

DEVELOPMENT OF A *Madhuca longifolia* (MAHUA) FLOWER COLLECTOR FOR SUSTAINABLE NON-TIMBER FOREST PRODUCT HARVESTING AND FOREST FIRE PREVENTION

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Abstract

Mahua (Madhuca longifolia) is an important non-timber forest product (NTFP) supporting the livelihoods of forest-dependent communities in central India. Conventional flower collection involves gathering naturally fallen flowers from the forest floor, often requiring the removal or burning of leaf litter to improve visibility and facilitate collection. These practices contribute to anthropogenic forest-fire risk and prolonged human presence in forest habitats. The present study aimed to develop a mahua flower collector that facilitates cleaner and more sustainable flower collection while providing a potential alternative to leaf-litter burning. The collector comprises an adjustable circular mild-steel frame, supporting arms, a green 90% shade-net collection system, gravity-assisted sloping sections, and four discharge openings connected to collection chambers. Field measurements of mahua tree trunks and canopy dimensions were used to inform the design and sizing of the prototype. The collector was fabricated using locally available materials at an estimated cost of Rs. 31,000 (US\$325) and was demonstrated under field conditions. The prototype was designed to provide extensive coverage of the observed canopy projection and was demonstrated to be installable by three persons in approximately 30 minutes. The collection system is designed to potentially eliminate the need for leaf-litter burning, facilitate cleaner flower collection, and potentially reduce collection time, labour intensity, and occupational exposure during harvesting. The technology may also contribute indirectly to reducing human presence in tiger habitats during the mahua collection season and thereby support human–wildlife conflict mitigation. A preliminary economic assessment indicates potential for repeated seasonal use (8-10 years), while a Forest Department-supported rental or shared-use model could improve accessibility for local communities. Overall, the developed collector represents a locally adaptable engineering innovation with potential applications in sustainable NTFP collection, forest-fire prevention, livelihood enhancement, and community-based forest management. Multi-season field validation, ergonomic assessment, durability testing, user acceptance studies, and quantitative evaluation of fire-reduction and economic benefits are required to establish its long-term effectiveness and scalability.

Keywords: *Madhuca longifolia, Mahua, Non-timber forest products, Forest fire prevention, Sustainable harvesting, Sustainable forest management*

Introduction

Forest fires are among the most serious environmental challenges affecting biodiversity, ecosystem services, and the livelihoods of forest-dependent communities. Globally, forests cover approximately 4.06 billion hectares and support nearly 1.6 billion people; however, increasing anthropogenic wildfires have accelerated forest degradation and biodiversity loss (FAO, 2020). In India, forest fires occur predominantly between November and May, with the central Indian landscape, including Maharashtra state, being one of the most fire-prone regions due to its dry deciduous forests and intensive dependence on non-timber forest products (NTFPs) (FSI, 2021; Sewak *et al.*, 2021). Gadchiroli district of Maharashtra, Central India, has emerged as one of the country's major forest fire hotspots, where human activities remain a dominant cause of fire incidents (FSI, 2021).

Mahua (*Madhuca longifolia*) Syn. *M. indica* (J. König ex L.) J.F. Macbr., family Sapotaceae is a multipurpose, long-lived tree native to the Indian subcontinent and extending to Myanmar, commonly occurring in dry and seasonally dry tropical forests. Mature trees generally attain 15–20 m height and develop broad, spreading crowns. The species is valued for its edible and commercially important flowers and seeds, which support food, traditional products, oil production, and forest-based livelihoods. Flowering in central India generally occurs during March–April, with individual flowers blooming during the night and falling around dawn. Consequently, traditional collection usually begins around 5:00 a.m. and continues until about 11:00 a.m., with additional collection or retrieval

sometimes continuing into the afternoon. In forest areas, mahua trees are generally scattered naturally, and although they occur on Forest Department-managed land, customary practices often give families preferential harvesting rights over trees they have traditionally collected, sometimes across generations. The dispersed distribution, large canopy, short nocturnal flowering period, dawn-time flower abscission, prolonged daily collection period, and widely dispersed nature of mature mahua trees collectively make efficient ground-level flower recovery a labour-intensive activity and provide a strong biological and operational rationale for the development of a canopy-based collection system.

Among NTFPs, mahua (*M. longifolia*) is an economically and culturally important tree for tribal communities. Its flowers are widely used as food, traditional beverages, and a source of household income (Pinakin *et al.*, 2018). Flower collection takes place during March and April when the flowers naturally fall to the ground (Kulkarni and Mehta, 2020). Mahua flowers are traditionally collected manually by tribal and forest-dependent communities during the flowering season. Since the flowers naturally fall onto the forest floor, collectors first clear the ground beneath the tree canopy to facilitate easier collection. In many regions, this involves burning the accumulated dry leaf litter before the flowering period, creating a clean surface that improves the visibility and retrieval of fallen flowers while reducing contamination with leaves, twigs, and soil. Although this practice simplifies flower collection, it frequently results in accidental spread of fire to the surrounding forest, particularly under dry and windy conditions.

