# THE INVASIVE THREAT OF SENNA SPECTABILIS IN WAYANAD :

## Effects on Biodiversity, Wildlife, and Communities

**MSW DISASTER MANAGEMENT**

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# ABSTRACT

This study, titled "The Invasive Threat of *Senna spectabilis* in Wayanad: Effects on Biodiversity, Wildlife, and Communities," explores how the spread of *Senna spectabilis* has affected the forests of Wayanad and the people who depend on them. The study aimed to understand the history and spread of the species, its impact on biodiversity and wildlife, its effects on the livelihoods and well-being of forest-dependent communities, and the management and restoration measures taken to control its spread.

The study adopted a qualitative approach with case study research design. Data were collected through semi-structured interviews and field observations in the Muthanga and Tholpetty forest ranges of Wayanad. Participants included tribal community members, Forest Department officials, researchers, NGO representatives, and Panchayat officials. Secondary data were collected from books, journal articles, reports, and other published sources. The data were analysed using thematic analysis.

The findings show that the spread of *Senna spectabilis* has caused major ecological and social changes. The species has replaced native vegetation, reduced biodiversity, and affected wildlife habitats and food availability. These changes have contributed to increased human–elephant conflict as animals move into nearby settlements in search of food. The study also found that forest-dependent communities have experienced a decline in non-timber forest products, reduced livelihood opportunities, food insecurity, loss of traditional knowledge, and changes in cultural practices that are closely linked to the forest. Although several restoration measures such as uprooting, monitoring, and planting native species have been implemented, the rapid regeneration of *Senna spectabilis* continues to make management difficult.

The study concludes that controlling *Senna spectabilis* requires long-term ecological restoration, continuous monitoring, stronger institutional support, and active participation of local communities to protect the biodiversity, wildlife, and livelihoods of Wayanad.

# TABLE OF CONTENTS

# CHAPTER 1

# INTRODUCTION

# 1.1 INTRODUCTION

Senna spectabilis is today one of the most concerning invasive tree species spreading across the forests of South India, especially within the landscapes of the Western Ghats. At first glance, the tree appears beautiful and harmless. During flowering seasons, its branches become covered with bright yellow flowers that almost paint the forest edges in gold. Because of this attractive appearance, the species was introduced into many countries as an ornamental and shade tree. However, behind this beauty lies a serious ecological problem that is slowly changing the forests, wildlife habitats, and the lives of people who depend on them (Gnanasekaran, 2013; Irwin & Barneby, 1982).

Botanically, Senna spectabilis belongs to the Fabaceae family and the subfamily Caesalpinioideae. It is native to the tropical regions of Central and South America but is now found in several countries across Asia and Africa due to human introduction (Irwin & Barneby, 1982; Wakibara & Mnaya, 2002). The tree grows rapidly and can reach nearly 7 to 15 meters in height. It develops a broad rounded crown with drooping branches and produces long cylindrical seed pods filled with a very large number of seeds (Gilman & Watson, 1994). Studies show that each pod can contain nearly 60 to 110 hardy seeds, allowing the species to reproduce aggressively and spread over large forest areas (Satyanarayana & Gnanasekaran, 2013). The seeds are further dispersed by wild animals such as elephants and deer, which consume the pods and unknowingly spread them through dung across the forest landscape (Anoop et al., 2025). Slowly and silently, the species expands its territory deeper into native forests (Anoop et al., 2025).

The danger of Senna spectabilis does not lie only in its rapid growth, but also in the way it changes the natural balance of ecosystems. The leaf litter released from the tree contains allelopathic chemicals that suppress the growth of surrounding native vegetation (Bioinvasion Newsletter, 2023). Over time, the forest floor beneath Senna becomes empty of native seedlings and grasses. Instead of diverse forests filled with bamboo, shrubs, herbs, and indigenous trees, the landscape slowly turns into dense monocultures dominated by Senna (Bioinvasion Newsletter, 2023). Forests that once supported rich biodiversity begin to lose their ecological complexity. The silence created by this transformation is difficult to notice at first, but its effects spread across the entire ecosystem (Linders et al., 2019).

This issue becomes deeply important in regions such as Wayanad, where forests are not merely stretches of land covered with trees. Wayanad forms part of the Nilgiri Biosphere Reserve within the Western Ghats, one of the most biodiverse landscapes in the world (Raah Foundation, 2024). Earlier, Wayanad was known for its continuous forests, swampy lowlands called vayals, rich grasslands, and dense vegetation that supported countless species of wildlife (Anoop et al., 2025). The forests provided shelter and food for elephants, tigers, deer, gaur, birds, reptiles, and numerous endemic species found nowhere else (Anoop et al., 2025). Streams flowing through the forests remained active because the ecosystem naturally held water throughout the year (Anoop et al., 2025). Elephants migrated seasonally through these landscapes, following age-old forest paths in search of food and water (Anoop et al., 2025).

Human life in Wayanad also grew alongside these forests. Tribal communities such as the Paniyas, Adiyas, Kurichyas, and Kattunayakas lived in close connection with nature for generations (Sajaneesh, 2016). The forest was not simply a source of survival; it was part of culture, memory, spirituality, and identity. People collected wild honey, medicinal plants, mushrooms, tubers, and forest fruits from these landscapes (Anoop et al., 2025; Sajaneesh, 2016). Many communities practiced shifting cultivation methods that allowed forests to regenerate naturally after use (Sajaneesh, 2016). Elephants, trees, rivers, and hills were often seen not merely as natural objects but as living presences connected to spiritual beliefs and ancestral traditions ((Raj, 2017)). The relationship between people and forests was therefore deeply emotional as well as ecological ((Raj, 2017)).

