

ASSESSING THE BIODIVERSITY AND ECOLOGICAL SIGNIFICANCE OF CHANGA MANGA: ONE OF THE WORLD'S OLDEST HAND-PLANTED FORESTS IN PAKISTAN

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ABSTRACT

The Changa Manga Forest is located in Punjab, within the Chunian Tehsil of the Kasur District, Pakistan, stands as one of the world's oldest and largest hand-planted forests, established in 1866 during the British colonial era to supply fuelwood for railway operations. Over time, it has evolved into a unique ecological landscape that supports rich biodiversity and provides critical ecosystem services in an otherwise human-dominated region. This review aims to assess the biodiversity status, ecological significance, and conservation challenges of the Changa Manga Forest by synthesizing available literature from scientific databases, government reports, and environmental surveys published between 1980 and 2025. The review systematically compiles data on floral and faunal diversity, forest composition, and ecosystem functions, with emphasis on dominant species, regeneration dynamics, and wildlife conservation value. Findings reveal substantial species richness across various taxa, including over 50 tree species, numerous avian populations, and significant invertebrate diversity. However, the forest faces threats from anthropogenic pressures, habitat fragmentation, invasive species, and climate change. Despite restoration and management interventions, ecological degradation remains a concern. The study concludes that Changa Manga serves as a vital biodiversity refuge and a model for sustainable reforestation. Strengthened conservation strategies, community engagement, and continuous monitoring are recommended to maintain its ecological integrity and long-term sustainability.

KEYWORDS: Changa Manga; Hand-Planted Forest; Biodiversity; Pakistan; Ecosystem Services; Forest Management; Conservation; Reforestation; Kasur District; Chunian Tehsil; Animals; Birds.

1. INTRODUCTION

Planted forests play a crucial role in global biodiversity conservation, carbon sequestration, and sustainable resource management. They occupy

nearly 7% of the world's total forest area and contribute significantly to timber production, ecosystem restoration, and climate regulation. In developing countries, planted forests have become

essential in mitigating deforestation and maintaining ecological balance in regions where natural forests have been extensively degraded. In Pakistan, forest cover remains below 5% of the total land area, making artificial forests vital for ecological and socioeconomic stability. These forests not only supply wood and non-timber resources but also serve as critical habitats for diverse plant and animal species in otherwise human-dominated landscapes (Sharif et al., 2022a). The Changa Manga Forest in Punjab, Pakistan, established in 1866 during British rule, is one of the world's largest man-made forests. Created to supply fuelwood for the North-Western Railway, it transformed arid scrubland into a thriving green landscape through canal irrigation and systematic plantation. Initiated by Dr. John Lindsay Stewart and later managed under B. Ribbentrop's 1871–72 plan, the forest became a model of sustainable forestry. By the 20th century, it spanned nearly 12,000 acres, featuring valuable species like Sheesham (Abrar et al., 2021). Despite challenges like logging and fires, Changa Manga remains a symbol of environmental engineering and human-driven ecological transformation. Despite its historical and ecological

importance, scientific understanding of Changa Manga's biodiversity and ecological dynamics remains limited. Previous research has primarily focused on its forestry and timber yield aspects, leaving considerable gaps in comprehensive biodiversity assessments, species distribution patterns, and ecosystem service evaluations. The increasing threats of habitat fragmentation, illegal logging, and climate change further underscore the urgency for updated ecological evaluations. This review aims to synthesize available scientific and technical data to assess the biodiversity, ecological functions, and conservation challenges of the Changa Manga Forest. It covers published and unpublished sources between 1980 and 2025, encompassing floral and faunal diversity, ecosystem services, and management practices. By integrating data across multiple taxonomic groups plants, mammals, birds, reptiles, amphibians, and invertebrates, the review seeks to provide a holistic understanding of Changa Manga's ecological significance and guide future conservation and policy interventions (Sharif et al., 2022a).



Figure No. 1: Overview of one-night camping in Changa Manga Forest Punjab Pakistan.

2. STUDY AREA: CHANGA MANGA AT A GLANCE

The Changa Manga Forest is located in the Kasur and Lahore districts of Punjab Province, Pakistan, approximately 80 kilometers southwest of Lahore city. Geographically, it lies between 30°55' to 31°00' N latitude and 73°55' to 74°05' E longitude, covering an area of about 12,000 acres (approximately 48 square

kilometers). It is managed by the Punjab Forest Department under the administrative control of the Lahore Forest Division. The forest is easily accessible by the Lahore–Multan Road and serves as a major ecological and recreational zone within the region. The climate of the area is classified as semi-arid subtropical, characterized by hot summers and mild

winters. Average annual rainfall ranges from 450 to 650 millimeters, with the majority occurring during the monsoon season (July to September). Mean summer temperatures often exceed 40°C, while winter temperatures can drop below 5°C. The forest's soils are predominantly alluvial loams and sandy loams, derived from riverine deposits, which are moderately fertile and well-drained. Hydrologically, the forest depends heavily on irrigation from the Upper Bari Doab Canal, an engineered water system that has sustained plantation growth and maintained soil moisture levels since its establishment in the late 19th century. Changa Manga is surrounded primarily by intensive agricultural lands, with nearby villages and urban settlements contributing to both economic opportunities and anthropogenic pressures. The surrounding matrix of cropland and rural development has fragmented natural habitats, increasing edge effects and reducing wildlife corridors. Historically, the forest was initiated in 1866 during the British colonial era as a managed plantation to supply fuelwood for railway locomotives. Initially, species such as *Dalbergia sissoo* (shisham), *Acacia nilotica* (kikar), and *Eucalyptus camaldulensis* were cultivated for their rapid growth and fuelwood potential. In the mid-20th century, management objectives shifted from purely industrial purposes toward timber production, biodiversity conservation, and recreation. Over the decades, the forest has undergone phases of degradation and rehabilitation, including large-scale replanting initiatives following overexploitation. Recent efforts by the Punjab Forest Department and environmental organizations have emphasized ecosystem restoration, wildlife conservation, and ecotourism development, marking Changa Manga as a key site for sustainable forestry and ecological research in Pakistan (S. S. Ahmad et al., 2014).

Location and Extent

The Changa Manga Forest is situated in the Kasur and Lahore districts of Punjab Province, Pakistan, approximately 80 kilometers southwest of Lahore. Geographically, it lies between 30°55' to 31°00' N latitude and 73°55' to 74°05' E longitude, covering an estimated area of 12,000 acres (about 48 square kilometers). The forest falls under the administrative control of the Punjab Forest Department, managed through the Lahore Forest Division. It is easily accessible via the Lahore–Multan Road, making it both an ecological and recreational landmark in central Punjab.

Climate

Changa Manga experiences a semi-arid subtropical climate, characterized by hot summers and mild winters. The mean annual rainfall ranges between 450 and 650 millimeters, concentrated mostly during

the monsoon season (July–September). The average summer temperature often exceeds 40°C, while winter temperatures may fall below 5°C. The pronounced temperature fluctuations and seasonal rainfall patterns strongly influence vegetation growth, soil moisture levels, and species composition within the forest ecosystem.

Soils and Hydrology

The forest soils are primarily alluvial loams and sandy loams, originating from riverine deposits of the Indus Basin. These soils are moderately fertile, well-drained, and suitable for plantation forestry. Changa Manga's hydrological system relies extensively on canal irrigation, primarily sourced from the Upper Bari Doab Canal, constructed during the colonial period. The irrigation network ensures consistent water availability for plantation growth and has been vital in sustaining forest vegetation under semi-arid conditions.

Land-Use Environment

Changa Manga is surrounded predominantly by agricultural fields and rural settlements, which form a mosaic of croplands and human habitation. This agro-ecological matrix provides economic benefits to local communities but also exerts significant anthropogenic pressure on forest resources through encroachment, fuelwood extraction, and livestock grazing. The lack of buffer zones and increasing land-use conversion have contributed to habitat fragmentation and reduced ecological connectivity with nearby natural areas.

Historical Timeline and Management Evolution

The establishment of Changa Manga dates back to 1866, under British colonial administration, when it was created to meet the fuelwood demands of the North-Western Railway. Early plantation efforts focused on fast-growing native and exotic species such as *Dalbergia sissoo* (shisham), *Acacia nilotica* (kikar), and *Eucalyptus camaldulensis*. By the mid-20th century, management goals evolved from industrial fuel production to timber yield, biodiversity conservation, and recreation. Over time, the forest faced cycles of degradation, overexploitation, and rehabilitation.

In recent decades, the Punjab Forest Department, along with environmental organizations, has launched several restoration and conservation projects to enhance biodiversity and promote ecotourism. These initiatives aim to balance ecological sustainability with socio-economic development, reinforcing Changa Manga's status as a model for reforestation and sustainable forest management in Pakistan (M. Ahmad, 2017).

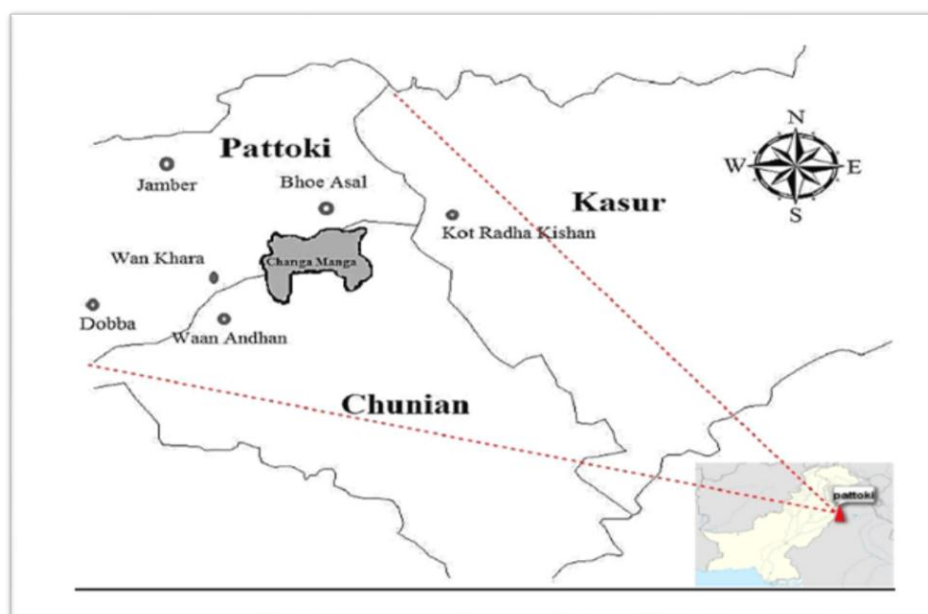


Figure No. 2: Map of Changa Manga Forest.