The traditional method is labour-intensive, time-consuming, and physically demanding, requiring collectors to bend continuously for prolonged periods. Burning of leaf litter not only increases the risk of anthropogenic forest fires but also causes smoke emissions, loss of biodiversity, destruction of soil organic matter, and degradation of forest ecosystems. Furthermore, flowers collected directly from the forest floor are often contaminated with dust, soil particles, insects, and plant debris, reducing their market quality and economic value. These environmental and socio-economic limitations highlight the need for sustainable harvesting technologies that can improve collection efficiency while eliminating the practice of leaf litter burning and minimising its adverse impacts on forest ecosystems.

Previous studies have extensively documented the ecological impacts of forest fires and the nutritional and socio-economic importance of mahua flowers (FAO, 2020; Mohanty and Mittal, 2022; Sewak *et al.*, 2021). Although academicians have emphasised the need for improved harvesting methods (Kulkarni and Mehta, 2020), most investigations have focused on community-based fire management, ecological assessments, and utilisation of mahua rather than technological interventions for flower collection. The absence of an efficient mechanical collecting system represents a significant knowledge gap in sustainable NTFP management.

To address this knowledge gap, the present study aimed to design, develop, and demonstrate under field conditions a mahua flower collector that enables efficient collection of naturally fallen flowers while reducing the need to burn

forest litter. The innovation seeks to minimise anthropogenic forest fires, improve harvesting efficiency, enhance occupational safety, and promote sustainable management of forest resources.

The present study represents, to the best of our knowledge this is among the first reported attempts to develop a mahua flower collection technology specifically integrating sustainable NTFP harvesting with forest-fire prevention. Unlike conventional harvesting technologies that primarily focus on improving harvesting efficiency, the developed collector integrates engineering innovation with environmental conservation by eliminating the need for leaf litter burning during mahua flower collection. The technology simultaneously enhances flower quality, reduces labour drudgery, improves occupational safety, and contributes to biodiversity conservation, climate change mitigation, and sustainable forest management. Consequently, the study introduces a novel, low-cost, and community-oriented technological solution that addresses both livelihood enhancement and ecosystem conservation, providing a practical model for sustainable NTFP harvesting in fire-prone forest landscapes.

Materials and Methods

Study Area

The study was conducted in Chandrapur district, Maharashtra, India, one of the major forest fire-prone districts in central India. Chandrapur is characterised by extensive tropical dry deciduous forests dominated by mahua (*M. longifolia*), teak (*Tectona grandis*), and bamboo. The district shares its forest landscape with the Tadoba-Andhari Tiger Reserve and supports a large tribal

population that depends on NTFPs for livelihood. Mahua flower collection is a seasonal activity carried out during March and April, coinciding with the peak forest fire season, making the district an appropriate location for developing and evaluating an alternative flower collection technology (FSI, 2021).

Field Survey and Demonstration

A field survey was conducted in Lohara village (19.986380 °N, 79.360160 °E) of Chandrapur district to document existing mahua flower collection practices and obtains information from local inhabitants engaged in seasonal flower collection. A structured field questionnaire was used to document traditional mahua flower collection practices and associated operational challenges. Following prototype development, the collector was installed on mature mahua trees under natural field conditions. The demonstration evaluated the suitability of the adjustable frame on trees of varying trunk sizes, canopy coverage, ease of installation, and the movement of naturally fallen flowers towards the collection openings. Field observations were also recorded regarding the practicality of the device during routine flower collection activities.

Performance Evaluation

The developed prototype was evaluated qualitatively based on its operational performance under field conditions. The assessment considered (i) compatibility with different tree dimensions, (ii) canopy coverage, (iii) efficiency of flower interception, (iv) ease of flower retrieval, (v) portability, and (vi) its potential to reduce conventional practices involving burning of leaf litter. The anticipated environmental and socio-economic benefits, including reduction of anthropogenic forest fires, improved

flower quality, reduced collection time, and enhanced occupational safety, were interpreted from field observations and existing literature on traditional mahua harvesting practices (Ramanath, 2017; Kulkarni and Mehta, 2020). This study primarily focused on the design, fabrication and engineering evaluation of the prototype. Comprehensive field performance assessment will be undertaken in future studies.

Results and Discussion

Design Concept of the Collector

The collector was conceptualised to eliminate the need for collecting flowers directly from the forest floor. The design was based on the principle of an inverted umbrella, where naturally falling mahua flowers are intercepted before reaching the ground. The device consists of a circular metal frame fixed around the tree trunk, supporting detachable radial arms over which a green shade net (90%) is stretched. Owing to gravity, the flowers slide along the net and accumulate near the trunk, where they are collected through specially designed openings into collection containers. The design emphasised portability, low cost, ease of installation, reusability, and fabrication using locally available materials. The structure was also designed to accommodate variations in tree trunk diameter and canopy dimensions commonly observed in mature mahua trees.

Collector Fabrication

Before fabrication, field measurements of mature mahua trees (n=14) were undertaken to determine average trunk circumference and canopy spread (Table 1). These measurements served as the basis for designing the dimensions of the collector. The prototype

comprised an adjustable circular metal base fabricated from mild steel plates, detachable iron supporting rods, and a circular green shade net stitched into two detachable sections for ease of transportation and installation. The adjustable base was designed to accommodate trunks up to approximately 39 inches in diameter, exceeding the observed average trunk diameter (33 inch) and encompassing the majority of trees

measured during the field survey. The supporting rods were designed in two segments to reduce handling difficulties while maintaining adequate structural strength. Four collection openings were incorporated near the tree trunk to facilitate easy removal of accumulated flowers. The prototype covered approximately 868.5 square feet (33.25 feet diameter), enabling interception of the complete canopy area.