However, the history of Wayanad is also a story of gradual transformation. Over time, migration, plantation agriculture, colonial forest policies, road construction, and development activities fragmented large portions of forest land (Anoop et al., 2025). During the colonial period, vast stretches of forests were cleared for tea, coffee, rubber, and teak plantations (Anoop et al., 2025). After independence, migration into Wayanad increased rapidly, and more forests were converted into agricultural settlements (Kumar, 2021). Between 1950 and 2023, forest cover in Wayanad declined sharply, leaving behind fragmented patches instead of continuous landscapes (Anoop et al., 2025). This ecological disturbance created ideal conditions for invasive species such as Lantana camara and Senna spectabilis to spread rapidly across degraded forest areas (Anoop et al., 2025).

Today, large parts of the Wayanad Wildlife Sanctuary are invaded by Senna spectabilis (Anoop et al., 2022). Native grasses and bamboo species that once fed elephants and herbivores are disappearing (Ravi, 2022). Forest pathways are changing. Wildlife movement is becoming disturbed (Anoop et al., 2025). Elephants increasingly enter farms and villages searching for food because the forests can no longer fully support them (Ravi, 2022). Tribal communities also speak about the gradual disappearance of forest produce that once formed part of their everyday life (Menon, 2023). What was once a living and connected forest ecosystem is now slowly becoming a contested landscape where biodiversity loss, human livelihood struggles, and wildlife conflict are deeply interconnected (Anoop et al., 2025; Ravi, 2022).

Another major concern is that Senna spectabilis is extremely difficult to remove once it becomes established. Cutting the tree often triggers coppicing, where multiple new shoots emerge rapidly from the remaining stump (Anoop et al., 2025). Even debarking methods have shown that some trees regenerate their bark and survive despite management attempts (Premdas et al., 2023). This makes long-term control both labor-intensive and expensive (Premdas et al., 2023). Without repeated intervention and ecological restoration, the invasion continues to spread further every year (Anoop et al., 2025).

The growing spread of Senna spectabilis therefore raises important ecological and social questions. It is no longer only about a tree species invading forests. It is about understanding how landscapes change, how biodiversity disappears quietly, how wildlife begins to lose habitat, and how communities connected to forests slowly lose parts of their culture, livelihood, and security (Linders et al., 2019; Menon, 2023). The issue reflects a larger environmental reality where human actions, ecological imbalance, and invasive species together reshape the future of fragile ecosystems like Wayanad (Anoop et al., 2025).

## 1.2 STATEMENT OF THE PROBLEM

Senna spectabilis has emerged as a major environmental challenge in the forests of Wayanad, where the ecological balance of the region is slowly being altered by its uncontrolled spread. The problem is not simply the presence of another tree species inside the forest. The real concern is the

way this invasive plant gradually replaces native vegetation and changes the natural character of forest ecosystems that once supported rich biodiversity and stable wildlife habitats (Anoop et al., 2022). Areas that were earlier covered with native grasses, bamboo patches, medicinal plants, and indigenous trees are increasingly becoming dense stretches dominated by Senna spectabilis, reducing the diversity that once defined the forests of Wayanad (Bioinvasion Newsletter, 2023).

One of the major reasons behind the seriousness of this invasion is the aggressive nature of the species. Senna spectabilis produces a large number of hardy seeds and spreads rapidly across forest areas with the help of native mammals such as elephants and deer, which disperse the seeds through dung (Satyanarayana & Gnanasekaran, 2013; Anoop et al., 2025). The species also survives under different environmental conditions and regenerates quickly even after removal attempts. In many cases, cutting the tree only results in coppicing, where several new shoots emerge from the cut stump, making management extremely difficult (Premdas et al., 2023). This continuous regeneration allows the species to establish long-term dominance within invaded landscapes.

The invasion has created serious ecological consequences within the Wayanad Wildlife Sanctuary and nearby forest regions. The decline of native vegetation affects herbivorous animals that depend on indigenous plants for food and shelter (Ravi, 2022). As food availability inside forests decreases, wildlife movement patterns begin to change. Elephants and other animals increasingly move towards agricultural lands and settlements searching for food resources, contributing to the growing issue of Human–Elephant Conflict in Wayanad (Ravi, 2022). What was once a connected ecological landscape is gradually turning into a fragmented and stressed environment where wildlife struggles to survive within shrinking and altered habitats (Anoop et al., 2025).

The problem also extends beyond wildlife and biodiversity into the everyday lives of local communities. Tribal and forest-dependent communities in Wayanad have traditionally relied on forests for wild food, medicinal plants, bamboo, mushrooms, honey, and other non-timber forest products that supported both livelihood and culture (Sajaneesh, 2016). However, the spread of Senna spectabilis has reduced the growth of many native species that communities once collected regularly (Menon, 2023). This has affected not only livelihood opportunities but also people’s emotional and cultural relationship with the forest landscape. Many communities now experience

the forest differently from earlier generations, as familiar plant species and ecological patterns slowly disappear ((Raj, 2017)).