3. VEGETATION AND FLORA

Tree Species Composition and Structure

The vegetation of the Changa Manga Forest is primarily composed of planted tree species, originally established under British colonial administration to serve as a sustainable source of timber and fuelwood. The dominant tree species include *Dalbergia sissoo* (shisham), *Acacia nilotica* (kikar), *Eucalyptus camaldulensis*, *Bombax ceiba* (simal), and *Morus alba* (white mulberry). These species were selected for their fast growth rates, adaptability to semi-arid conditions, and high wood yield. Over the decades, natural regeneration has occurred beneath these

plantations, gradually increasing the structural complexity of the forest. The forest canopy height generally ranges between 15 to 25 meters, depending on species composition and site conditions. The stand structure varies across compartments, reflecting different management regimes, irrigation availability, and soil fertility. Studies by the Punjab Forest Department and Pakistan Forest Institute indicate that *Dalbergia sissoo* and *Acacia nilotica* remain the most dominant and economically valuable species, contributing to over 60% of the total basal area in many compartments (Fatima et al., 2025).



Overview of plants species in Changa Manga Forest, Punjab, Pakistan

Figure No. 3: Plants Species in Changa Manga Forest, Punjab, Pakistan.

Understorey Vegetation and Regenerative Dynamics

The understorey vegetation is relatively sparse but ecologically important for soil stabilization, nutrient cycling, and wildlife habitat. Common understorey species include grasses such as *Cynodon dactylon* (Bermuda grass), *Desmostachya bipinnata*, and herbs like *Parthenium hysterophorus*, *Chenopodium album*, and *Achyranthes aspera*. These species thrive in partially shaded areas and disturbed forest patches. Natural regeneration of key native species has been observed, particularly in areas with reduced grazing and adequate moisture levels. Seedling establishment of *Dalbergia sissoo* and *Acacia nilotica* is most successful in canal-irrigated zones, whereas *Eucalyptus camaldulensis* regenerates primarily through coppicing. Regeneration studies reveal that anthropogenic disturbance, soil compaction, and invasive weeds are major constraints on natural recruitment. Effective management interventions such as selective thinning and enrichment planting have been implemented to improve regeneration and maintain species diversity (ASAD et al., n.d.) (Iqbal, Ahmed, et al., n.d.).

Native, Non-Native, and Invasive Species

The Changa Manga Forest contains a mix of native and exotic species, reflecting its artificial origin and long history of silvicultural experimentation. Native species like *Dalbergia sissoo*, *Acacia nilotica*, *Albizia lebbek*, and *Ficus religiosa* contribute to local biodiversity and ecosystem balance. However, the introduction of non-native species, particularly *Eucalyptus camaldulensis* and *Prosopis juliflora*, has altered ecological dynamics. *Eucalyptus camaldulensis* though fast-growing and drought-tolerant has been criticized for its high water uptake,

allelopathic effects, and low understory biodiversity. Similarly, *Prosopis juliflora*, originally introduced for fuelwood production, has become an aggressive invasive species, outcompeting native vegetation and altering soil chemistry. These invasions threaten native plant communities and reduce available forage for wildlife. Restoration efforts now emphasize replacing invasive exotics with indigenous species to restore ecological functionality (KHALIL et al., 2022).

Floristic Diversity and Ecological Indicators

Floristic surveys conducted by various researchers and the Punjab Forest Department report that the Changa Manga Forest hosts over 70 species of trees and shrubs, 50 species of herbs, and 25 species of grasses. The Shannon–Wiener diversity index (H') values for tree communities range between 1.8 and 2.4, indicating moderate diversity typical of managed forests. The Simpson's diversity index values also confirm that no single species completely dominates, reflecting relatively balanced species distribution in well-managed compartments. In terms of alpha diversity (within-habitat diversity), the central irrigated zones exhibit higher species richness due to stable moisture and nutrient conditions, while beta diversity (between-habitat diversity) is more pronounced between irrigated and dry compartments, reflecting strong environmental gradients. Overall, the vegetation structure of Changa Manga represents a dynamic interplay between artificial plantation management and natural successional processes. The ongoing transition toward mixed native plantations and enrichment of degraded sites highlights its potential as a model for ecological restoration and sustainable forest management in semi-arid regions of South Asia (Waheed et al., 2022).



Figure No. 4: Plants Species in Changa Manga Forest, Punjab, Pakistan.

Table 1: Tree Species in the Changa Manga Forest, Punjab, Pakistan.

Sr.No	Common Name	Scientific Name	Native/Exotic Status	IUCN Status	Notes on Occurrence in Changa Manga
1	Shisham / Sissoo	<i>Dalbergia sissoo</i>	Native	Least Concern	Documented – widely planted in irrigation zones
2	Kikar / Babul	<i>Acacia nilotica</i>	Native	Least Concern	Documented – major plantation species
3	River Red Gum	<i>Eucalyptus camaldulensis</i>	Exotic	Not Evaluated	Documented – used as fast-growing plantation species
4	White Mulberry	<i>Morus alba</i>	Exotic	Not Evaluated	Likely – used as fodder and shade tree
5	Sacred Fig / Peepal	<i>Ficus religiosa</i>	Native	Not Evaluated	Documented – part of mixed native regeneration
6	Banyan	<i>Ficus benghalensis</i>	Native	Least Concern	Documented – mature individuals near water bodies
7	Neem	<i>Azadirachta indica</i>	Native	Least Concern	Documented – common avenue tree
8	Mesquite	<i>Prosopis juliflora</i>	Exotic	Least Concern	Documented – invasive patches observed
9	Siris / Lebbek	<i>Albizia lebbek</i>	Native	Least Concern	Documented – shade tree and soil enricher
10	Jamun / Black Plum	<i>Syzygium cumini</i>	Native	Least Concern	Documented – planted in moist areas
11	Moringa / Drumstick	<i>Moringa oleifera</i>	Native	Least Concern	Likely – found in peripheral zones
12	Ber / Indian Jujube	<i>Ziziphus mauritiana</i>	Native	Least Concern	Documented – found in dry edges
13	Tamarisk	<i>Tamarix aphylla</i>	Native	Least Concern	Documented – along water channels
14	Casuarina	<i>Casuarina equisetifolia</i>	Exotic	Least Concern	Likely – used as windbreak plantation
15	Chinaberry	<i>Melia azedarach</i>	Exotic	Least Concern	Documented – avenue and ornamental planting
16	Pongamia / Karanja	<i>Millettia pinnata</i>	Native	Least Concern	Likely – found in demonstration plots
17	Mango	<i>Mangifera indica</i>	Native	Least Concern	Likely – near residential quarters
18	Sweet Orange	<i>Citrus sinensis</i>	Exotic	Not Evaluated	Ornamental – in park areas
19	Lemon	<i>Citrus limon</i>	Exotic	Not Evaluated	Ornamental – garden planting
20	Indian Almond	<i>Terminalia catappa</i>	Exotic	Least Concern	Ornamental – scattered individuals
21	Arjun	<i>Terminalia arjuna</i>	Native	Least Concern	Documented – riverbank stabilization species
22	Bahera	<i>Terminalia bellirica</i>	Native	Least Concern	Likely – part of mixed plantations
23	Haritaki / Myrobalan	<i>Terminalia chebula</i>	Native	Least Concern	Likely – mixed forest restoration plots
24	Pomegranate	<i>Punica granatum</i>	Native	Least Concern	Ornamental – near rest houses
25	Amla / Indian Gooseberry	<i>Phyllanthus emblica</i>	Native	Least Concern	Documented – medicinal plantation area
26	Jackfruit	<i>Artocarpus heterophyllus</i>	Exotic	Least Concern	Ornamental – demonstration area

27	Chinese Jujube	<i>Ziziphus jujuba</i>	Exotic	Least Concern	Likely – similar ecological range
28	Common Fig	<i>Ficus carica</i>	Exotic	Least Concern	Ornamental – in garden belts
29	Coral Tree	<i>Erythrina variegata</i>	Native	Least Concern	Documented – ornamental species in periphery
30	Jacaranda	<i>Jacaranda mimosifolia</i>	Exotic	Least Concern	Ornamental – roadside plantation
31	Gulmohar / Flame Tree	<i>Delonix regia</i>	Exotic	Least Concern	Documented – along main roads
32	Golden Shower	<i>Cassia fistula</i>	Native	Least Concern	Documented – ornamental and medicinal value
33	Silk Oak	<i>Grevillea robusta</i>	Exotic	Least Concern	Ornamental – scattered stands
34	Golden Wattle	<i>Acacia saligna</i>	Exotic	Least Concern	Likely – used for soil binding
35	Shami / Ghaf	<i>Prosopis cineraria</i>	Native	Least Concern	Documented – dry zone plantation
36	Weeping Willow	<i>Salix babylonica</i>	Exotic	Least Concern	Documented – near water channels
37	Poplar	<i>Populus deltoides</i>	Exotic	Least Concern	Documented – timber plantation species
38	Olive	<i>Olea europaea</i>	Exotic	Least Concern	Likely – experimental plantation
39	Chinese Banyan	<i>Ficus microcarpa</i>	Exotic	Least Concern	Ornamental – landscape planting
40	Tree-of-Heaven	<i>Ailanthus altissima</i>	Exotic	Least Concern	Documented – invasive tendency
41	Crape Myrtle	<i>Lagerstroemia indica</i>	Exotic	Least Concern	Ornamental – park area
42	Guava	<i>Psidium guajava</i>	Native	Least Concern	Likely – near residences
43	Rose Apple	<i>Syzygium jambos</i>	Exotic	Least Concern	Ornamental – rare occurrence
44	Mandarin	<i>Citrus reticulata</i>	Exotic	Not Evaluated	Ornamental – limited use
45	Manila Tamarind	<i>Pithecellobium dulce</i>	Exotic	Least Concern	Documented – naturalized along roads
46	Butea / Flame of Forest	<i>Butea monosperma</i>	Native	Least Concern	Documented – sporadic stands
47	Kachnar / Orchid Tree	<i>Bauhinia variegata</i>	Native	Least Concern	Documented – ornamental avenue tree
48	Eucalyptus tereticornis	<i>Eucalyptus tereticornis</i>	Exotic	Not Evaluated	Documented – industrial plantation
49	Eucalyptus globulus	<i>Eucalyptus globulus</i>	Exotic	Not Evaluated	Likely – limited extent
50	Deodar Cedar	<i>Cedrus deodara</i>	Native	Least Concern	Ornamental – introduced species
51	Italian Cypress	<i>Cupressus sempervirens</i>	Exotic	Least Concern	Ornamental – garden use
52	Himalayan Pine	<i>Pinus wallichiana</i>	Native	Least Concern	Ornamental – limited individuals
53	Wild Fig	<i>Ficus palmata</i>	Native	Least Concern	Likely – natural regeneration areas
54	Black Mulberry	<i>Morus nigra</i>	Exotic	Not Evaluated	Likely – cultivated form
55	Sidr / Nabq	<i>Ziziphus</i>	Native	Least Concern	Documented – boundary

		<i>spina-christi</i>			zones
56	Phulai	<i>Acacia modesta</i>	Native	Least Concern	Documented – dry and arid margins
57	Indian Elm / Chir	<i>Holoptelea integrifolia</i>	Native	Least Concern	Documented – native tree patches
58	Rain Tree	<i>Samanea saman</i>	Exotic	Least Concern	Ornamental – shade tree
59	Sterculia	<i>Sterculia foetida</i>	Exotic	Least Concern	Ornamental – occasional
60	Peruvian Pepper	<i>Schinus molle</i>	Exotic	Least Concern	Likely – in landscaping
61	Indian Laurel / Saj	<i>Terminalia elliptica</i>	Native	Least Concern	Likely – experimental planting
62	Chitwan Fig	<i>Ficus neriifolia</i>	Native	Least Concern	Likely – planted near streams
63	Bay Laurel	<i>Laurus nobilis</i>	Exotic	Least Concern	Ornamental – rare
64	Alstonia / Devil Tree	<i>Alstonia scholaris</i>	Native	Least Concern	Documented – scattered individuals
65	Ceylon Oak	<i>Lagerstroemia speciosa</i>	Exotic	Least Concern	Ornamental – along avenues
66	Eucalyptus hybrids	<i>Eucalyptus spp.</i>	Exotic	Not Evaluated	Documented – extensive plantations
67	Indian Beech	<i>Melia dubia</i>	Native	Least Concern	Documented – mixed plantations
69	Soapnut / Reetha	<i>Sapindus mukorossi</i>	Native	Least Concern	Likely – scattered individuals
70	Canary Island Palm	<i>Phoenix canariensis</i>	Exotic	Least Concern	Ornamental – along entry roads



Figure No 5: Overview of Ornamental plants in Changa Manga Forest, Punjab, Pakistan.