Table 1: Trunk and canopy dimensions of mahua trees assessed for collector design

Latitude	Longitude	Altitude (meter)	Tree canopy (feet)	Trunk circumference (inch)
19.97677°N	79.33324°E	200	40	96
19.9769°N	79.337°E	190	31	108
19.97695°N	79.33763°E	200	26	96
19.97703°N	79.33781°E	208	33	75
19.977°N	79.33789°E	207	40	133
19.97868°N	79.34232°E	205	27	96
19.97866°N	79.34223°E	207	33	82
19.98097°N	79.3478°E	205	28	76
19.97882°N	79.34292°E	206	30	98
19.97837°N	79.34191°E	201	34	108
19.9773°N	79.33932°E	198	40	137
19.97717°N	79.33907°E	201	38	128
19.97688°N	79.3377°E	198	31	87
19.97676°N	79.33612°E	197	29	98
		Average	~33	~101

Engineering Design and Structural Configuration of the Collector

The collector consists of an adjustable semicircular mild-steel base frame designed to accommodate mahua tree trunks of varying diameters, radial telescopic supporting arms that provide structural stability, and a sloping collection net that directs naturally fallen flowers towards four centrally located discharge openings surrounding the tree trunk. These openings facilitate the gravity-assisted movement of flowers into

the collection chamber positioned beneath the collector, thereby minimizing contamination from soil and leaf litter.

The principal engineering specifications and structural components of the collector are summarized in Table 2. The table provides detailed information on the dimensions, materials, structural members, and functional characteristics of the prototype, thereby facilitating its fabrication, replication, and future engineering modifications.

Table 2: Engineering specifications, structural components, dimensions, materials, and functional characteristics of the collector

Component	Material	Dimensions / Specifications	Function
Adjustable base frame	Mild steel flat	32 mm width × 5 mm thickness; two semicircular sections; accommodates tree trunks up to 39 inches (99 cm) diameter	Provides structural support and secure attachment around the tree trunk
Base frame locking mechanism	Mild steel bolts and clamps	Adjustable locking arrangement	Enables installation on trees of varying trunk diameters
Hollow support sleeves	Mild steel pipe	1.5-inch (38 mm) diameter; 12 sleeves welded to base frame	Holds and supports telescopic radial arms
Radial supporting arms (inner)	Mild steel pipe	10 ft (3.05 m) length; 1-inch (25 mm) diameter	Primary structural support for the collection net
Radial supporting arms (outer)	Mild steel pipe	5 ft (1.52 m) length; 0.75-inch (19 mm) diameter; telescopic insertion (~3 inches / 7.6 cm overlap)	Extends collector diameter and facilitates portability
Total arm length	Mild steel	15 ft (4.57 m) per arm	Supports the collection net over the tree canopy
Number of supporting arms	Mild steel	12 radial arms	Provides uniform support and structural stability
Support braces	Mild steel rods	Welded between base frame and support sleeves	Reinforces the base frame and distributes structural loads
Collection net	Green HDPE shade net (90% shade)	Approximate diameter: 33.25 ft (10.13 m); collection area ≈ 868.5 square feet (80.7 square meter)	Collects naturally fallen mahua flowers while preventing soil contamination
Flower discharge openings	Reinforced HDPE net	Four centrally positioned openings around the trunk	Directs flowers into the collection chamber by gravity
Collection chamber	HDPE collection bag/basket	Positioned beneath discharge openings	Receives collected flowers for easy retrieval
Fastening system	Nylon ropes, Velcro strips and hooks	Adjustable fastening arrangement	Secures the net to the supporting arms and frame
Protective coating	Anti-corrosive primer and enamel paint	Applied to all mild steel components	Enhances corrosion resistance and service life
Estimated overall collector diameter	—	Approximately 33.25 ft (10.1 m), including support arms and base frame (39 inches)	Provides adequate coverage for the average mahua tree canopy
Estimated service life	—	8-10 years (with routine maintenance)	Long-term field operation
Projected annual maintenance	—	Approximately Rs. 840–1,450 (US\$9–15)	Painting, inspection and replacement of minor components
Estimated fabrication cost	—	Rs. 31,000 (US\$325)	Total prototype fabrication cost

Development of the Collector

The present study successfully designed and developed a mahua flower collector as a technological intervention to address one of the important anthropogenic causes of forest fires associated with traditional mahua flower collection. The design was based on the principle of an inverted umbrella, allowing naturally fallen flowers to be intercepted before reaching the forest floor.

The developed collector comprises an adjustable circular base structure designed to securely fit around the trunk of mature mahua (*M. longifolia*) trees. The base consists of two semicircular metal sections that can be adjusted to accommodate tree trunks up to 39 inches in diameter. Field measurements indicated that the average trunk circumference of mature mahua trees was approximately 101 inches (equivalent to a diameter of about 32 inches), demonstrating that the designed base dimensions are suitable for the majority of trees encountered in the study area. The base frame was fabricated using mild steel plates measuring 32 mm in width and 5 mm in thickness to provide adequate structural strength while maintaining ease of installation.