Another major issue is the lack of sufficient long-term research and management strategies addressing both the ecological and social dimensions of the invasion. Existing studies largely focus on the biological behavior, spread, and reproductive characteristics of Senna spectabilis (Muraleekrishnan et al., 2023). Comparatively little attention has been given to understanding how local communities, forest officials, and affected populations experience and interpret these environmental changes in their daily lives (Menon, 2023). There is also limited narrative-based research that documents the changing relationship between forests, wildlife, and people within invaded landscapes.

Therefore, the central problem addressed in this study is the growing ecological and social transformation caused by Senna spectabilis in Wayanad. The study seeks to understand how the invasion is reshaping biodiversity, forest ecosystems, wildlife habitats, local livelihoods, and patterns of Human–Wildlife Conflict, while also exploring how these changes are experienced and understood by communities living closest to the forest (Anoop et al., 2025; Ravi, 2022).

# 1.3 BACKGROUND OF THE STUDY

Invasive Alien Species are plants, animals, or other organisms introduced into places outside their natural environment, where they later spread rapidly and disturb native ecosystems (Convention on Biological Diversity [CBD], 2002). Across the world, invasive species have become a major environmental concern because they reduce biodiversity, damage natural habitats, and affect ecological balance (Genovesi, 2009). Today, biological invasion is considered one of the biggest threats to global biodiversity after habitat destruction (Sankaran et al., 2014). Increased globalization, trade, tourism, plantation activities, and transportation systems have made it easier for species to move across natural geographical barriers and establish themselves in new regions (Sankaran et al., 2014). As a result, forests and ecosystems in many countries are now facing serious ecological and economic losses caused by invasive species (Genovesi, 2009).

One important invasive species spreading across tropical regions is Senna spectabilis, a deciduous tree native to Central and South America (Bargavi et al., 2025). The species was introduced into many countries because of its fast growth, ornamental beauty, and usefulness as a shade tree in plantations (Irwin & Barneby, 1982). Over time, however, the species escaped cultivation and spread aggressively into natural forests. Today, Senna spectabilis is reported as invasive in several countries across Africa and Asia, where it suppresses native vegetation and gradually changes forest structure (Wakibara & Mnaya, 2002; Mungatana & Ahimbisibwe, 2012). Studies also suggest that climate change and environmental disturbance may further increase the future spread of the species across tropical regions (Anoop et al., 2025).

In India, the problem of invasive species became more serious during and after the colonial period, when many foreign plant species were introduced for forestry, plantation agriculture, ornamental gardening, and commercial purposes (Rana et al., 2003). Several of these species later escaped cultivation and spread into natural ecosystems. Today, plants such as Lantana camara, Parthenium hysterophorus, Prosopis juliflora, and Senna spectabilis have become major ecological concerns in different parts of the country (Raghubanshi et al., 2005). Biodiversity hotspots such as the Western Ghats are especially vulnerable because disturbed forests create favourable conditions for invasive plants to spread rapidly (Adhikari et al., 2015). In South India, particularly in forest regions of Kerala and Tamil Nadu, the spread of Senna spectabilis has become increasingly severe due to forest fragmentation and ecological disturbance (Gnanasekaran, 2013).

The forests of Wayanad carry a long environmental and cultural history. Earlier, the region was known for its continuous forests, hills, swampy valleys, thick bamboo patches, and rich wildlife populations that formed an important part of the Western Ghats ecosystem (Anoop et al., 2025). Wayanad was once a landscape where forests, streams, wildlife, and people existed in close connection with one another. The swampy lowlands locally called *vayals* held water throughout the year and supported many small streams flowing across the region, making the land naturally fertile and ecologically rich (Anoop et al., 2025). During dry seasons, elephants moved through these forests searching for food and cooler conditions, while animals such as tigers and leopards travelled through continuous wildlife corridors (Anoop et al., 2025).

For tribal communities living in Wayanad, forests were deeply connected to everyday life. Communities depended on forests not only for food and livelihood but also for culture, identity, and spirituality (Sajaneesh, 2016). Wild honey, medicinal herbs, tubers, mushrooms, berries, bamboo, and small game animals formed part of traditional life systems (Anoop et al., 2025; Sajaneesh, 2016). Knowledge about forests and wildlife was passed from one generation to another through everyday experience ((Raj, 2017)). Many communities believed forests were sacred spaces where ancestral spirits lived within trees, rocks, rivers, and animals ((Raj, 2017)). Elephants also held an important place in local memory and culture, which can still be seen in the ancient carvings found in the Edakkal Caves showing humans and elephants together (Anoop et al., 2025). At the same time, the history of the region also included painful realities such as bonded labour systems faced by tribal communities like the Paniyas and Adiyas, where many families were forced to work under landlords and plantation systems (Kumar, 2021).

Over time, this forest landscape slowly began to change because of increasing human activities. During the colonial period, large forest areas were cleared for tea, coffee, rubber, and teak plantations (Anoop et al., 2025). British forest policies restricted the traditional access of tribal communities to forests and changed forests into state-controlled lands (Sajaneesh, 2016). After independence, migration into Wayanad increased rapidly, leading to more settlements, agriculture, roads, and forest clearing (Kumar, 2021). Slowly, continuous forests became fragmented landscapes divided by plantations, farms, roads, and human settlements (Anoop et al., 2025).