Table 2: Shrub Species in the Changa Manga Forest, Punjab, Pakistan.

Sr.No	Common Name	Scientific Name	Native/Exotic Status	IUCN Status	Notes on Occurrence in Changa Manga
1	Lantana	<i>Lantana camara</i>	Exotic	Least Concern	Documented – common invasive shrub in open areas
2	Jharberi	<i>Ziziphus nummularia</i>	Native	Least Concern	Documented – dominant native shrub in dry areas
3	Henna / Mehndi	<i>Lawsonia inermis</i>	Native	Least Concern	Likely – planted in managed plots
4	Dodonaea	<i>Dodonaea viscosa</i>	Native	Least Concern	Documented – used for soil binding
5	Carissa / Karonda	<i>Carissa spinarum</i>	Native	Least Concern	Documented – thorny shrub in degraded zones
6	Vitex	<i>Vitex negundo</i>	Native	Least Concern	Documented – medicinal shrub along edges
7	Bougainvillea	<i>Bougainvillea spectabilis</i>	Exotic	Not Evaluated	Ornamental – planted near offices
8	Cassia tora	<i>Cassia tora</i>	Native	Least Concern	Likely – found in disturbed soils
9	Plumbago	<i>Plumbago zeylanica</i>	Native	Least Concern	Likely – medicinal species in shaded areas
10	Calotropis / Aak	<i>Calotropis procera</i>	Native	Least Concern	Documented – common xerophytic shrub
11	Capparis / Kachri	<i>Capparis decidua</i>	Native	Least Concern	Documented – dry sandy areas
12	Aerva	<i>Aerva javanica</i>	Native	Least Concern	Documented – along dry margins
13	Leptadenia	<i>Leptadenia pyrotechnica</i>	Native	Least Concern	Documented – found in sandy sites
14	Tobacco bush	<i>Nicotiana glauca</i>	Exotic	Least Concern	Likely – escaped ornamental
15	Tecoma / Yellow bell	<i>Tecoma stans</i>	Exotic	Least Concern	Ornamental – planted near roads
16	Ixora	<i>Ixora coccinea</i>	Exotic	Least Concern	Ornamental – garden species
17	Clerodendrum	<i>Clerodendrum inerme</i>	Exotic	Least Concern	Ornamental – hedgerow plant
18	Justicia	<i>Justicia adhatoda</i>	Native	Least Concern	Documented – medicinal shrub (vasaka)
19	Cassia auriculata	<i>Cassia auriculata</i>	Native	Least Concern	Likely – found in restored plots
20	Croton	<i>Croton bonplandianus</i>	Exotic	Least Concern	Likely – along disturbed edges
21	Ruellia	<i>Ruellia tuberosa</i>	Exotic	Least Concern	Ornamental – planted near pathways
22	Duranta	<i>Duranta erecta</i>	Exotic	Least Concern	Ornamental – hedge and boundary plant
23	Hibiscus / China rose	<i>Hibiscus rosa-sinensis</i>	Exotic	Not Evaluated	Ornamental – planted in gardens
24	Jatropha	<i>Jatropha curcas</i>	Exotic	Least Concern	Ornamental – experimental biofuel plot
25	Euphorbia	<i>Euphorbia tirucalli</i>	Native	Least Concern	Documented – xerophytic hedge species
26	Cassia alata	<i>Cassia alata</i>	Exotic	Least Concern	Likely – ornamental plantation
27	Cestrum	<i>Cestrum</i>	Exotic	Least	Ornamental – night-blooming

	nocturnum	<i>nocturnum</i>		Concern	jasmine
28	Barleria	<i>Barleria prionitis</i>	Native	Least Concern	Documented – medicinal shrub in open woodlands
29	Clitoria	<i>Clitoria ternatea</i>	Native	Least Concern	Likely – planted for research plots
30	Abutilon	<i>Abutilon indicum</i>	Native	Least Concern	Documented – disturbed ground flora
31	Acalypha	<i>Acalypha indica</i>	Native	Least Concern	Likely – found in shaded understory
32	Alternanthera	<i>Alternanthera sessilis</i>	Exotic	Least Concern	Ornamental – along lawns
33	Lawsonia	<i>Lawsonia alba</i>	Native	Least Concern	Documented – naturalized in dry regions
34	Lippia	<i>Lippia nodiflora</i>	Native	Least Concern	Likely – found near water bodies
35	Cassia occidentalis	<i>Cassia occidentalis</i>	Native	Least Concern	Documented – under open canopy
36	Crotalaria	<i>Crotalaria juncea</i>	Native	Least Concern	Likely – nitrogen-fixing shrub
37	Indigofera	<i>Indigofera tinctoria</i>	Native	Least Concern	Documented – common leguminous shrub
38	Solanum / Nightshade	<i>Solanum incanum</i>	Native	Least Concern	Documented – scattered undergrowth
39	Achyranthes	<i>Achyranthes aspera</i>	Native	Least Concern	Documented – roadside and degraded areas
40	Clerodendrum phlomidis	<i>Clerodendrum phlomidis</i>	Native	Least Concern	Documented – medicinal hedgerow species
41	Cassia siamea	<i>Cassia siamea</i>	Exotic	Least Concern	Likely – ornamental shrub planting
42	Tagetes	<i>Tagetes erecta</i>	Exotic	Not Evaluated	Ornamental – flowerbeds
43	Tephrosia	<i>Tephrosia purpurea</i>	Native	Least Concern	Documented – nitrogen fixer in dry soils
44	Calotropis gigantea	<i>Calotropis gigantea</i>	Native	Least Concern	Documented – xeric shrub species
45	Pergularia	<i>Pergularia daemia</i>	Native	Least Concern	Likely – climbing shrub in open fields
46	Senna italica	<i>Senna italica</i>	Native	Least Concern	Documented – sandy areas
47	Cassia absus	<i>Cassia absus</i>	Native	Least Concern	Likely – rare in degraded forest edges
48	Leucas	<i>Leucas aspera</i>	Native	Least Concern	Documented – common medicinal herbaceous shrub
49	Ocimum / Basil	<i>Ocimum sanctum</i>	Native	Least Concern	Documented – cultivated for cultural and medicinal use
50	Aerva lanata	<i>Aerva lanata</i>	Native	Least Concern	Likely – near canal margins

Table 3: Grass Species in the Changa Manga Forest, Punjab, Pakistan.

Sr. No	Common Name	Scientific Name	Native/Exotic Status	IUCN Status	Notes on Occurrence in Changa Manga
1	Bermuda Grass	<i>Cynodon dactylon</i>	Native	Least Concern	Documented – common throughout forest floor
2	Vetiver Grass	<i>Vetiveria zizanioides</i>	Native	Least Concern	Documented – used for soil stabilization

3	Khabal Grass	<i>Cymbopogon jwarancusa</i>	Native	Least Concern	Documented – aromatic grass in open areas
4	Spear Grass	<i>Heteropogon contortus</i>	Native	Least Concern	Documented – common in dry patches
5	Saccharum Grass	<i>Saccharum spontaneum</i>	Native	Least Concern	Documented – along canal banks and open spaces
6	Dhaman Grass	<i>Cenchrus ciliaris</i>	Native	Least Concern	Documented – dominant pasture grass
7	Buffel Grass	<i>Cenchrus setigerus</i>	Native	Least Concern	Documented – natural pasture areas
8	Para Grass	<i>Brachiaria mutica</i>	Exotic	Least Concern	Documented – near water bodies and irrigation channels
9	Elephant Grass	<i>Pennisetum purpureum</i>	Exotic	Least Concern	Ornamental/forage – planted for erosion control
10	Guinea Grass	<i>Panicum maximum</i>	Exotic	Least Concern	Likely – planted in managed pastures
11	Johnson Grass	<i>Sorghum halepense</i>	Exotic	Least Concern	Documented – along roadsides and disturbed lands
12	Kallar Grass	<i>Leptochloa fusca</i>	Native	Least Concern	Documented – salt-tolerant grass in saline soils
13	Love Grass	<i>Eragrostis tenella</i>	Native	Least Concern	Documented – forest understory areas
14	Goose Grass	<i>Eleusine indica</i>	Native	Least Concern	Documented – common weed in forest margins
15	Setaria Grass	<i>Setaria glauca</i>	Native	Least Concern	Documented – common forage grass
16	Paspalum	<i>Paspalum distichum</i>	Native	Least Concern	Documented – found near moist habitats
17	Wild Oat	<i>Avena fatua</i>	Exotic	Least Concern	Likely – found near cultivated boundaries
18	Baru Grass	<i>Sporobolus diander</i>	Native	Least Concern	Documented – sandy patches and disturbed sites
19	Rescue Grass	<i>Bromus catharticus</i>	Exotic	Least Concern	Likely – introduced as pasture grass
20	Ryegrass	<i>Lolium perenne</i>	Exotic	Least Concern	Ornamental – experimental plot species
21	Crowfoot Grass	<i>Dactyloctenium aegyptium</i>	Native	Least Concern	Documented – forest edges and pathways
22	Indian Goosegrass	<i>Chloris barbata</i>	Native	Least Concern	Documented – common in open clearings
23	Panic Grass	<i>Panicum antidotale</i>	Native	Least Concern	Documented – dry grasslands and canal banks
24	Kangni	<i>Setaria italica</i>	Exotic	Least Concern	Likely – found in experimental agricultural fields
25	Blue Panic	<i>Panicum antidotale</i>	Native	Least Concern	Documented – dominant tall grass species

Table 4: Pharmacological Importance of Trees, Shrubs, and Grasses of the Changa Manga Forest, Punjab, Pakistan.