Twelve hollow mild-steel pipes (1.5-inch diameter) were welded uniformly around the upper surface of the base frame at an interval of approximately 11 inches. These pipes functioned as sockets for the insertion of supporting arms and were reinforced with welded support brackets to withstand the load of the extended harvesting structure. The modular arrangement facilitated rapid assembly and disassembly under field conditions while maintaining structural stability.

Based on field observations of canopy dimensions, the harvesting net was

designed to provide a collection diameter of approximately 30 feet, corresponding to a collection area of nearly 868.5 square feet. Considering that mahua flower collection is predominantly carried out by tribal women, the supporting arms were designed as detachable units to improve portability and reduce physical effort during transportation and installation. Each of the twelve supporting arms consisted of two telescopic sections: an inner rod measuring 10 feet in length with a diameter of 1 inch and an outer rod measuring 5 feet in length with a diameter of 0.75 inch. The smaller rod was designed to slide approximately 3 inches into the larger rod, ensuring adequate rigidity while facilitating easy assembly. Hooks provided at the distal ends of the outer rods enabled secure attachment of the harvesting net.

The overall span of the collector is 33.25 feet, comprising the 39-inch (3.25 feet) central base frame, two 10-foot inner supporting rods, and two 5-foot outer supporting rods positioned on opposite sides of the tree. This configuration provided canopy coverage sufficient to intercept flowers falling from the crown area of mature mahua trees. The structural dimensions therefore closely matched the average tree architecture observed during the field survey, ensuring efficient flower interception while maintaining mechanical stability and ease of operation under forest conditions. The modular design also enhances the practicality of seasonal installation, transportation, maintenance, and storage, making the collector suitable for community-level adoption in mahua-growing regions. The use of locally available materials ensured that the device remained simple, reusable, and economically feasible for rural communities.

Unlike conventional flower collection practices that require flowers to be picked manually from the ground, the developed system collected flowers directly from the tree canopy. This design minimised contamination from soil, leaf litter, insects, and other debris, thereby improving the quality of harvested flowers. Similar observations have been reported by Kulkarni and Mehta (2020), who emphasised the need for affordable and user-friendly technologies for mahua flower harvesting. However, unlike previous studies that merely identified the need for improved harvesting methods, the present study developed and demonstrated a functional field prototype.

Structural Characteristics of the Collector

Field measurements of mature mahua trees were used to determine the dimensions of the collector. The

adjustable circular metal base enabled installation on trees of varying trunk diameters, while detachable supporting rods facilitated transportation and assembly under forest conditions. The collector possessed an overall diameter of 33.25 feet (30 feet net diameter and 3.25 feet of metal base frame), covering approximately 868.5 square feet of canopy area. The detachable net design, secured using Velcro strips and ropes, simplified installation and removal after the flowering season. The total weight of the complete prototype was approximately 105 kg (Table 3). The collector is not intended to be carried as a single assembled unit. Its modular construction allows the major components to be transported separately and assembled at the tree site. Its durability under repeated seasonal use remains to be validated.

Table 3: Technical specifications and structural components of the collector

Component	Specification
Overall collector dimensions and weight	
Width × Height (from ground)	33.25 feet x ~1.5 feet
Weight	105 kg
Area	868.5 square feet
Metal base (frame)	
Shape	Circular
Diameter	39 inches (Circumference 123 inches)
Weight	32 kg
Collector Arms (rods)	
Material	Iron rods
Length	First rod 10 feet, second 5 feet
Collector net	
Material	Green shade net 90%
Shape	Circular
Diameter	33.25 feet

Field observations showed that the collector provided substantial coverage of the observed canopy projection by the collection net, thereby intercepting most naturally falling flowers before they

reached the forest floor. This represents a substantial improvement over conventional collection methods that depend entirely on flowers accumulating beneath the tree.

Field Demonstration and Operational Performance

The prototype was demonstrated under natural field conditions in Lohara village (19.986380° N, 79.360160° E), Chandrapur district. Installation of the collector on mature mahua trees showed that the adjustable base could accommodate different trunk sizes without causing any apparent damage to the tree. Once installed, naturally falling flowers can land on the inclined shade net and moved downward through gravity towards the collection openings, where they can be easily removed using suitable containers.

The large collection surface ensured effective interception of flowers over most of the canopy area, thereby substantially reducing flower losses. Furthermore, the green shade net visually blended with the surrounding vegetation, potentially reducing the visual conspicuousness of the structure. The detachable components also facilitated seasonal installation, transportation, and storage. These observations indicate that the developed collector is operationally feasible under the demonstrated field conditions.

Comparative Performance of the Collector and Conventional Flower Collection Method

Table 4 presents a comparative assessment of the conventional mahua flower collection method and the collector. The traditional method requires manual collection of flowers from the forest floor, making it labour-intensive, time-consuming, and dependent on the burning of dry leaf litter to improve flower visibility. This practice not only contaminates the harvested flowers but also increases the likelihood of anthropogenic forest fires and exposes collectors to occupational hazards, including prolonged physical exertion and wildlife encounters. In contrast, the developed collector intercepts naturally falling flowers before they reach the ground, thereby minimising contamination, reducing physical effort, improving flower recovery, and eliminating the need to burn forest litter. The modular and reusable design further enhances its suitability for seasonal use in forested landscapes. Although the comparative assessment demonstrates clear operational and environmental advantages of the developed technology, quantitative evaluation of collection efficiency, labour savings, and economic benefits is recommended to further validate its performance under diverse field conditions.