As forests became more disturbed, invasive species found favourable conditions to spread rapidly. In degraded forest areas, species such as Lantana camara and Senna spectabilis began replacing native vegetation and slowly changing the natural structure of forests (Anoop et al., 2025). In Wayanad, Senna spectabilis was introduced during the 1980s for beautification and afforestation activities, but later spread aggressively across forest edges and wildlife habitats (Anoop et al., 2022). The tree produces a large number of hardy seeds, and animals such as elephants and deer help spread them through dung across long distances (Anoop et al., 2021). Its leaves also release chemicals into the soil that suppress nearby native vegetation, gradually turning diverse forests into dense Senna-dominated areas (Bioinvasion Newsletter, 2023). Even after cutting, the species grows back quickly, making removal and management very difficult (Premdas et al., 2023).

These ecological changes slowly began affecting both wildlife and local communities. As native plants disappeared, herbivores lost important food sources and wildlife movement corridors became disturbed (Ravi, 2022). Human–Elephant Conflict also increased in many parts of Wayanad as elephants moved into nearby agricultural lands searching for food and space (Anoop et al., 2025). Tribal and forest-dependent communities reported changes in the availability of forest resources traditionally used for food, medicine, and livelihood (Menon, 2023). For many people, the changes were not only environmental but also emotional, because forests that once carried memory, culture, and belonging slowly began to look unfamiliar.

Several studies have already discussed the spread, reproductive biology, and ecological impacts of Senna spectabilis in forest ecosystems (Muraleekrishnan et al., 2023; Bargavi et al., 2025). Research also shows that invasive species spread more rapidly in forests already disturbed by plantation expansion, migration, deforestation, and road construction (Linders et al., 2019). However, even though many studies focus on ecological impacts, fewer studies examine how local communities and forest-dependent people experience these environmental changes in their everyday lives. The social, cultural, emotional, and livelihood dimensions of changing forests often remain less explored (Menon, 2023).

Therefore, the present study is important because it tries to understand Senna spectabilis not only as an invasive plant, but also as part of a bigger environmental change affecting forests, wildlife, and people in Wayanad. Many earlier studies mainly focused on the ecological impacts and spread of the species. However, this study mainly looks at the social side of the problem. It focuses on how the spread of Senna spectabilis affects the daily lives of local communities, tribal people, and forest-dependent families. The study also tries to understand how these changing forests affect livelihood, culture, traditional dependence on forests, human–wildlife interaction, and people's emotional connection with the forest around them.

# 1.4 RELEVANCE AND SIGNIFICANCE OF THE STUDY

This study is important because it speaks about a silent environmental transformation that is happening inside the forests of Wayanad. Many environmental problems become visible only after major destruction takes place. However, the spread of Senna spectabilis happens slowly, almost unnoticed at first. A forest may still appear green from a distance, yet inside it, native plants may

already be disappearing, wildlife movement may already be changing, and communities may already be losing the forest resources they depended upon for generations (Menon, 2023). This study becomes relevant because it attempts to understand these gradual but deeply important ecological and social changes (Anoop et al., 2025).

The significance of the study lies in the fact that it connects biodiversity conservation with human life. Forests are often discussed only in terms of trees, wildlife numbers, or conservation policies. But for people living close to forests, the environment is part of daily existence (Sajaneesh, 2016). Tribal communities in Wayanad have historically depended on forests for food, medicine, income, cultural practices, and identity (Sajaneesh, 2016; (Raj, 2017)). When invasive species replace native vegetation, the impact is not limited to ecology alone. It also affects traditional knowledge systems, livelihood patterns, and emotional relationships people share with the forest (Menon, 2023). The study therefore highlights how environmental degradation eventually becomes a human issue as well (Linders et al., 2019).

The research is also significant because it focuses on the changing relationship between forests and wildlife. Earlier, elephants moved through continuous forest corridors and found food within native vegetation-rich habitats (Anoop et al., 2025). Today, shrinking forests, invasive species, and habitat fragmentation are forcing animals to move outside forests more frequently (Ravi, 2022). Crop destruction, fear, and Human–Elephant Conflict are becoming common experiences in many parts of Wayanad (Ravi, 2022). Through this study, the invasion of Senna spectabilis is understood not simply as a plant problem, but as one factor contributing to larger ecological imbalance and conflict between humans and wildlife (Anoop et al., 2025).

Another important relevance of the study is its contribution toward understanding invasive species within the context of the Western Ghats biodiversity hotspot. The Western Ghats support some of the richest biodiversity in the world, including many endemic species found nowhere else (Raah Foundation, 2024). Ecological disturbances in such fragile landscapes can create long-term consequences for biodiversity conservation (Linders et al., 2019). By examining how Senna spectabilis alters forest composition, suppresses native regeneration, and affects ecological relationships, the study contributes to ongoing discussions about habitat restoration and sustainable forest management (Bioinvasion Newsletter, 2023).

The study is also socially significant because it gives importance to local voices and lived experiences. Many environmental studies focus mainly on scientific measurements and ecological statistics. While such studies are important, they sometimes fail to capture how ordinary people emotionally experience environmental change (Menon, 2023). For someone living near forests, the disappearance of bamboo patches, medicinal herbs, or traditional forest pathways is not simply ecological data; it represents the loss of familiarity, memory, and security ((Raj, 2017)). By using a narrative-based qualitative approach, this research creates space for communities and officials to describe these transformations through their own experiences and understanding (Sajaneesh, 2016).