Sr. No	Plant Type	Common Name	Scientific Name	Pharmacological Importance
1	Tree	Neem	<i>Azadirachta indica</i>	Used for antibacterial, antifungal, and anti-inflammatory properties
2	Tree	Sheesham	<i>Dalbergia sissoo</i>	Antioxidant and antimicrobial activities; used in traditional medicine
3	Tree	Kikar /	<i>Acacia nilotica</i>	Used for wound healing, anti-inflammatory

		Babul		and antidiabetic activity
4	Tree	Amaltas	<i>Cassia fistula</i>	Laxative, antimicrobial, and antioxidant properties
5	Tree	Mango	<i>Mangifera indica</i>	Used for antidiabetic, anti-inflammatory, and immunomodulatory effects
6	Tree	Arjun	<i>Terminalia arjuna</i>	Cardioprotective and antioxidant activities
7	Tree	Eucalyptus	<i>Eucalyptus camaldulensis</i>	Antiseptic and anti-inflammatory essential oils
8	Tree	Mulberry	<i>Morus alba</i>	Antidiabetic and neuroprotective properties
9	Tree	Banyan	<i>Ficus benghalensis</i>	Used for wound healing and diabetes management
10	Tree	Peepal	<i>Ficus religiosa</i>	Antioxidant and anti-inflammatory activities
1	Shrub	Vitex / Nirgundi	<i>Vitex negundo</i>	Used for arthritis, inflammation, and analgesic properties
2	Shrub	Adhatoda / Vasaka	<i>Justicia adhatoda</i>	Expectorant and bronchodilator for respiratory diseases
3	Shrub	Aak	<i>Calotropis procera</i>	Analgesic, anti-inflammatory, and wound healing uses
4	Shrub	Carissa / Karonda	<i>Carissa spinarum</i>	Antioxidant and antimicrobial properties
5	Shrub	Dodonaea	<i>Dodonaea viscosa</i>	Anti-inflammatory and hepatoprotective effects
6	Shrub	Cassia tora	<i>Cassia tora</i>	Laxative and antidiabetic properties
7	Shrub	Lawsonia / Henna	<i>Lawsonia inermis</i>	Antimicrobial and antioxidant properties
8	Shrub	Leptadenia	<i>Leptadenia pyrotechnica</i>	Used for diuretic and antimicrobial activity
9	Shrub	Barleria	<i>Barleria prionitis</i>	Antioxidant and anti-inflammatory potential
10	Shrub	Clerodendrum	<i>Clerodendrum inerme</i>	Used for anti-inflammatory and antipyretic properties
1	Grass	Vetiver	<i>Vetiveria zizanioides</i>	Used for skin diseases, stress relief, and as a coolant
2	Grass	Khabal Grass	<i>Cymbopogon jwarancusa</i>	Aromatic; antimicrobial and insecticidal uses
3	Grass	Dhaman Grass	<i>Cenchrus ciliaris</i>	Used as forage; soil stabilization; minimal pharmacological use
4	Grass	Saccharum Grass	<i>Saccharum spontaneum</i>	Traditionally used for urinary and kidney disorders
5	Grass	Para Grass	<i>Brachiaria mutica</i>	Primarily forage; no major pharmacological use
6	Grass	Blue Panic	<i>Panicum antidotale</i>	Antidiabetic and antioxidant activities reported
7	Grass	Crowfoot Grass	<i>Dactyloctenium aegyptium</i>	Antibacterial potential studied in extracts
8	Grass	Kallar Grass	<i>Leptochloa fusca</i>	Used in phytoremediation of saline soils
9	Grass	Johnson Grass	<i>Sorghum halepense</i>	Source of antioxidant phenolic compounds
10	Grass	Guinea Grass	<i>Panicum maximum</i>	Forage species with antioxidant compounds

4. FAUNAL BIODIVERSITY

Mammals

The Changa Manga Forest supports a diverse assemblage of large and small mammalian species, representing both forest-dwelling and generalist taxa. Historically, large mammals such as the Asiatic jackal (*Canis aureus*), Indian mongoose (*Herpestes edwardsii*), and wild boar (*Sus scrofa*) have been recorded as dominant carnivorous and omnivorous species. Smaller mammals, including the Indian hare (*Lepus nigricollis*), house mouse (*Mus musculus*), and Indian palm squirrel (*Funambulus pennantii*), are commonly observed throughout the forest. Recent

wildlife monitoring by the Punjab Wildlife and Parks Department indicates that canopy cover restoration and improved water availability have facilitated the gradual return of certain medium-sized mammals such as jungle cat (*Felis chaus*) and porcupine (*Hystrix indica*). However, the fragmentation of habitat and limited ecological corridors connecting Changa Manga to other forest patches constrain the movement of larger mammals. Historically, species such as nilgai (*Boselaphus tragocamelus*) were reported, but they are now locally extinct due to habitat loss and poaching (Aslam et al., 2022) (Iqbal, Altaf, et al., n.d.).

Table 5: Mammalian Diversity of Changa Manga Forest, Punjab, Pakistan.

Sr. No	Type	Common Name	Scientific Name	Native/Exotic Status	IUCN Status	Notes on Occurrence in Changa Manga
1	Large Mammal	Indian Jackal	<i>Canis aureus</i>	Native	Least Concern	Documented – common carnivore in the forest
2	Large Mammal	Wild Boar	<i>Sus scrofa</i>	Native	Least Concern	Documented – widespread, causes crop damage nearby
3	Large Mammal	Nilgai (Blue Bull)	<i>Boselaphus tragocamelus</i>	Native	Least Concern	Likely – occasional sightings reported
4	Large Mammal	Rhesus Macaque	<i>Macaca mulatta</i>	Native	Least Concern	Documented – common near forest edges
5	Large Mammal	Indian Palm Civet	<i>Paradoxurus hermaphroditus</i>	Native	Least Concern	Documented – nocturnal, arboreal species
6	Large Mammal	Jungle Cat	<i>Felis chaus</i>	Native	Least Concern	Documented – found in grassland patches
7	Large Mammal	Indian Porcupine	<i>Hystrix indica</i>	Native	Least Concern	Documented – burrowing species, common
8	Large Mammal	Small Indian Mongoose	<i>Herpestes javanicus</i>	Native	Least Concern	Documented – seen near plantation edges
9	Large Mammal	Common Grey Mongoose	<i>Herpestes edwardsii</i>	Native	Least Concern	Documented – active during day near human areas
10	Large Mammal	Chinkara (Indian Gazelle)	<i>Gazella bennettii</i>	Native	Least Concern	Rare – historically present, now seldom seen
11	Small Mammal	Indian Hare	<i>Lepus nigricollis</i>	Native	Least Concern	Documented – common in grasslands
12	Small Mammal	Five-striped Palm Squirrel	<i>Funambulus pennantii</i>	Native	Least Concern	Documented – abundant on trees
13	Small Mammal	Soft-furred Field Rat	<i>Millardia meltada</i>	Native	Least Concern	Documented – common in undergrowth
14	Small Mammal	House Mouse	<i>Mus musculus</i>	Native	Least Concern	Common – near settlements and forest quarters
15	Small Mammal	Indian Gerbil	<i>Tatera indica</i>	Native	Least Concern	Documented – burrowing rodent in dry areas

16	Small Mammal	Indian Pipistrelle Bat	Pipistrellus coromandra	Native	Least Concern	Documented – found roosting in tree hollows
17	Small Mammal	Lesser Mouse-tailed Bat	Rhinopoma hardwickii	Native	Least Concern	Likely – roosts in abandoned structures
18	Small Mammal	Desert Hedgehog	Paraechinus aethiopicus	Native	Least Concern	Likely – found in dry, open areas
19	Small Mammal	Long-eared Hedgehog	Hemiechinus auritus	Native	Least Concern	Likely – nocturnal, occasionally sighted
20	Small Mammal	Short-nosed Fruit Bat	Cynopterus sphinx	Native	Least Concern	Documented – frugivorous bat, roosts in trees

Avifauna (Birds)

The Changa Manga Forest is regarded as one of the most significant avian habitats in central Punjab. Over 200 bird species have been recorded, comprising both resident and migratory populations. Resident species include the rose-ringed parakeet (*Psittacula krameri*), common myna (*Acridotheres tristis*), red-vented bulbul (*Pycnonotus cafer*), and black drongo (*Dicrurus macrocercus*), which are abundant year-round. During the winter migration season, the forest serves as a critical stopover site for various migratory birds originating from Central Asia and Siberia. Species such as the rosy starling (*Pastor roseus*), blue-

throat (*Luscinia svecica*), Indian roller (*Coracias benghalensis*), and black kite (*Milvus migrans*) are seasonally abundant. The nearby irrigation canals and artificial lakes provide essential water and feeding resources for wading birds like little egret (*Egretta garzetta*) and cattle egret (*Bubulcus ibis*). The high avian diversity underscores the forest's importance as a bird refuge and breeding habitat, especially within an agricultural landscape. However, deforestation, pesticide exposure, and tourism-related disturbances continue to affect nesting and foraging behaviors (Sadia et al., 2024).

Table 6: Avifauna of Changa Manga Forest, Punjab, Pakistan.

Sr .No	Common Name	Scientific Name	Resident/Migratory Status	IUCN Status	Notes on Occurrence in Changa Manga
1	Indian Peafowl	<i>Pavo cristatus</i>	Resident	Least Concern	Commonly seen in forest clearings
2	Black Drongo	<i>Dicrurus macrocercus</i>	Resident	Least Concern	Abundant in open areas
3	House Crow	<i>Corvus splendens</i>	Resident	Least Concern	Common near human settlements
4	Common Myna	<i>Acridotheres tristis</i>	Resident	Least Concern	Very common and adaptive
5	Red-vented Bulbul	<i>Pycnonotus cafer</i>	Resident	Least Concern	Common in shrubs and edges
6	Jungle Babbler	<i>Turdoides striata</i>	Resident	Least Concern	Frequently seen in groups
7	Green Bee-eater	<i>Merops orientalis</i>	Resident	Least Concern	Common in grasslands
8	Rose-ringed Parakeet	<i>Psittacula krameri</i>	Resident	Least Concern	Abundant; cavity nester
9	White-throated Kingfisher	<i>Halcyon smyrnensis</i>	Resident	Least Concern	Found near water bodies
10	Indian Roller	<i>Coracias benghalensis</i>	Resident	Least Concern	Perches on electric wires
11	Eurasian Collared Dove	<i>Streptopelia decaocto</i>	Resident	Least Concern	Very common species
12	Laughing Dove	<i>Spilopelia senegalensis</i>	Resident	Least Concern	Common in all habitats
13	Cattle Egret	<i>Bubulcus ibis</i>	Resident	Least	Abundant; feeds with