Table 4: Qualitative comparison of conventional mahua flower collection and the developed collector

Parameter	Conventional method	Developed collector
Collection time	Prolonged ground-level collection	Potentially reduced through continuous interception
Flower recovery	Potential losses on forest floor	Potentially improved through canopy interception
Contamination	Direct contact with soil/litter	Reduced contact with forest floor
Labour	Manual ground collection	Reduced repetitive ground-level picking
Leaf-litter burning	Commonly practiced in some areas	Not required for flower visibility
Fire risk	Burning can create ignition risk	Potentially reduced by eliminating this practice
Occupational exposure	Prolonged forest-floor activity	Potentially reduced collection duration

Implications for Forest Fire Prevention

One of the most important outcomes of the developed collector is its potential contribution to forest fire prevention. In some mahua-collection areas, collectors clear or burn dry leaf litter beneath trees to improve flower visibility. Although such fires are initially small, they frequently spread to surrounding dry vegetation, resulting in uncontrolled forest fires during the peak dry season (Ramanath, 2017). By intercepting flowers before they reach the forest floor, the developed collector eliminates the necessity of burning accumulated leaf litter for collection purposes.

This technological intervention therefore addresses the source of fire ignition rather than only its consequences. Community-based forest fire management programmes have traditionally focused on awareness generation and suppression activities (Sewak *et al.*, 2021). In contrast, the present innovation provides a preventive engineering solution capable of potentially reducing anthropogenic fire ignition associated with mahua collection. Such preventive approaches are increasingly recommended in integrated forest fire management strategies (FAO, 2020).

Occupational Safety and Livelihood Benefits

Traditional mahua flower collection requires collectors, predominantly tribal women, to spend several hours on the forest floor during early morning hours when wildlife activity is highest. The prolonged collection period increases exposure to physical fatigue, musculoskeletal strain, insect bites, and encounters with wild animals, particularly tigers. Previous reports have documented several fatalities during mahua collection

in Chandrapur and adjoining districts (Kamble, 2026).

The developed collector has the potential to substantially reduce the duration of flower collection because flowers accumulate automatically within the collection system. Consequently, if the collector reduces the duration of flower retrieval, collectors could spend less time beneath individual trees and within forest areas, thereby reducing occupational risks and the likelihood of human-wildlife conflict. In addition, potentially improving the cleanliness and market quality of collected flowers and supporting livelihood security for forest-dependent communities.

Economic Assessment (Preliminary)

Table 5 presents the estimated fabrication cost of the collector. The total prototype cost was approximately Rs. 31,000 (US\$325), with the metal frame and supporting rods accounting for nearly 60% of the total expenditure. Although the initial fabrication cost is relatively high for an individual collector, the collector is designed as a reusable structure with an expected service life of 8-10 years, thereby reducing the annual cost of operation. The technology is particularly suitable for community ownership through Forest Departments, Joint Forest Management Committees (JFMCs), Forest Rights Committees (FRCs), tribal cooperatives, self-help groups (SHGs), or Farmer Producer Organisations (FPOs), where the investment can be shared among multiple users. Future design improvements using lightweight materials such as aluminium or fibre-reinforced composites may further reduce both fabrication cost and overall weight, enhancing its affordability and field portability.

Table 5: Cost analysis of the collector

Component	Estimated Cost (Rs.)	Estimated Cost (US\$)*
Mild steel base frame (32 mm × 5 mm)	8,500	89.1
Supporting rods and hollow pipes	10,500	110.1
Green shade net (90% shade)	3,200	33.6
Fasteners, ropes, Velcro strips and fittings	1,300	13.6
Welding and fabrication charges	4,000	42.0
Painting and finishing	1,000	10.5
Labour (assembly and installation)	2,500	26.2
Total Estimated Cost	31,000	325.0

*US\$ values are approximate, based on an exchange rate of US\$1 ≈ Rs. 95.4.

Projected Economic Feasibility of the Collector

For preliminary economic assessment, a potential service life of 8–10 years was assumed, subject to durability validation. Projected annual maintenance requirements are minimal and primarily involve tightening of fasteners, repainting metallic components to prevent corrosion, and replacing damaged shade netting, with projected annual maintenance cost of approximately 3–5% of the initial fabrication cost, equivalent to Rs. 840–1,450 (US\$9–15) per year.

Mahua flowers are an important non-timber forest product with an average

market value of approximately Rs. 60/kg (US\$0.63/kg). By improving flower recovery, minimising contamination with soil and leaf litter, and reducing post-harvest losses, the developed collector is expected to enhance both the quantity and quality of harvested flowers, thereby increasing their market value. Under the stated assumptions regarding flower value, labour savings and repeated seasonal use, the investment could potentially be recovered within approximately two to three flowering seasons; however, this estimate requires field-based economic validation (Table 6).

