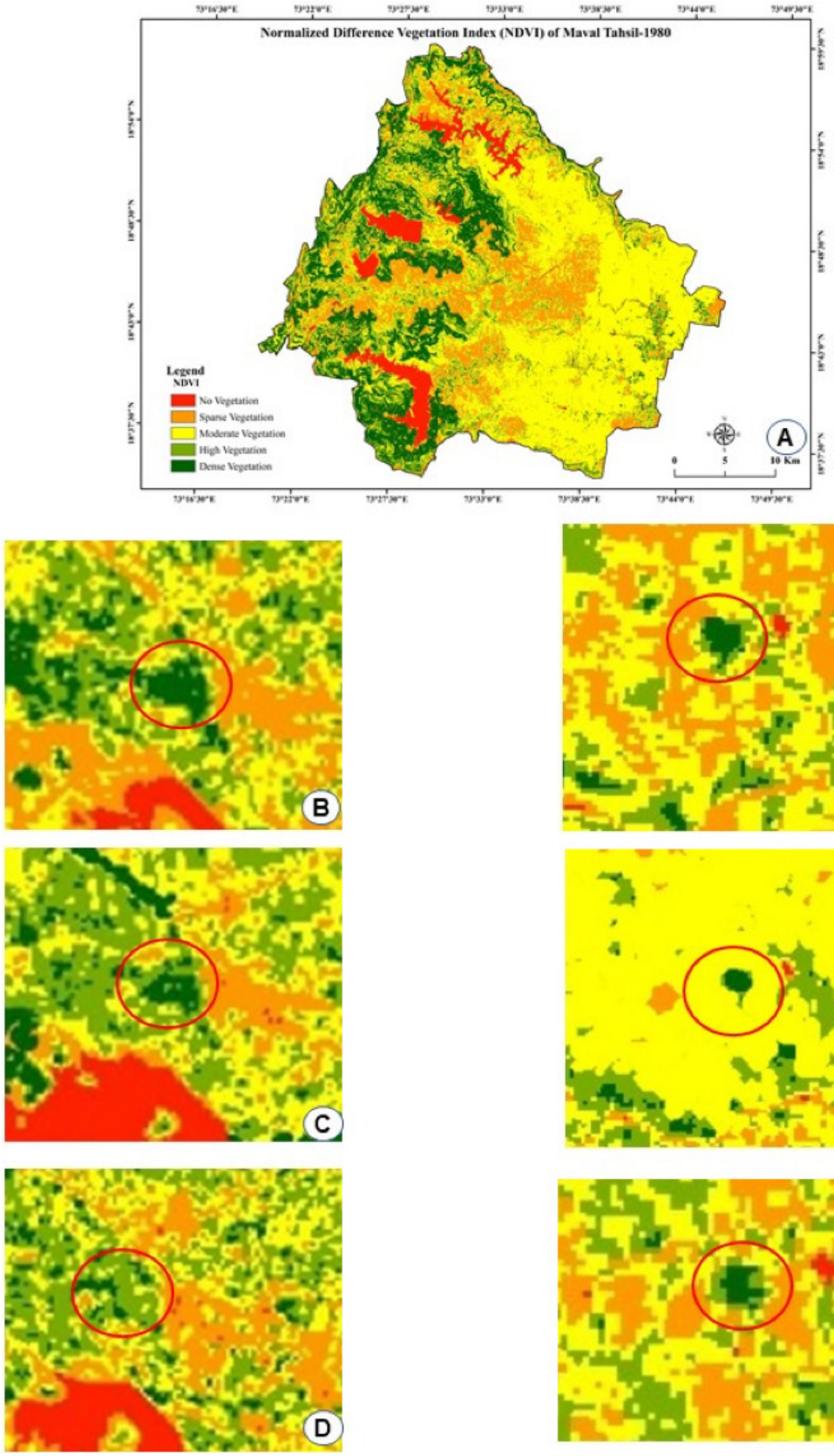

Image 4. A—NDVI of Maval Tehsil | B—NDVI of LG 1980 | C—NDVI of LG 2000, showing the decline of dense vegetation | D—NDVI of LG 2020, showing the decline of dense vegetation | E—NDVI of KG 1980 | F—NDVI of KG 2000, showing the decline of dense vegetation | G—NDVI of KG 2020 showing a rise in dense vegetation due to social forestry.

1903. After a century, there are 24 trees, 10 climbers, and 14 shrubs in both groves (Table 6).

CONCLUSION

The conversion of the sacred forest into gardens and urban areas has a paramount impact on biodiversity in the Western Ghats hill stations. Therefore, these sacred groves need protection under the Biological Diversity Act of 2002.

Traditional practices were used to preserve these groves in the past, but now there is a change in the management of these groves and a consequent loss of protective sentiments towards the sacred groves. To initiate conservation efforts, it is essential to first record the diversity of flora and closely observe the effects of development as well as the overall health of vegetation, utilising remote sensing techniques (Mahabaleshwarkar et al. 2023). Subsequently, the next phase involves lessening the impact of urban expansion on these wooded areas by adopting contemporary strategies, organising community awareness initiatives, and maintaining thorough documentation. Lastly, it is crucial to designate urban sacred natural sites as Biodiversity Heritage Sites under the regulations outlined in this Act, ensuring their sustained protection and welfare (Ormsby 2021).

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