				Concern	livestock
14	Little Egret	<i>Egretta garzetta</i>	Resident	Least Concern	Found near ponds and canals
15	Black Kite	<i>Milvus migrans</i>	Resident	Least Concern	Common scavenger
16	Shikra	<i>Accipiter badius</i>	Resident	Least Concern	Forest predator
17	Spotted Owlet	<i>Athene brama</i>	Resident	Least Concern	Common nocturnal bird
18	Barn Owl	<i>Tyto alba</i>	Resident	Least Concern	Found near villages
19	Indian Grey Hornbill	<i>Ocyeros birostris</i>	Resident	Least Concern	Breeds in forest cavities
20	Rufous Treepie	<i>Dendrocitta vagabunda</i>	Resident	Least Concern	Common in canopy
21	White Wagtail	<i>Motacilla alba</i>	Winter Migrant	Least Concern	Seen in open fields in winter
22	Grey Wagtail	<i>Motacilla cinerea</i>	Winter Migrant	Least Concern	Occasional visitor
23	Common Sandpiper	<i>Actitis hypoleucos</i>	Winter Migrant	Least Concern	Found near canals
24	Barn Swallow	<i>Hirundo rustica</i>	Migratory	Least Concern	Common in summer
25	Red-rumped Swallow	<i>Cecropis daurica</i>	Migratory	Least Concern	Seen during spring
26	Blue Rock Thrush	<i>Monticola solitarius</i>	Winter Migrant	Least Concern	Occasional
27	Black Redstart	<i>Phoenicurus ochruros</i>	Winter Migrant	Least Concern	Common in open fields
28	Common Chiffchaff	<i>Phylloscopus collybita</i>	Winter Migrant	Least Concern	Small migratory warbler
29	Eurasian Hoopoe	<i>Upupa epops</i>	Migratory	Least Concern	Common during migration
30	Pied Kingfisher	<i>Ceryle rudis</i>	Resident	Least Concern	Seen along water channels
31	Grey Francolin	<i>Francolinus pondicerianus</i>	Resident	Least Concern	Common ground-dweller
32	Common Quail	<i>Coturnix coturnix</i>	Migratory	Least Concern	Seasonal visitor
33	Indian Paradise Flycatcher	<i>Terpsiphone paradisi</i>	Summer Migrant	Least Concern	Breeds in forest canopy
34	Common Hawk Cuckoo	<i>Hierococcyx varius</i>	Summer Migrant	Least Concern	Known as “brain fever bird”
35	Yellow-footed Green Pigeon	<i>Treron phoenicoptera</i>	Resident	Least Concern	Seen in fruiting trees
36	Greater Coucal	<i>Centropus sinensis</i>	Resident	Least Concern	Common in dense vegetation
37	Purple Sunbird	<i>Cinnyris asiaticus</i>	Resident	Least Concern	Abundant nectar feeder
38	Indian Robin	<i>Saxicoloides fulicatus</i>	Resident	Least Concern	Common near forest edges
39	Common Tailorbird	<i>Orthotomus sutorius</i>	Resident	Least Concern	Common among shrubs
40	Black-headed Ibis	<i>Threskiornis melanocephalus</i>	Resident	Near Threatened	Occasionally seen in wetlands

Insects and pollinators

Insects and pollinators of the Changa Manga Forest play a vital role in maintaining ecosystem balance and biodiversity. They facilitate pollination of native flora, ensuring plant reproduction and genetic diversity. Species such as bees, butterflies, and beetles contribute significantly to forest regeneration and productivity. Decomposers like ants, flies, and

beetles recycle nutrients, enhancing soil fertility. Additionally, predatory insects help control pest populations naturally. These interactions support the forest’s ecological stability, sustain food webs, and provide essential ecosystem services for both wildlife and human communities dependent on the forest’s resources for ecological and economic well-being (Masood et al., 2024).



Figure No. 6: Overview of Insect in Changa Manga Forest, Punjab, Pakistan.

Table 7: Insects and Pollinators of Changa Manga Forest, Punjab, Pakistan.

Sr. No	Common Name	Scientific Name	Resident/Migratory Status	IUCN Status	Notes on Occurrence in Changa Manga
1	Honey Bee	<i>Apis cerana indica</i>	Resident	Not Evaluated	Common pollinator in forest flora
2	Giant Honey Bee	<i>Apis dorsata</i>	Resident	Not Evaluated	Large hives on tall trees
3	Little Honey Bee	<i>Apis florea</i>	Resident	Not Evaluated	Builds small exposed combs
4	Carpenter Bee	<i>Xylocopa fenestrata</i>	Resident	Not Evaluated	Pollinates woody plants
5	Bumblebee	<i>Bombus haemorrhoidalis</i>	Resident	Least Concern	Occasional visitor, seasonal
6	Green Lacewing	<i>Chrysoperla carnea</i>	Resident	Not Evaluated	Important biological control agent
7	Asian Lady Beetle	<i>Harmonia axyridis</i>	Resident	Not Evaluated	Predates on aphids
8	Red Cotton Bug	<i>Dysdercus cingulatus</i>	Resident	Not Evaluated	Common on silk-cotton trees
9	Blue Tiger Butterfly	<i>Tirumala limniace</i>	Resident	Not Evaluated	Common in flowering season
10	Common Mormon	<i>Papilio polytes</i>	Resident	Not Evaluated	Frequent in forest gardens
11	Common Lime Butterfly	<i>Papilio demoleus</i>	Resident	Not Evaluated	Abundant; citrus feeder
12	Plain Tiger Butterfly	<i>Danaus chrysippus</i>	Resident	Not Evaluated	Seen year-round
13	Common Jezebel	<i>Delias eucharis</i>	Resident	Not Evaluated	Active during flowering periods

14	Common Grass Yellow	<i>Eurema hecabe</i>	Resident	Not Evaluated	Common nectar feeder
15	Common Evening Brown	<i>Melanitis leda</i>	Resident	Not Evaluated	Found in shaded areas
16	Striped Tiger Butterfly	<i>Danaus genutia</i>	Resident	Not Evaluated	Prefers open grassy zones
17	Common Crow Butterfly	<i>Euploea core</i>	Resident	Not Evaluated	Occurs throughout forest trails
18	Crimson Rose Butterfly	<i>Pachliopta hector</i>	Resident	Not Evaluated	Attractive and locally common
19	Common Pierrot	<i>Castalius rosimon</i>	Resident	Not Evaluated	Small butterfly, common
20	Dragonfly (Common Darter)	<i>Sympetrum striolatum</i>	Resident	Not Evaluated	Found near forest ponds
21	Globe Skimmer Dragonfly	<i>Pantala flavescens</i>	Migratory	Not Evaluated	Seasonally migratory species
22	Damselfly (Blue Sprite)	<i>Pseudagrion microcephalum</i>	Resident	Not Evaluated	Found along wet areas
23	Praying Mantis	<i>Hierodula tenuidentata</i>	Resident	Not Evaluated	Common predator of insects
24	Termite	<i>Odontotermes obesus</i>	Resident	Not Evaluated	Found in decaying logs
25	Ant (Weaver Ant)	<i>Oecophylla smaragdina</i>	Resident	Not Evaluated	Builds leaf nests
26	Black Ant	<i>Camponotus compressus</i>	Resident	Not Evaluated	Common ground species
27	Honey Ant	<i>Myrmecocystus mimicus</i>	Resident	Not Evaluated	Seen near forest roots
28	Fruit Fly	<i>Bactrocera dorsalis</i>	Resident	Not Evaluated	Associated with fruiting plants
29	House Fly	<i>Musca domestica</i>	Resident	Not Evaluated	Abundant near human areas
30	Mosquito	<i>Culex pipiens</i>	Resident	Not Evaluated	Found near stagnant water
31	Black Soldier Fly	<i>Hermetia illucens</i>	Resident	Not Evaluated	Important decomposer
32	Green Bottle Fly	<i>Lucilia sericata</i>	Resident	Not Evaluated	Common decomposer
33	Dung Beetle	<i>Onthophagus gazella</i>	Resident	Not Evaluated	Vital for nutrient recycling
34	Rhinoceros Beetle	<i>Oryctes rhinoceros</i>	Resident	Not Evaluated	Found in decaying wood
35	Longhorn Beetle	<i>Anoplophora chinensis</i>	Resident	Not Evaluated	Wood-boring beetle
36	Firefly	<i>Lampyrus noctiluca</i>	Resident	Not Evaluated	Active at night
37	Leaf Beetle	<i>Chrysolina fastuosa</i>	Resident	Not Evaluated	Feeds on plant foliage
38	Wasp	<i>Vespa tropica</i>	Resident	Not Evaluated	Aggressive; builds paper nests
39	Mud Dauber Wasp	<i>Sceliphron formosum</i>	Resident	Not Evaluated	Builds mud nests
40	Green Butterfly	<i>Graphium agamemnon</i>	Resident	Not Evaluated	Found near flowering shrubs

Herpetofauna (Reptiles and Amphibians)

The herpetofaunal diversity of Changa Manga is moderately rich, representing a variety of reptiles and amphibians adapted to the semi-arid environment. Common reptilian species include the Indian cobra (*Naja naja*), Russell's viper (*Daboia russelii*), Oriental garden lizard (*Calotes versicolor*), house gecko (*Hemidactylus flaviviridis*), and skinks (*Eutropis carinata*). Amphibians such as the Indian bullfrog (*Hoplobatrachus tigerinus*) and common toad

(*Duttaphrynus melanostictus*) are observed in moist and irrigated areas, particularly near canals and ponds. These species contribute to insect population control and soil aeration, playing a vital role in the forest's ecological balance. However, limited herpetological research has been conducted in the region, and many amphibian populations remain understudied and potentially threatened by pesticide runoff, habitat alteration, and water pollution (Siddique et al., 2023).

Table 8: Herpetofauna (Reptiles and Amphibians) of Changa Manga Forest, Punjab, Pakistan.

Sr.No	Common Name	Scientific Name	Resident/Migratory Status	IUCN Status	Notes on Occurrence in Changa Manga
1	Indian Cobra	<i>Naja naja</i>	Resident	Least Concern	Common; found in forest undergrowth
2	Common Krait	<i>Bungarus caeruleus</i>	Resident	Least Concern	Nocturnal; occurs in leaf litter
3	Russell's Viper	<i>Daboia russelii</i>	Resident	Least Concern	Rare but potentially present
4	Saw-scaled Viper	<i>Echis carinatus</i>	Resident	Least Concern	Found in dry forest edges
5	Rat Snake	<i>Ptyas mucosa</i>	Resident	Least Concern	Common non-venomous snake
6	Checkered Keelback	<i>Fowlea piscator</i>	Resident	Least Concern	Found near ponds and canals
7	Common Sand Boa	<i>Eryx conicus</i>	Resident	Least Concern	Prefers sandy patches and burrows
8	Indian Rock Python	<i>Python molurus</i>	Resident	Near Threatened	Rare; sighted in dense vegetation
9	Indian Monitor Lizard	<i>Varanus bengalensis</i>	Resident	Least Concern	Common in open forest and fields
10	Garden Lizard	<i>Calotes versicolor</i>	Resident	Least Concern	Common arboreal species
11	Oriental Skink	<i>Eutropis carinata</i>	Resident	Least Concern	Common on forest floor
12	Indian House Gecko	<i>Hemidactylus frenatus</i>	Resident	Least Concern	Common near forest quarters
13	Brook's Gecko	<i>Hemidactylus brookii</i>	Resident	Least Concern	Found under tree bark and rocks
14	Banded Gecko	<i>Cyrtodactylus fasciolatus</i>	Resident	Least Concern	Prefers moist forest habitats
15	Indian Garden Gecko	<i>Hemidactylus flaviviridis</i>	Resident	Least Concern	Found near buildings and lights
16	Common Toad	<i>Duttaphrynus melanostictus</i>	Resident	Least Concern	Common after rainfall
17	Indus Valley Toad	<i>Duttaphrynus stomaticus</i>	Resident	Least Concern	Common amphibian species
18	Skittering Frog	<i>Euphlyctis cyanophlyctis</i>	Resident	Least Concern	Found in water bodies
19	Indian Bullfrog	<i>Hoplobatrachus tigerinus</i>	Resident	Least Concern	Abundant during monsoon
20	Indus Frog	<i>Fejervarya limnocharis</i>	Resident	Least Concern	Common near irrigation channels
21	Painted Frog	<i>Kaloula pulchra</i>	Resident	Least	Burrows underground