Table 6: Projected economic feasibility of the collector

Parameter	Estimated Value
Estimated fabrication cost	US\$325 (Approximately Rs. 31,000)
Average market price of mahua flowers	Rs. 60/kg (US\$0.63/kg)
Expected service life	8–10 years
Projected annual maintenance cost	Rs. 840–1,450 (US\$9–15) (3–5% of fabrication cost)
Flowering period	30–60 days annually
Expected investment recovery period	2–3 flowering seasons
Reusability	Reusable for multiple flowering seasons
Suggested dissemination model	Forest Department/JFMC-owned collectors provided to local communities on a seasonal rental basis
Potential long-term benefits	Improved flower quality, reduced labour requirement, elimination of leaf litter burning, potential reduction in forest fire incidence, enhanced livelihoods, and biodiversity conservation

From a community perspective, the technology offers an innovative institutional implementation model. Rather than requiring individual forest-dependent households to purchase the collector, Forest Departments or Joint Forest Management Committees (JFMCs) could fabricate multiple collectors and provide them to local inhabitants on a seasonal rental basis during the mahua flowering period. Such a system would substantially reduce the financial burden on tribal and rural households while ensuring equitable access to the technology. A proposed dissemination model of rental-based distribution would encourage widespread adoption of the collector, thereby potentially eliminating the traditional practice of burning leaf litter to facilitate flower collection. Consequently, large-scale deployment of the collector could significantly reduce anthropogenic forest fires, conserve biodiversity, improve forest ecosystem health, and lower public expenditure on forest fire suppression. Furthermore, rental income generated through this system could be utilised for routine maintenance, replacement of damaged components, and fabrication of additional collectors, thereby establishing a financially sustainable, community-based management model. A centralised rental system managed by the Forest Department could also facilitate periodic inspection, maintenance and standardisation of collectors, thereby ensuring long-term operational efficiency and safety.

Although the present study did not include a field-based economic evaluation, the engineering design and anticipated operational performance suggest that the collector would reduce the effective collection cost per kilogram of mahua flowers over successive flowering

seasons. Future studies should undertake comprehensive field validation to quantify labour savings, flower recovery efficiency, cost-benefit ratio, payback period, and overall economic returns under different forest conditions.

Operational Feasibility of the Collector

A preliminary field demonstration was conducted to evaluate the operational feasibility of the collector under natural forest conditions. The demonstration revealed that the prototype can be installed efficiently by a team of three persons within approximately 30 minutes, indicating that the assembly and installation procedures are practical for seasonal field deployment. The modular construction, comprising an adjustable semicircular base frame and telescopic supporting arms, facilitates transportation, assembly, and installation around mature mahua trees of varying trunk diameters.

The collector exhibited satisfactory structural stability during the field demonstration under the prevailing conditions under normal operating conditions. For improved stability during windy conditions, peripheral support ropes can be anchored to ground pegs or locally available stones positioned around the collector, thereby minimizing displacement and maintaining the integrity of the collection net throughout the flowering season. Field observations further indicated that the collector provides effective canopy coverage for mahua trees with both regular and moderately irregular crown architecture. The overall dimensions of the collector were determined from detailed field measurements of mature mahua trees, ensuring that the collection net adequately covers the crown projection area encountered in the study region. Consequently, the developed collector is

expected to facilitate efficient collection of naturally fallen flowers without requiring modification for most mature mahua trees.

Although the preliminary field demonstration confirmed the operational feasibility of the prototype, comprehensive multi-season field evaluation under varying climatic conditions, flowering intensities, and forest environments is required to validate its long-term performance, durability, harvesting efficiency, user acceptance, and overall economic viability. Such evaluations will provide additional evidence for optimizing the design and supporting its large-scale adoption for sustainable non-timber forest product harvesting and anthropogenic forest fire prevention.

Potential Contribution of the Collector in Reducing Human–Tiger Conflict

In addition to its environmental and livelihood benefits, the collector has the potential to contribute indirectly to reducing human–tiger conflict, which has emerged as one of the major conservation and management challenges in the Central Indian landscape (Athreya *et al.*, 2013; Goodrich, 2010). A recent study conducted in the Chandrapur Forest Circle documented 15 human fatalities associated with mahua (*M. longifolia*) flower collection between 2013 and 2023, with 66.6% of the incidents occurring during the early morning hours (06:00–09:00 h) and 87% of fatalities recorded during April, coinciding with the peak mahua flowering season. The study further demonstrated that traditional mahua flower collection requires collectors to spend prolonged periods searching beneath tree canopies and manually gathering flowers from the forest floor, thereby increasing the

duration of human activity within tiger habitats during periods when mahua collection activity and reported human–tiger encounters are concentrated (Kamble, 2026).

The collector offers a practical intervention by collecting naturally falling flowers on a suspended net before they reach the forest floor. This design has the potential to reduce the time spent collecting flowers beneath individual trees, minimise unnecessary movement within dense forest vegetation, and eliminate the practice of leaf litter burning. Consequently, widespread adoption of the collector could potentially reduce the duration and frequency of human presence in tiger habitats during the mahua flowering season, thereby decreasing opportunities for accidental encounters between people and tigers. In addition to improving the safety of forest-dependent communities, the technology supports sustainable NTFP harvesting while simultaneously contributing to potential forest fire prevention, biodiversity conservation, and ecosystem protection. Although the influence of the collector on reducing human–tiger conflict requires validation through dedicated field investigations, the technology represents a promising nature-based solution that integrates community livelihood improvement with wildlife conservation and sustainable forest management.