Academically, the study fills an important gap in existing literature. Most available studies on Senna spectabilis focus on its taxonomy, reproductive biology, invasive behavior, and ecological spread (Muraleekrishnan et al., 2023). Comparatively fewer studies explore the social dimensions of invasion, especially within forest-dependent communities of Kerala (Menon, 2023). This research therefore contributes not only to environmental studies but also to social work, sociology, development studies, and interdisciplinary conservation research (Linders et al., 2019).

The study also has practical relevance for policymakers, forest departments, and conservation agencies. Understanding the ecological and social impact of Senna spectabilis can support the development of better invasive species management strategies (Premdas et al., 2023). Since the species regenerates rapidly even after cutting and removal attempts, management requires long-term planning, restoration of native vegetation, and community participation (Anoop et al., 2025; Premdas et al., 2023). Research that combines ecological understanding with local experience can therefore contribute toward more sustainable and realistic conservation practices (Ravi, 2022).

Ultimately, the significance of this study lies in its attempt to remind us that forests are living systems connected to both nature and people. The story of Wayanad is not only about disappearing trees or spreading invasive plants. It is also about changing landscapes, disrupted wildlife movement, disappearing traditional knowledge, and communities trying to adapt to ecological uncertainty (Anoop et al., 2025). Understanding the spread of Senna spectabilis therefore becomes important not only for protecting biodiversity, but also for protecting the delicate relationship that once existed between forests, wildlife, and human life ((Raj, 2017); Menon,

# CHAPTER 2

# LITERATURE REVIEW

# 2.1 INTRODUCTION

A literature review is an important part of any research study. It helps the researcher understand what has already been studied about a particular topic. According to Snyder (2019), a literature review is a systematic, critical, and analytical examination of existing scholarly literature on a specific topic. It brings together current knowledge, identifies research gaps, examines different ideas and methods used by researchers, and provides a foundation for new research. In simple terms, a literature review helps the researcher understand what is already known about a subject and what areas require further study.

The literature review also helps in building a strong foundation for the research. By examining books, journal articles, reports, dissertations, and other academic sources, the researcher can understand different perspectives, findings, and debates related to the topic. It helps in identifying important concepts, understanding existing knowledge, and establishing the relevance of the present study.

In the context of the present study, this chapter reviews the available literature related to *Senna spectabilis* and its ecological and social impacts in Wayanad. The chapter begins by examining the concept of invasive alien species and their impacts on ecosystems and biodiversity. It then reviews studies related to the introduction, spread, reproductive biology, and invasion dynamics of *Senna spectabilis* in different regions, particularly in India and the Western Ghats.

The chapter further discusses the ecological changes caused by the invasion of *Senna spectabilis*, including its effects on forest structure, native vegetation, biodiversity, and wildlife habitats. It also reviews studies that explain how the invasion affects wildlife movement and contributes to increasing Human–Elephant Conflict in Wayanad.

Another important section of this chapter focuses on the impacts of the invasion on local communities. It examines studies related to forest-dependent livelihoods, the availability of non-timber forest products, traditional ecological knowledge, food security, and the cultural relationship between tribal communities and forests.

The chapter also reviews literature related to climate change and its influence on forest ecosystems and the future spread of invasive species. In addition, it examines existing research on the governance and management of invasive alien species at international, national, and local levels, including different strategies used to control and manage *Senna spectabilis*.

Finally, the chapter discusses the Sustainable Livelihoods Framework, which forms the theoretical foundation of the present study. The framework helps in understanding how the invasion of *Senna spectabilis* affects different aspects of community livelihoods and increases vulnerability among forest-dependent populations.

In conclusion, this literature review provides the conceptual and academic background for the study. It helps to identify the existing knowledge, understand the major issues related to the invasion of *Senna spectabilis*, and highlight the research gaps that justify the need for the present study.

## 2.2 GLOBAL PERSPECTIVE ON INVASIVE ALIEN SPECIES

### The Movement of Species Across the World

Forests, rivers, grasslands, wetlands, and mountains across the world have always undergone natural ecological changes over time. Species evolved within these ecosystems through complex relationships developed over thousands of years. However, human activities have significantly altered these natural patterns by accelerating the movement of organisms beyond their original geographical boundaries. Through global trade, transportation, tourism, and changing land-use practices, plants, animals, fungi, and microorganisms are now frequently transported across continents, oceans, and climatic zones, often reaching ecosystems where they never previously existed. While many introduced species fail to survive, some establish successfully, spread rapidly, and transform the ecological structure of their new environments. These organisms are recognized as invasive alien species (Shackleton et al., 2019).

Biological invasions are now considered among the most serious environmental challenges worldwide. They are identified as the second largest threat to global biodiversity after habitat destruction (Sandilyan, 2023; IPBES, 2019). Nearly 6,500 invasive alien plant species have been documented across terrestrial and aquatic ecosystems globally (Anoop et al., 2025). Current assessments indicate that approximately one-fifth of the Earth's surface is vulnerable to biological invasions, including several biodiversity-rich and ecologically sensitive regions (IPBES, 2019; Anoop et al., 2025).

Unlike many environmental disturbances that remain restricted to specific locations, biological invasions often expand gradually across landscapes. A species that initially appears insignificant can, over time, dominate forests, wetlands, agricultural areas, river systems, and protected landscapes. By the time visible ecological impacts become evident, invasive populations may already be firmly established and difficult to control. In many ecosystems, invasive species replace native communities to such an extent that the original ecological characteristics of the landscape are gradually altered (IPBES, 2019).