				Concern	during dry season
22	Tree Frog	<i>Polypedates maculatus</i>	Resident	Least Concern	Breeds near water bodies
23	Skink	<i>Lygosoma punctata</i>	Resident	Least Concern	Common in dry leaf litter
24	Toad-headed Agama	<i>Phrynocephalus maculatus</i>	Resident	Least Concern	Found in drier parts of forest
25	Common Garden Snake	<i>Lycodon aulicus</i>	Resident	Least Concern	Nocturnal; feeds on small vertebrates
26	Banded Kukri Snake	<i>Oligodon arnensis</i>	Resident	Least Concern	Rare; recorded in nearby districts
27	Smooth Snake	<i>Coronella brachyura</i>	Resident	Least Concern	Rarely observed, cryptic species
28	Indian Chameleon	<i>Chamaeleo zeylanicus</i>	Resident	Least Concern	Occasionally seen on shrubs
29	Indian Tent Turtle	<i>Pangshura tentoria</i>	Resident	Near Threatened	Found in canals and ponds
30	Softshell Turtle	<i>Nilssonia gangetica</i>	Resident	Vulnerable	Occasionally seen in nearby rivers
31	Common Garden Frog	<i>Sphaerotheca breviceps</i>	Resident	Least Concern	Found near moist forest edges
32	Indian Flap-shelled Turtle	<i>Lissemys punctata</i>	Resident	Least Concern	Found in wetland habitats
33	Striped Keelback	<i>Amphiesma stolatum</i>	Resident	Least Concern	Common water snake
34	Tree Lizard	<i>Calotes versicolor farooqi</i>	Resident	Not Evaluated	Local subspecies, common
35	Indian Skittering Frog	<i>Euphlyctis cyanophlyctis</i>	Resident	Least Concern	Active in rainy season
36	Marsh Frog	<i>Fejervarya syhadrensis</i>	Resident	Least Concern	Common near marshy areas
37	Common Indian Frog	<i>Minervarya pierrei</i>	Resident	Least Concern	Found near small streams
38	Banded Krait	<i>Bungarus fasciatus</i>	Resident	Least Concern	Rare; found in moist zones
39	Roofed Turtle	<i>Kachuga tecta</i>	Resident	Least Concern	Observed near irrigation ponds
40	Indian Pond Turtle	<i>Melanochelys trijuga</i>	Resident	Near Threatened	Found in water channels

Invertebrates

Invertebrate diversity within Changa Manga has received less scientific attention but represents a significant component of the forest's ecosystem. Insect surveys have reported abundant pollinators, such as honeybees (*Apis dorsata* and *Apis florea*), butterflies (family Nymphalidae and Pieridae), and hoverflies (Syrphidae), which contribute to the pollination of flowering plants. Soil macrofauna, including termites,

earthworms, and beetles, aid in organic matter decomposition and nutrient recycling. Additionally, the forest harbors several species of dragonflies and damselflies, indicating the ecological health of wetland zones. However, the increased use of chemical pesticides in surrounding agricultural fields poses a growing threat to invertebrate diversity, with potential cascading effects on higher trophic levels (Hemmatzadehd et al., n.d.).

Table 9: Invertebrates (Pollinators, Soil Fauna, and Ecologically or Pest Significant Insects) of Changa Manga Forest, Punjab, Pakistan

Sr. No	Common Name	Scientific Name	Functional Group	IUCN Status	Ecological Role / Significance	Notes on Occurrence in Changa Manga
1	Honeybee	<i>Apis cerana indica</i>	Pollinator	Not Evaluated	Vital pollinator for forest flora and nearby crops	Common; nests in tree cavities and old trunks.
2	Rock Honeybee	<i>Apis dorsata</i>	Pollinator	Not Evaluated	Major wild pollinator; supports forest regeneration	Found in forest canopies; threatened by honey collection.
3	Bumblebee	<i>Bombus haemorrhoidalis</i>	Pollinator	Least Concern	Important pollinator for wildflowers and shrubs	Rare; recorded seasonally in open forest areas.
4	Butterfly (Lemon Pansy)	<i>Junonia lemonias</i>	Pollinator	Not Evaluated	Pollination and aesthetic biodiversity value	Common in forest clearings and along trails.
5	Common Mormon Butterfly	<i>Papilio polytes</i>	Pollinator	Not Evaluated	Pollinates flowering plants and supports biodiversity	Regularly observed; depends on citrus species for larvae.
6	Dragonfly	<i>Orthetrum sabina</i>	Predator (control insect)	Not Evaluated	Controls mosquito and small insect populations	Common near ponds and canals.
7	Damselfly	<i>Ischnura aurora</i>	Predator	Not Evaluated	Indicator of healthy freshwater systems	Found near moist habitats and wetlands.
8	Termite	<i>Odontotermes obesus</i>	Soil fauna/decomposer	Not Evaluated	Decomposes organic matter, improves soil aeration	Common in decaying wood and soil mounds.
9	Ant (Black Carpenter Ant)	<i>Camponotus compressus</i>	Soil fauna/seed disperser	Not Evaluated	Enhances soil turnover and nutrient cycling	Common in both open and shaded forest areas.
10	Dung Beetle	<i>Onthophagus taurus</i>	Decomposer	Not Evaluated	Recycles animal waste; enhances soil fertility	Common; active during moist seasons.
11	Ladybird Beetle	<i>Coccinella septempunctata</i>	Predator (biocontrol agent)	Not Evaluated	Controls aphid populations on vegetation	Frequently observed on tree foliage.
12	Praying Mantis	<i>Hierodula patellifera</i>	Predator	Not Evaluated	Controls pest insects; indicator of balanced ecosystem	Common in shrub layers and grasslands.
13	Grasshopper	<i>Oxya hyla hyla</i>	Herbivore	Not Evaluated	Part of food web; prey for birds and reptiles	Abundant in grassy patches; occasional pest species.
14	Silk Moth	<i>Antheraea mylitta</i>	Pollinator/larval host	Not Evaluated	Supports silk production and pollination	Rare; presence linked with host tree abundance.
15	Honey Ant	<i>Myrmecocystus</i>	Soil fauna	Not Evaluated	Soil aeration,	Uncommon;

		<i>mimicus</i>			organic decomposition	reported in dry soil areas.
16	Termite (White Ant)	<i>Microtermes obesi</i>	Decomposer	Not Evaluated	Breaks down lignin-rich plant debris	Common across plantation zones.
17	Housefly	<i>Musca domestica</i>	Decomposer/ pest	Not Evaluated	Organic decomposition; can spread pathogens	Abundant near human settlements and waste areas.
18	Mosquito	<i>Culex quinquefasciatus</i>	Pest	Not Evaluated	Vector of diseases; part of aquatic food chain	Common near standing water bodies.
19	Earthworm	<i>Eisenia fetida</i>	Soil fauna/ decomposer	Not Evaluated	Enhances soil fertility through bioturbation	Found in moist, humus-rich soils; indicator of soil health.
20	Carpenter Bee	<i>Xylocopa violacea</i>	Pollinator	Not Evaluated	Pollinates large and legumes	Found in decaying wood; important for tree pollination.

Aquatic and Riverine Species

Although Changa Manga is primarily a terrestrial forest, its canal-fed irrigation system and artificial lakes support diverse aquatic species. Common freshwater fish include Rohu (*Labeo rohita*), Catla (*Catla catla*), and Common carp (*Cyprinus carpio*), which are occasionally cultivated for local fisheries.

Aquatic insects and amphibians also thrive in these habitats, contributing to local food webs and enhancing ecological productivity. The presence of wetland-associated bird species further emphasizes the ecological significance of these man-made aquatic systems (NASIR et al., n.d.).

Table 10: Aquatic and Riverine Species of Changa Manga Forest, Punjab, Pakistan.

Sr. No	Common Name	Scientific Name	Resident/Migratory Status	IUCN Status	Notes on Occurrence in Changa Manga
1	Indian Rohu	<i>Labeo rohita</i>	Resident	Least Concern (LC)	Commonly found in nearby irrigation channels and ponds.
2	Catla	<i>Catla catla</i>	Resident	Least Concern (LC)	Stocked in artificial lakes; used for fish farming.
3	Mrigal Carp	<i>Cirrhinus mrigala</i>	Resident	Least Concern (LC)	Common in slow-moving freshwater habitats.
4	Snakehead Murrel	<i>Channa striata</i>	Resident	Least Concern (LC)	Found in ponds and waterlogged areas; predator species.
5	Walking Catfish	<i>Clarias batrachus</i>	Resident	Least Concern (LC)	Survives in low-oxygen waters; common in wetlands.
6	Freshwater Eel	<i>Anguilla bengalensis bengalensis</i>	Migratory	Near Threatened (NT)	Occasionally seen in irrigation canals connected to the forest.
7	Common Carp	<i>Cyprinus carpio</i>	Resident	Vulnerable (VU)	Introduced species; widely distributed in fish ponds.
8	Striped Dwarf Catfish	<i>Mystus vittatus</i>	Resident	Least Concern (LC)	Found in smaller streams and vegetated ponds.
9	Spotted Snakehead	<i>Channa punctata</i>	Resident	Least Concern (LC)	Abundant in ditches and marshy areas.

10	Indian Pond Mussel	<i>Lamellidens marginalis</i>	Resident	Not Evaluated (NE)	Common in muddy substrates of ponds.
11	Freshwater Prawn	<i>Macrobrachium rosenbergii</i>	Resident	Least Concern (LC)	Found in freshwater canals and ponds.
12	Asian Swamp Eel	<i>Monopterus albus</i>	Resident	Least Concern (LC)	Burrows into muddy beds; seen in waterlogged sites.
13	Indian River Turtle	<i>Pangshura tecta</i>	Resident	Near Threatened (NT)	Found near streams and forest ponds; protected species.
14	Softshell Turtle	<i>Nilssonina gangetica</i>	Resident	Vulnerable (VU)	Found in canals and slow-flowing water; declining due to habitat loss.
15	Indian Bullfrog	<i>Hoplobatrachus tigerinus</i>	Resident	Least Concern (LC)	Common after monsoon; found near ponds and grassy wetlands.
16	Skittering Frog	<i>Euphlyctis cyanophlyctis</i>	Resident	Least Concern (LC)	Very common near forest water bodies.
17	Indian Tree Frog	<i>Polypedates maculatus</i>	Resident	Least Concern (LC)	Found around vegetation near water; calls during rainy season.
18	Asian Common Toad	<i>Duttaphrynus melanostictus</i>	Resident	Least Concern (LC)	Common in moist forest edges; active after rainfall.
19	Indian Flap-shelled Turtle	<i>Lissemys punctata</i>	Resident	Least Concern (LC)	Found in small ponds and canals; adaptable to altered environments.