The present study complements the findings of Kamble (2026) by proposing a practical engineering intervention that not only improves the efficiency of mahua flower collection but also has the potential to reduce human exposure within tiger habitats. Consequently, the developed collector addresses two major environmental challenges of the

Chandrapur region - anthropogenic forest fires and human - tiger conflict - through a single community-based technological innovation.

SWOT Analysis of the Collector

To evaluate the practical applicability of the collector beyond its technical performance, a SWOT (Strengths,

Weaknesses, Opportunities, and Threats) analysis was conducted (Table 7). The analysis summarises the operational advantages, current limitations, and future opportunities associated with large-scale adoption of the technology for sustainable NTFP harvesting and potential forest fire prevention.

Table 7: SWOT analysis

Strengths	Weaknesses
Low-cost technology fabricated using locally available materials	Comparatively heavy due to mild steel construction
Reusable for multiple flowering seasons	Initial installation requires time and manpower
Eliminates the need for burning leaf litter, thereby reducing forest fire risk	Suitable primarily for mature mahua trees with accessible canopy architecture
Improves flower cleanliness and quality	May require periodic maintenance of the metal frame and shade net
Reduces labour intensity and occupational drudgery	Transportation may be difficult in remote forest locations
Modular and detachable design facilitates seasonal storage and reuse	Prototype has been evaluated only under limited field conditions
Opportunities	Threats
Adoption by Forest Departments and Joint Forest Management Committees	Damage due to strong winds, falling branches, or wildlife
Promotion through tribal cooperatives and self-help groups	Limited adoption if the initial investment is unaffordable for small collectors
Commercial production by local fabricators and rural entrepreneurs	Corrosion or deterioration of metallic components under prolonged outdoor exposure
Integration into forest fire prevention programmes and NTFP management policies	Lack of awareness and training among end users
Scope for further design improvements using lightweight materials such as aluminium or composites	Vandalism or theft of components in remote forest areas

Environmental, Socio-economic and Sustainability Benefits of the Collector

The technology serves as a low-cost intervention that addresses one of the principal anthropogenic causes of forest fires associated with traditional mahua flower collection practices. By eliminating the functional need to burn leaf litter for flower visibility, the collector has the potential to reduce the risk of

accidental fires and associated smoke and greenhouse-gas emissions. Consequently, the technology contributes to improved forest ecosystem health through the conservation of biodiversity, protection of wildlife habitats, and maintenance of ecological processes in dry deciduous forests.

In addition to its environmental benefits, the developed collector promotes

sustainable NTFP harvesting by improving flower cleanliness, minimising contamination, reducing harvesting losses, and decreasing the physical drudgery experienced by collectors. These improvements have the potential to enhance the quality and market value of mahua flowers while improving occupational safety and seasonal income opportunities for tribal and forest-dependent communities. The reusable and modular design of the collector further supports efficient and responsible utilisation of forest resources.

The conceptual framework also demonstrates the broader sustainability significance of the innovation through its contribution to multiple United Nations Sustainable Development Goals (SDGs). By preventing anthropogenic forest fires, the technology advances SDG 13 (Climate Action). It could contribute to reduced greenhouse-gas emissions and strengthened climate resilience. Sustainable collection of mahua flowers without disturbing forest ecosystems supports SDG 15 (Life on Land) by promoting biodiversity conservation and sustainable forest management. Improved harvesting efficiency and enhanced livelihood opportunities contribute to SDG 1 (No Poverty), while efficient utilisation of NTFP aligns with SDG 12 (Responsible Consumption and Production). Overall, the collector represents an integrated technological solution that simultaneously addresses potential forest fire prevention, biodiversity conservation, sustainable resource management, and livelihood enhancement, thereby demonstrating its potential as a scalable model for community-based forest management and climate-resilient rural development.

Policy Implications for Sustainable Forest Management

The collector has significant policy implications for sustainable forest management and community-based potential forest fire prevention in India. The technology is designed to address an anthropogenic fire risk associated with mahua flower collection of forest fires in central Indian forests by eliminating the traditional practice of burning leaf litter during mahua flower collection. Consequently, the innovation complements the objectives of the National Action Plan on Forest Fires (NAPFF), which emphasises prevention, early intervention, community participation, and the adoption of innovative approaches to reduce forest fire incidences. By preventing fire ignition at its source, the developed collector represents a practical, low-cost technological intervention that can strengthen existing forest fire management programmes.

The technology is also consistent with the principles of Joint Forest Management (JFM), which promotes collaborative management of forest resources through active participation of local communities. Since mahua flowers constitute an NTFP for tribal and forest-dependent households, adoption of the developed collector through Joint Forest Management Committees (JFMCs), Forest Rights Committees (FRCs), tribal cooperatives, and self-help groups could improve collection efficiency while simultaneously reducing forest degradation and enhancing community stewardship of forest resources.

Furthermore, the innovation supports the objectives of the Green India Mission (GIM) under India's National Action Plan on Climate Change by contributing to the

conservation of forest ecosystems, enhancement of ecosystem services, and strengthening the resilience of forest-dependent communities. Reducing anthropogenic forest fires helps conserve biodiversity, improve forest health, and maintain carbon sequestration potential, thereby supporting national climate change mitigation and adaptation strategies.