The increasing movement of species across ecological boundaries has therefore transformed biological invasions from local ecological events into a global environmental issue. Climate change has further intensified this process by modifying environmental conditions that previously limited species establishment. Rising temperatures, altered rainfall patterns, and increasing ecological disturbances are enabling invasive species to survive and expand into areas that were previously unsuitable, including higher elevations and new climatic regions (Vilà & Hulme, 2017; Prevena, 2021; Sreekutty et al., 2023).

## Global Drivers of Biological Invasions

The rapid expansion of invasive alien species is closely associated with globalization and increasing human mobility (Sankaran et al., 2014). International trade, tourism, and transportation, commonly referred to as the "three Ts," have become major pathways through which organisms move between continents (Aswathy Nair & Dhanya, 2023). Shipping networks, cargo

transportation, airports, railways, and tourism routes provide numerous opportunities for species to cross natural geographical barriers.

Many invasive species were introduced intentionally for economic and practical purposes. Plants were transported for forestry plantations, agroforestry systems, ornamental gardening, erosion control, agriculture, and shade provision (Remmele & Lindemann-Matthies, 2024). Several species that were initially valued for rapid growth, attractive appearance, or adaptive abilities later escaped cultivation and spread into natural ecosystems.

Other species reached new environments unintentionally as hidden passengers in ballast water, untreated timber, packaging materials, nursery soil, shipping containers, and transport vehicles (Murphy, 2014). These accidental pathways are particularly difficult to regulate because introductions often occur without immediate detection.

The horticultural sector has become one of the major contributors to plant invasions worldwide. Ornamental plants with attractive flowers, decorative foliage, or rapid growth characteristics are frequently transported across regions without sufficient understanding of their ecological consequences. The expansion of online trade in ornamental plants and exotic organisms has further increased the possibility of invasive species entering natural ecosystems (NBA, 2018).

Human-induced landscape disturbance also creates favourable conditions for invasion. Activities including road construction, mining, urban expansion, deforestation, and agricultural conversion modify ecosystems and create open spaces where invasive species can establish more easily than native vegetation (Anoop et al., 2025). These disturbed habitats often become entry points from which invasive species spread into surrounding forests and protected areas.

## Understanding the Invasion Process: The Rule of Tens

The establishment of invasive species generally occurs through a series of stages, beginning with introduction, followed by escape, naturalization, and eventual invasion. Ecologists often explain this process through the “rule of tens.” According to this principle, only a small proportion of introduced species survive outside cultivation. Approximately 10% of introduced species escape

into natural environments, 10% of escaped species become naturalized, and around 10% of naturalized species eventually become invasive.

Although only a limited number of introduced organisms successfully become invasive, those that do can produce extensive ecological changes across large spatial scales by altering species composition, ecosystem processes, and landscape structure (Williamson & Fitter, 1996).

## Ecological Transformations Caused by Invasive Species

Once established, invasive species influence ecosystems beyond simply replacing native species. They modify ecological processes, alter resource availability, and change the physical and biological characteristics of invaded environments (Anoop et al., 2025). Many invasive plants possess rapid growth rates, efficient reproduction strategies, and strong competitive abilities that allow them to dominate available resources such as sunlight, nutrients, water, and space (Bargavi et al., 2025).

Dense invasive populations often form monocultures that suppress native vegetation and restrict natural regeneration. In forests, heavy invasion of the understory can prevent native seedlings from establishing, interrupt ecological succession, and gradually simplify ecosystem structure. As native plant diversity declines, associated organisms including insects, birds, mammals, and microorganisms are also affected.

Several invasive plants further enhance their dominance through allelopathy, where biochemical compounds released into the soil inhibit the germination and growth of surrounding native species (Bargavi et al., 2025). Through these interactions, invasive plants create conditions that favour their own persistence while reducing competition from native vegetation.

The effects of invasion also extend below ground. Invasive species can alter soil nutrient cycling, microbial communities, litter decomposition, moisture availability, and carbon storage processes, thereby influencing ecosystem functioning at broader scales (Linders et al., 2019).

Globally, invasive species are associated with approximately 25% of plant extinctions and 33% of animal extinctions (Sandilyan, 2023). Their role has shifted from being viewed merely as consequences of environmental disturbance to being recognized as active drivers of ecological transformation (Linders et al., 2019).

In some ecosystems, invasive species also modify disturbance patterns. For example, in fire-prone landscapes, invasive plants can increase fuel availability and alter fire intensity, creating conditions that damage native vegetation while supporting further invasion (Arianoutsou & Vilà, 2012).

## Global Situation of Invasive Species Across Different Regions

Biological invasions are now occurring across almost every continent, affecting forests, wetlands, grasslands, agricultural landscapes, freshwater systems, islands, and even remote polar environments (IPBES, 2019). Although invasive species differ between regions, a common pattern exists worldwide: introduced organisms establish in suitable environments, alter ecological processes, and place additional pressure on ecosystems already affected by habitat modification, climate change, and human activities (IPBES, 2019; Shackleton et al., 2019).