Species of Conservation Concern

Several species found in Changa Manga are listed under the IUCN Red List as near-threatened or vulnerable. The Indian pangolin (*Manis crassicaudata*), occasionally reported from the region, is endangered due to illegal poaching and habitat loss. Bird species such as the black kite (*Milvus migrans*) and Indian peafowl (*Pavo cristatus*) are locally protected under the Punjab Wildlife (Protection, Preservation, Conservation, and Management) Act of 1974. The loss of connectivity between Changa Manga and other forested areas has restricted gene flow for several terrestrial species, emphasizing the need for wildlife corridors and protected area linkages. Conservation interventions focusing on habitat restoration, anti-poaching measures, and community awareness programs are essential for maintaining faunal diversity and ensuring the long-term ecological resilience of this historic forest ecosystem (Sharif et al., 2022b).

Mushroom Species of Changa Manga Forest

The mushroom species of Changa Manga Forest hold significant ecological, economic, and medicinal importance. Ecologically, they act as decomposers, recycling nutrients and maintaining soil fertility, which supports the forest's overall biodiversity. Certain species form symbiotic relationships with trees, enhancing forest health and resilience. Economically, edible and medicinal mushrooms offer potential for local livelihoods and sustainable harvesting. Medicinal species contain bioactive compounds with antimicrobial, antioxidant, and anti-inflammatory properties, contributing to pharmaceutical research. Studying these fungi also helps document biodiversity, monitor environmental changes, and inform conservation strategies, highlighting Changa Manga Forest as a critical habitat for fungal diversity in Pakistan (Abrar et al., 2020).



Figure No:7. Overview of Mushroom Species in Changa Manga Forest, Punjab, Pakistan.

Table 11: Mushroom Species in Changa Manga Forest, Punjab, Pakistan.

Sr. No	Species Name	Genus	Key Features / Description	Habitat / Location
1	Leucoagaricus rosuliformis	Leucoagaricus	Rosette-like central disc, dense squamules scattered toward margins; confirmed by molecular phylogeny	Changa Manga Forest
2	Agaricus punjabensis	Agaricus	Pileus with fissured, irregular patterns; dark brownish-grey squamules; morphologically variable	Changa Manga Forest, Lahore
3	Ganoderma multipileum	Ganoderma	Polypore species; contributes to fungal diversity	Changa Manga Forest, Lahore
4	Tomophagus cattienensis	Tomophagus	Adds to regional fungal biodiversity	Changa Manga Forest, Lahore
5	Podoscypha petalodes	Podoscypha	Found under Morus sp.; identified via morpho-anatomical and phylogenetic analysis	Changa Manga Forest
6	Limacella species (new)	Limacella	Newly described species contributing to local fungal diversity	Changa Manga Forest
7	Lepiota species (new)	Lepiota	New species and new record of genus Lepiota	Changa Manga Forest

5. ECOSYSTEM FUNCTIONS AND SERVICES
Provisioning Services

The Changa Manga Forest was originally established for its provisioning role, supplying timber and fuelwood to meet the industrial and infrastructural needs of the British colonial administration. Dominant tree species such as *Dalbergia sissoo* (Shisham), *Acacia nilotica* (Kikar), and *Eucalyptus camaldulensis* continue to provide valuable timber, poles, and fuelwood to local and regional markets. Additionally, the forest contributes to non-timber forest products (NTFPs) such as fodder, medicinal plants, resins, and honey, supporting local livelihoods.

In recent decades, sustainable harvesting practices have been encouraged to reduce overexploitation and maintain ecosystem productivity(Sadia et al., 2024).

Regulating Services

The forest plays a crucial role in regulating ecosystem processes, particularly in carbon sequestration and climate regulation. Studies indicate that the dense canopy and layered vegetation structure significantly contribute to carbon storage in both biomass and soil, helping mitigate greenhouse gas emissions. Furthermore, Changa Manga acts as a microclimatic buffer, lowering local temperatures and increasing

humidity compared to surrounding agricultural landscapes. Its root systems and leaf litter cover also contribute to erosion control, while irrigation-fed hydrological networks assist in groundwater recharge and maintaining soil moisture. These regulating functions are critical for the ecological resilience of the Punjab region, which faces pressures from deforestation and agricultural expansion (Waheed, Haq, et al., 2025).

Supporting Services

As one of the largest hand-planted forests, Changa Manga offers extensive supporting ecosystem services. The continuous decomposition of organic matter enhances soil fertility and nutrient cycling, fostering a balanced forest floor ecosystem. The forest supports pollination services, providing habitat for numerous insect pollinators that benefit both wild and cultivated plant species. Moreover, it serves as a biodiversity reservoir, maintaining ecological processes that sustain flora and fauna diversity. The intricate interactions among trees, understory vegetation, and soil biota underline its importance as a self-sustaining ecological system despite being man-made (Sharif et al., 2022b).

Cultural and Recreational Services

Changa Manga holds significant cultural, educational, and recreational value. It is a popular eco-tourism site, attracting visitors to its wildlife park, boating lake, and picnic areas. The forest serves as a living classroom for students, researchers, and conservationists studying afforestation, biodiversity, and sustainable forest management. Locally, it contributes to the social and cultural identity of the region, being a source of pride and livelihood for nearby communities. Such cultural services reinforce the social-ecological importance of the forest beyond its tangible economic benefits (Haq, Khoja, et al., 2024).

Valuation Studies and Economic Insights

While comprehensive economic valuation studies on Changa Manga's ecosystem services remain limited, some reports estimate substantial economic returns from timber and ecotourism. Proxy estimates from regional forestry models suggest that carbon sequestration and recreational services could collectively contribute millions of Pakistani rupees annually if appropriately monetized. However, there remains a need for formal ecosystem service valuation frameworks to guide sustainable management, ensure equitable benefit sharing, and integrate ecological functions into regional development planning. Changa Manga provides a multifaceted suite of ecosystem services that sustain both environmental health and human well-being. Protecting and managing these services holistically is essential to maintain the

forest's long-term ecological and socio-economic significance (ur Rahman et al., 2022).

6. LANDSCAPE CONTEXT, CONNECTIVITY, AND ECOLOGICAL ROLES

Changa Manga as a Habitat Island

The Changa Manga Forest, despite its large size and historical significance, now functions as a habitat island within an extensively agricultural and urbanized landscape of central Punjab. Surrounded by croplands and human settlements, the forest is increasingly isolated from other natural or semi-natural habitats, which affects ecological interactions and wildlife movement. This fragmentation has led to limited dispersal opportunities for many forest-dependent species, particularly large mammals and specialist birds. As a result, the forest may serve as a sink habitat—supporting species populations that cannot sustain themselves independently due to restricted gene flow and small population sizes. However, for adaptable and generalist species, Changa Manga still provides a source of refuge and breeding ground, highlighting its dual ecological role within the fragmented landscape (Ali et al., n.d.).

Connectivity with Other Forest Patches

Historically, Changa Manga was part of a broader network of riparian and plantation forests extending across Punjab. However, with increasing agricultural expansion and infrastructure development, landscape connectivity has been severely reduced. Presently, the nearest forested areas such as Balloki, Kasur, and Rakh Jhok forests are separated by several kilometers of non-forested land, restricting natural gene flow and species migration. Limited corridors exist along irrigation canals and small vegetated patches, which may facilitate partial movement of birds, reptiles, and small mammals. The absence of continuous habitat corridors poses challenges for maintaining genetic diversity, particularly among resident fauna with small home ranges. Restoration of green belts, riparian vegetation, and canal-side plantations could significantly enhance ecological connectivity and promote metapopulation stability across the regional landscape (Sial, 2024).

Role in Regional Biodiversity Networks

Despite its isolation, Changa Manga remains an ecologically critical node in Punjab's biodiversity network. It serves as a stepping stone habitat for migratory birds traveling across the Indo-Gangetic plains, offering foraging and nesting sites during seasonal movements. The forest's diverse plant and animal communities contribute to maintaining regional ecological balance, supporting ecosystem services such as pollination, seed dispersal, and pest control that extend beyond its boundaries. Moreover, the forest acts as a carbon and nutrient reservoir,

indirectly benefiting surrounding agricultural ecosystems through microclimatic stabilization and soil conservation. Given its strategic location and biological richness, Changa Manga has the potential to play a central role in Punjab's ecological restoration initiatives. Integrating the forest into a broader conservation landscape through the establishment of wildlife corridors, buffer zones, and community-managed reserves could transform it from an isolated habitat island into a functional component of a regional ecological network. Such landscape-level management would enhance biodiversity resilience, genetic exchange, and ecosystem sustainability across Pakistan's most densely populated province (Niazi & Ghafoor, 2023).

7. THREATS AND STRESSORS

Historical and Contemporary Anthropogenic Pressures

Since its establishment in 1866, the Changa Manga Forest has experienced a long history of anthropogenic exploitation. Initially managed for fuelwood and railway timber production, intensive and unsustainable harvesting practices during the colonial and post-colonial periods led to significant degradation of native vegetation. In recent decades, pressures from illegal logging, overgrazing, and excessive fuelwood collection have continued to stress the ecosystem. Encroachment by nearby settlements and infrastructure development further contribute to habitat loss and disturbance, reducing the forest's ecological integrity and resilience. Despite reforestation and afforestation efforts by the Punjab Forest Department, unchecked human activity remains a persistent challenge (Yasmeen & Asif, 2022).

Agricultural Expansion and Fragmentation

Changa Manga lies within one of Pakistan's most intensively cultivated regions. Continuous agricultural expansion, driven by population growth and economic dependence on farming, has resulted in landscape fragmentation and the loss of buffer zones surrounding the forest. This isolation not only restricts wildlife movement but also increases edge effects, such as higher exposure to pollutants, noise, and invasive species from adjacent farmlands. Irrigation canals and roads, while beneficial for agriculture, have further divided the landscape, altering natural hydrology and fragmenting habitat continuity (Mumtaz et al., 2021).

Invasive Species and Pest Outbreaks

The introduction of non-native tree species, particularly *Eucalyptus camaldulensis* and *Prosopis juliflora*, has altered the forest's ecological composition and soil nutrient balance. These species often outcompete native flora, suppress regeneration,

and modify hydrological regimes through high water uptake. Additionally, pest outbreaks such as defoliating insects and fungal infections have periodically affected both planted and natural vegetation, leading to declines in forest productivity and biodiversity. Limited pest management capacity exacerbates these issues, threatening long-term forest sustainability (Khan et al., 2020).

Fire Regimes and Accidental/Intentional Fires

Forest fires, both accidental and intentional, pose recurrent threats to Changa Manga's vegetation and wildlife. Dry seasons, coupled with high temperatures and human negligence, increase fire frequency, especially near picnic areas and plantation blocks. Some fires are deliberately set to clear undergrowth for grazing or illegal wood extraction, resulting in severe habitat loss, soil degradation, and the destruction of nesting sites. Inadequate fire surveillance systems and limited firefighting resources hinder effective response, emphasizing the need for proactive fire risk management plans (Abid et al., 2024).