At the international level, the collector contributes directly to several United Nations Sustainable Development Goals (SDGs). By preventing anthropogenic forest fires it could contribute to maintaining forest carbon stocks, the technology advances SDG 13 (Climate Action). Through sustainable harvesting of non-timber forest products and conservation of biodiversity, it supports SDG 15 (Life on Land). Improved flower recovery, enhanced product quality, and increased livelihood opportunities for tribal communities contribute to SDG 1 (No Poverty), while promoting efficient and environmentally responsible utilisation of forest resources aligns with SDG 12 (Responsible Consumption and Production). These multiple policy linkages demonstrate that the developed collector extends beyond a localised technological innovation and represents a scalable approach for integrating sustainable livelihoods with forest conservation and climate-resilient resource management.

Overall, the collector provides a practical example of how technological innovations can support national environmental policies and global sustainability agendas simultaneously. Wider adoption through government agencies, Forest Departments, and community-based institutions could strengthen sustainable non-timber forest

product management while contributing to long-term forest conservation and climate resilience.

Discussion

Mechanical harvesting technologies have been developed for several horticultural crops to reduce labour requirements and improve harvesting efficiency. However, these systems generally target fruits or nuts that remain attached to standing plants, whereas the present collector is designed specifically to intercept naturally falling forest produce. More importantly, the developed system integrates harvesting with an environmental objective - eliminating the functional need for leaf-litter burning during mahua collection (Mohsenin, 1986). Similarly, coffee harvesting technologies have been designed to improve harvesting efficiency and reduce labour costs through mechanical shaking or stripping systems. Mechanical harvesters developed for arecanut and coconut utilise climbing or cutting mechanisms to improve worker safety and harvesting efficiency. In date palm cultivation, harvesting devices have primarily focused on reducing occupational risks associated with climbing tall trees and improving fruit collection efficiency.

Although these technologies have significantly improved harvesting operations in cultivated agricultural systems, they are designed primarily for direct harvesting from standing trees rather than for the collection of naturally fallen forest products. Moreover, they do not address environmental issues such as forest fire prevention, biodiversity conservation, or sustainable management of NTFPs.

The collector differs fundamentally from these existing harvesting technologies in terms of both design and intended application. Unlike conventional harvesters that detach fruits from trees, the proposed collector is installed around the tree trunk to intercept naturally falling mahua flowers before they reach the forest floor. This eliminates the need for the traditional practice of burning leaf litter, which is widely recognised as one of the principal causes of anthropogenic forest fires in central Indian forests. Consequently, the developed collector performs a dual function by simultaneously improving collection efficiency and preventing accidental forest fires.

Another important innovation is its modular and reusable design, which allows installation around mature mahua trees of varying trunk diameters while covering a large collection area beneath the canopy. The collector reduces flower contamination by soil and leaf litter, improves product quality, minimises harvesting losses, and substantially reduces the physical drudgery associated with manual flower collection. These features distinguish the developed technology from conventional fruit harvesting equipment, which primarily targets productivity and labour efficiency without addressing broader environmental concerns.

Based on the literature reviewed for this study, it is found that no published literature describing a mahua flower collection technology specifically designed to integrate flower harvesting with forest-fire prevention. The present study therefore represents a novel contribution by integrating engineering design with sustainable forest management, biodiversity conservation, climate change mitigation, and livelihood enhancement. This multidisciplinary approach extends the application of harvesting technologies beyond agricultural production and

demonstrates how simple innovations can simultaneously support environmental conservation and rural development.

Conclusion

The present study successfully designed, developed, and demonstrates under field conditions a mahua (*M. longifolia*) flower collector as a practical intervention for sustainable NTFP harvesting and potential forest fire prevention. The prototype was designed to intercept naturally fallen mahua flowers before they reach the forest floor, thereby eliminating the functional need for leaf-litter burning to improve flower visibility and retrieval. This innovation represents a cost-effective, reusable, and community-friendly technology that integrates local knowledge with engineering principles to address an important environmental challenge in fire-prone forest ecosystems.

The developed collector offers multiple environmental and socio-economic benefits. By eliminating the functional need for leaf-litter burning, the technology has the potential to reduce an anthropogenic fire risk associated with mahua collection. It further contributes to biodiversity conservation, protection of forest ecosystems, and potential reduction in smoke and greenhouse-gas emissions associated with leaf-litter burning. Furthermore, cleaner flower collection, reduced physical drudgery, improved occupational safety, and enhanced collection efficiency have the potential to strengthen the livelihoods of tribal and forest-dependent communities. The technology also supports sustainable utilisation of forest resources and aligns with national forest fire management strategies and the United Nations Sustainable Development Goals, particularly SDG 13 (Climate Action) and SDG 15 (Life on Land).

The findings demonstrate that the collector has considerable potential for adoption through Forest Departments, Joint Forest Management Committees, tribal cooperatives, and other community-based organisations engaged in sustainable forest management. Wider dissemination and refinement of the technology could facilitate its integration into forest fire prevention programmes and sustainable NTFP management initiatives across mahua-growing regions.

Future investigations should focus on large-scale field validation, quantitative assessment of harvesting efficiency and economic benefits, and the development of lightweight, durable materials to enhance operational performance and promote widespread adoption. Through continued technological improvement and institutional support, the developed collector could provide a model for sustainable collection technologies that simultaneously advance forest conservation, climate resilience, and rural livelihood security.

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