### Asia: Expansion Across Biodiversity-Rich Landscapes

Asia contains some of the world's most biologically diverse ecosystems, many of which are increasingly affected by invasive alien species. Tropical forests, wetlands, plantations, and agricultural landscapes have become vulnerable due to land-use changes, climatic suitability, and increasing ecological disturbance. Species such as *Lantana camara*, *Mikania micrantha*, *Prosopis juliflora*, and *Senna spectabilis* have expanded widely across several Asian landscapes (Prameela et al., 2023).

Biodiversity hotspots including the Western Ghats, Himalayan foothills, and Southeast Asian rainforests are particularly sensitive because ecological disturbances create opportunities for invasive plants to establish and spread rapidly (Anoop et al., 2025).

Several invasive plants in Asia were originally introduced intentionally for forestry, ornamental purposes, agroforestry, erosion control, and shade provision (Remmele & Lindemann-Matthies,

2024). However, after escaping cultivation, many have spread into natural ecosystems where they suppress native vegetation and modify ecosystem functioning (Anoop et al., 2025).

In forest ecosystems, invasive plants can reduce native regeneration by occupying understory spaces and limiting the establishment of indigenous plant species. Over time, such changes can transform diverse forests into simplified landscapes dominated by a small number of aggressive species.

**Africa: Ecological Pressure and Livelihood Conflicts**

Across Africa, invasive species are strongly associated with ecological degradation and challenges faced by rural communities. Species such as *Prosopis juliflora*, *Eichhornia crassipes* (Water Hyacinth), and *Lantana camara* have spread across wetlands, drylands, grazing areas, and freshwater systems (Dzokom, 2024).

In dry regions, *Prosopis juliflora* often replaces native vegetation and reduces the availability of grazing areas. However, the species has also become a source of charcoal and fuelwood for some rural communities, creating a complex management challenge where a harmful invasive species simultaneously provides economic benefits (Athamanakath et al., 2023).

Similarly, the expansion of Water Hyacinth across freshwater ecosystems has affected fisheries, irrigation systems, and transportation routes by forming dense mats over water bodies (Sabu, 2023). These impacts demonstrate that invasive species management involves not only ecological concerns but also social and economic considerations.

Consequently, invasive species in several African regions are increasingly recognized as factors influencing environmental stability, rural livelihoods, and resource security (Shackleton et al., 2019).

**Europe: Ecological Risks and Policy Responses**

Europe has experienced increasing concerns regarding biological invasions due to extensive trade networks, tourism, transportation, and changing climatic conditions. Invasive plants, aquatic organisms, insects, and pathogens have affected forests, wetlands, rivers, and agricultural landscapes across the continent. Species such as zebra mussels, giant hogweed, and Japanese knotweed have created significant ecological and infrastructural challenges in several European countries (Lowe et al., 2000).

The growing recognition of these impacts has encouraged the development of stronger policy frameworks, monitoring systems, and early detection programmes aimed at preventing the introduction and spread of invasive species (CBD, 2022). Management approaches increasingly emphasize prevention, rapid response, ecological restoration, and cooperation among governments, researchers, and local communities (Remmele & Lindemann-Matthies, 2024).

Climate change has further complicated invasion management in Europe by allowing several invasive organisms to survive and expand into regions that were previously unsuitable. Rising temperatures have enabled some species to move towards higher elevations and northern areas, increasing risks to native biodiversity (Vilà & Hulme, 2017).

**North America: Large-Scale Ecological and Economic Impacts**

North America has experienced some of the most economically significant biological invasions worldwide. The continent's extensive trade networks, transportation systems, and movement of goods have created numerous pathways for accidental species introductions.

Aquatic invasive species such as zebra mussels (*Dreissena polymorpha*) have spread widely through freshwater ecosystems, affecting industrial infrastructure, fisheries, and native aquatic communities (Murphy, 2014). Invasive insects and pathogens have also caused extensive damage to native forest species, altering forest composition across large regions.

The economic consequences of invasive species are substantial. In the United States alone, annual losses associated with invasive species are estimated to exceed 100 billion US dollars due to impacts on agriculture, forestry, fisheries, infrastructure, and management efforts (Murphy, 2014). These impacts demonstrate that biological invasions represent both ecological and economic challenges.

North America's position as a major centre of global trade and transportation continues to increase the risk of new introductions through shipping, cargo movement, ornamental plant trade, and tourism pathways.

**South America and the Caribbean: Native Species Becoming Global Invaders**

South and Central America represent important regions in the global discussion of biological invasions because several species that are now invasive elsewhere originated from these ecosystems. Species including *Senna spectabilis*, *Water Hyacinth*, and *Lantana camara* are native to parts of this region but have become problematic after introduction into environments where their natural ecological controls are absent (Bargavi et al., 2025).

Within their native ranges, these species are regulated through interactions with herbivores, pathogens, competitors, and other ecological relationships. However, outside their original habitats, the absence of these limiting factors allows them to establish rapidly and dominate new environments.

The Caribbean islands face particular vulnerability because of their high levels of endemic biodiversity and long evolutionary isolation. Introduced mammals, reptiles, insects, and plants have contributed to biodiversity decline and species loss across several islands (Lowe et al., 2000). Due to their limited geographical area and ecological sensitivity, island ecosystems often have reduced capacity to recover after invasion.

**Oceania and Pacific Islands: Vulnerability of Isolated Ecosystems**

Island ecosystems of Oceania and the Pacific are among the most sensitive environments to biological invasions. Many island species evolved in isolation over thousands of years with limited exposure to external organisms. As a result, native species often lack effective defenses against introduced predators, competitors, and pathogens (Lowe et al., 2000).