Climate Change Impacts and Projections

Climate change poses an escalating threat to the ecological stability of Changa Manga. Rising temperatures, prolonged droughts, and irregular monsoon patterns are altering soil moisture dynamics and increasing tree mortality rates. Shifts in species distribution and the potential loss of moisture-dependent flora could disrupt food webs and ecosystem services. Moreover, extreme weather events, including heatwaves and windstorms, heighten the vulnerability of plantation stands. Long-term projections suggest potential declines in forest cover and carbon storage capacity if adaptive management strategies are not implemented (Haq, Lone, et al., 2024).

Socioeconomic Drivers and Governance Challenges

Socioeconomic pressures, including poverty, population growth, and dependence on forest resources, remain core challenges in the sustainable management of Changa Manga. Local communities rely heavily on the forest for fuelwood, grazing, and small-scale forest products, often without formal regulation or sustainable practices. Weak institutional governance, inconsistent policy enforcement, and insufficient community participation further exacerbate degradation. Although conservation initiatives exist, their effectiveness is often undermined by limited funding, lack of awareness, and overlapping jurisdiction among governmental agencies.

Changa Manga faces multifaceted ecological and socioeconomic threats that compromise its biodiversity, ecosystem services, and resilience.

Addressing these stressors requires a multi-stakeholder approach, integrating scientific research, adaptive management, community involvement, and policy reform to safeguard the long-term sustainability of one of the world's oldest hand-planted forests (Hena et al., 2021).

8. MANAGEMENT HISTORY, GOVERNANCE, AND CONSERVATION MEASURES

Past Management Objectives

The management history of Changa Manga Forest reflects shifting priorities from colonial-era exploitation to contemporary conservation and recreation. Initially established in 1866 under British colonial administration, the forest's primary objective was the production of fuelwood and timber to support the North-Western Railway network, which required vast quantities of wood for steam locomotives. The forest was managed under a plantation forestry model, focusing on fast-growing species such as *Dalbergia sissoo* (Shisham) and *Acacia nilotica* (Kikar). During the mid-20th century, the management strategy gradually diversified to include silvicultural improvements, irrigation-based afforestation, and controlled harvesting. By the late 1900s, with rising environmental awareness, the focus began to shift towards recreation, biodiversity conservation, and ecosystem restoration, aligning with global sustainability principles (Arshad et al., 2022).

Current Management Institutions

At present, the Punjab Forest Department (PFD) serves as the primary governing authority responsible for the management, protection, and restoration of Changa Manga. The forest is administered under the Lahore Forest Division, which oversees operations related to plantation upkeep, wildlife conservation, and tourism management. Additional stakeholders include the Punjab Wildlife and Parks Department, responsible for the Changa Manga Wildlife Park, and local community representatives engaged through social forestry initiatives. Collaborative input is also provided by academic institutions, non-governmental organizations (NGOs), and environmental research groups working on biodiversity monitoring, climate adaptation, and reforestation planning (Rasib, 2021).

Conservation Initiatives and Restoration Projects

Over the past two decades, a number of conservation and restoration projects have been initiated to address degradation and biodiversity loss. The Punjab Forest Department's afforestation programs, supported by the Ten Billion Tree Tsunami Programme (TBTTP) and Green Pakistan Initiative, have focused on replanting native species, rehabilitating degraded plots, and enhancing forest cover. The Changa Manga Wildlife Park, established

within the forest, serves as both a biodiversity refuge and ecotourism hub, featuring species such as deer, peafowl, and migratory birds. Community-based conservation projects have encouraged local participation in tree planting, protection of saplings, and eco-education campaigns, fostering stewardship among nearby residents. Additionally, GIS-based forest monitoring systems have been introduced to assess vegetation changes and improve transparency in management practices (Bashir et al., 2025).

Community Participation and Co-Management Approaches

Recognizing the importance of local involvement, the PFD has implemented social forestry programs that integrate community participation into forest management. Under these initiatives, villagers living near Changa Manga are provided incentives such as fuelwood rights, employment in plantation activities, and profit-sharing from timber sales in exchange for their cooperation in protecting the forest from illegal logging and encroachment. However, participation levels remain inconsistent due to socioeconomic challenges and limited awareness. Enhanced capacity-building programs, including environmental education and livelihood diversification, are essential to ensure sustained community engagement (Ijaz & Haq, 2021).

Successes, Failures, and Management Trade-offs

Management efforts in Changa Manga have achieved notable successes, particularly in forest regeneration, recreational development, and public awareness. The reforestation of degraded areas, improvement of irrigation infrastructure, and establishment of wildlife enclosures have all contributed to partial ecological recovery. However, these achievements are counterbalanced by persistent challenges. Overemphasis on fast-growing exotic species has sometimes undermined native biodiversity, while increased tourism has led to littering, soil compaction, and wildlife disturbance. Furthermore, limited inter-agency coordination, insufficient scientific monitoring, and budgetary constraints continue to hinder effective implementation of sustainable forest management plans. In essence, while Changa Manga's management has evolved from resource exploitation to ecological restoration, enduring success will depend on balancing economic, ecological, and social objectives. Strengthening governance transparency, enhancing community co-management, and prioritizing native ecosystem restoration are crucial for ensuring the long-term conservation of one of the world's oldest hand-planted forests (Zia et al., 2022).

9. RESEARCH GAPS AND METHODOLOGICAL RECOMMENDATIONS

Taxonomic Gaps

Despite the ecological significance of Changa Manga, existing research remains heavily biased toward floristic and avian diversity, with limited attention to other taxonomic groups. Invertebrates, particularly pollinators, soil macrofauna, and decomposers, are significantly understudied despite their critical roles in ecosystem functioning. Similarly, herpetofauna (reptiles and amphibians) and microbial communities have received minimal scientific focus. The mammalian assemblage has been documented only superficially, with scarce information on population dynamics, reproductive behavior, or trophic interactions. Addressing these gaps through comprehensive multi-taxa inventories will provide a more holistic understanding of the forest's biodiversity structure and ecological balance (Maqsood et al., 2024).

Temporal Gaps

Most existing studies on Changa Manga are short-term and site-specific, often based on one-time surveys or seasonal observations. There is a lack of long-term ecological monitoring to track changes in species composition, vegetation cover, and climate impacts over time. This temporal deficiency limits the ability to assess biodiversity trends, succession processes, and ecosystem resilience. Establishing permanent monitoring plots and implementing longitudinal biodiversity surveys are essential to capture dynamic ecological responses to natural and anthropogenic pressures. Integration of climate and hydrological data into long-term monitoring will further enhance understanding of ecosystem change (Waheed et al., 2024).

Spatial Gaps

Research efforts have been concentrated in easily accessible zones, such as near roads, canals, and recreational areas, leaving interior and edge habitats underexplored. Consequently, spatial biases hinder the accurate representation of forest heterogeneity and species distribution patterns. There is also limited mapping of microhabitats, canopy gradients, and soil diversity, which are vital for understanding habitat-specific biodiversity. Future studies should employ stratified sampling designs that encompass core forest areas, buffer zones, and disturbed edges to achieve more comprehensive spatial coverage (Umar et al., 2023).

Need for Standardized Monitoring Protocols

The lack of standardized sampling and data collection methods poses a major challenge for comparative analyses across studies. To ensure data consistency and reliability, it is recommended to adopt

standardized monitoring protocols, such as Fixed-plot vegetation surveys for assessing plant composition, biomass, and regeneration. Camera trap networks for monitoring medium and large mammals, as well as nocturnal activity patterns. Acoustic monitoring systems for birds, bats, and amphibians to capture temporal and seasonal variations. Insect sampling methods (e.g., pitfall traps, light traps, and sweep nets) for evaluating pollinator and decomposer diversity. Such uniform approaches would allow integration of data into national and global biodiversity databases, improving conservation decision-making (Bukhari et al., 2025).

Recommended Analytical and Technological Methods

Modern analytical tools and remote technologies offer valuable opportunities to bridge existing methodological gaps. Future studies should emphasize Remote sensing and GIS-based analysis to monitor land-use changes, vegetation cover dynamics, and NDVI (Normalized Difference Vegetation Index) trends. Occupancy modeling and population trend analysis for assessing species distribution, detectability, and habitat suitability under varying disturbance regimes. Molecular and genetic studies to examine gene flow, population connectivity, and the effects of habitat fragmentation. Ecosystem service valuation frameworks, such as InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) and Total Economic Valuation (TEV), to quantify and monetize the forest's ecological and socio-economic contributions. In addressing these taxonomic, temporal, and spatial research deficiencies through standardized, multidisciplinary, and technology-integrated methodologies is vital for developing a robust ecological knowledge base of Changa Manga. Such an evidence-driven approach will strengthen conservation planning, guide sustainable management practices, and ensure the preservation of this historic hand-planted forest for future generations (Hena et al., 2021).

10. FUTURE DIRECTIONS AND PRIORITIES

Future research and management of the Changa Manga Forest should focus on strengthening its ecological resilience, biodiversity conservation, and socio-environmental sustainability. Priority research questions include assessing the forest's resilience to climate change, understanding species adaptation mechanisms, and exploring restoration ecology approaches that enhance natural regeneration. Socioecological studies examining local community dependence, perceptions, and participation in forest management are equally vital for developing inclusive conservation strategies. Restoration and adaptive management actions should emphasize native species enrichment, replacing exotic monocultures with ecologically compatible indigenous flora such as

Dalbergia sissoo and *Acacia nilotica*. Invasive species control, particularly for *Eucalyptus* and *Prosopis juliflora*, must be prioritized to restore ecosystem balance. Additionally, promoting community-based forest management through co-management models can ensure both ecological protection and local livelihood benefits. At the policy and planning level, there is an urgent need to integrate forestry practices into broader landscape management frameworks, linking Changa Manga with other green corridors for enhanced connectivity. Strengthening legal protection, enforcing sustainable harvesting regulations, and developing eco-tourism and livelihood diversification programs will further support conservation goals. Collectively, these actions can transform Changa Manga into a model of sustainable, climate-adaptive forest restoration and governance in Pakistan (Waheed, Arshad, et al., 2025).

11. CONCLUSIONS

The Changa Manga Forest stands as a living testament to successful large-scale afforestation and remains one of the world's most significant hand-planted forests. Its rich biodiversity, ecological functions, and socioeconomic value highlight its pivotal role in sustaining environmental health and regional livelihoods in Punjab, Pakistan. Despite extensive anthropogenic pressures and ecological challenges, the forest continues to support diverse flora and fauna, regulate microclimates, sequester carbon, and provide essential ecosystem services. However, escalating threats such as habitat fragmentation, invasive species, and climate change demand immediate and coordinated conservation efforts. Priority actions should include restoration of native vegetation, control of invasive species, establishment of ecological corridors, and enhancement of community-based management frameworks. Simultaneously, long-term monitoring, standardized biodiversity assessments, and ecosystem valuation studies are critical research needs. Protecting and revitalizing Changa Manga is not only an ecological imperative but also a national responsibility to preserve Pakistan's natural heritage.

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