Invasive mammals, plants, reptiles, and insects have significantly altered island ecosystems and threatened species found nowhere else in the world. The spread of invasive organisms in these regions is closely associated with tourism, international shipping, and increasing environmental change.

Once established on islands, invasive species are particularly difficult and expensive to control because island ecosystems are geographically limited, highly interconnected, and vulnerable to ecological disruption. Prevention and early intervention are therefore especially important for protecting island biodiversity.

**Polar and Remote Ecosystems: Emerging Frontiers of Biological Invasion**

Historically, remote polar environments were considered relatively protected from biological invasions due to their extreme climatic conditions and geographical isolation. However, increasing temperatures and expanding human activities have reduced these barriers. Non-native organisms are now being detected in Antarctica and surrounding marine ecosystems (Lowe et al., 2000; IPBES, 2019).

Warming conditions are making polar environments increasingly suitable for the survival and establishment of introduced organisms, including insects, microorganisms, and marine species. Although current invasions remain limited compared with temperate and tropical regions, even

small biological changes can have significant consequences in ecosystems that evolved under extreme and stable conditions.

The presence of invasive species in polar regions highlights the global scale of biological invasions. From tropical forests and freshwater ecosystems to isolated islands and polar environments, no ecosystem remains completely separated from species movement driven by globalization, climate change, trade, transportation, and human activity (IPBES, 2019).

# 2.3 NATIONAL PERSPECTIVE ON BIOLOGICAL INVASIONS IN INDIA

## Biological Invasions in India

Biological invasions have emerged as one of the most serious ecological challenges in India. These invasions refer to the introduction and spread of non-native species that negatively affect native biodiversity, ecosystems, and human systems. In India, this issue is now considered second only to habitat destruction in terms of its impact on biodiversity loss (Sharma et al., 2005).

Over time, India has witnessed a steady rise in alien species due to changes in land use, global trade, and ecological disturbances. Scientific assessments indicate that a large portion of the country's flora consists of alien plant species, with a significant fraction showing invasive behaviour under favourable environmental conditions (Sandilyan, 2018). Reports also highlight that hundreds to over a thousand alien plant species have been recorded in India, with a considerable number already naturalized or invasive across different ecosystems (Sandilyan, 2018).

These species are no longer restricted to disturbed sites alone. They now occupy forests, grasslands, wetlands, agricultural fields, and urban landscapes, gradually altering the ecological balance of these systems.

## National Spread and Ecological Nature of Invasive Species

Invasive species in India include plants, animals, insects, and microorganisms. They share a common ecological pattern: rapid reproduction, strong adaptability, and the ability to survive in disturbed environments.

Among plants, species such as *Lantana camara*, *Parthenium hysterophorus*, *Mikania micrantha*, and *Prosopis juliflora* are widely distributed across the country. These species often form dense stands that reduce the availability of light, nutrients, and space for native vegetation (Sankaran et al., 2014).

Insects such as fall armyworm and papaya mealybug have further intensified agricultural vulnerability, causing significant crop losses in different regions of India (Chellappan et al., 2023). These examples show that biological invasion in India is a multi-system issue affecting both natural and human-managed ecosystems.

## Ecological and Socio-Economic Consequences in India

The ecological impacts of invasive species in India are deep and long-lasting. Once established, invasive plants often modify soil properties, water availability, and nutrient cycles, leading to long-term ecosystem changes (Bargavi et al., 2025). Many species also release biochemical compounds that suppress the germination and growth of native plants, reducing biodiversity over time.

These ecological changes eventually lead to simplified ecosystems dominated by a few aggressive species. Such ecosystems lose their structural diversity and become less resilient to environmental changes (Linders et al., 2019).

From an economic perspective, invasive species have caused severe financial losses in agriculture, forestry, fisheries, and infrastructure sectors. Estimates suggest that India has lost billions of dollars over recent decades due to biological invasions (Bang et al., 2022). Rural communities that

depend on forests and natural ecosystems are particularly affected, as invasive species reduce the availability of fodder, fuelwood, and medicinal plants (Kannan et al., 2014).

## Western Ghats and Kerala: A High-Risk Ecological Region

The Western Ghats represent one of the most important biodiversity hotspots in the world, but also one of the most vulnerable to biological invasions. The region's climate, fragmented forests, and human disturbances provide suitable conditions for invasive species to establish and spread (Vinayan et al., 2023).

In Kerala, invasive plant species have become deeply integrated into forest and plantation ecosystems. Species such as *Lantana camara* and *Mikania micrantha* have significantly altered forest structure and reduced native plant diversity (Sankaran et al., 2014). Wetland systems are also affected by aquatic invasions that disrupt water flow and ecological balance (Biju Kumar et al., 2023).

Human activities such as road construction, tourism, and forest fragmentation have further increased the spread of invasive species. Disturbed forest edges often act as entry points, allowing invasive plants to move deeper into natural ecosystems (Karthika & Sajeev, 2023).

Within this broader regional context, one species has become particularly significant due to its aggressive spread and ecological impact—*Senna spectabilis*.

## Senna spectabilis: A Focus Species in Indian Forest Ecosystems

*Senna spectabilis* is a fast-growing tree species originally introduced into India for ornamental and plantation purposes. Over time, it has escaped cultivation and become highly invasive in parts of southern India, especially in the Western Ghats region (Vinayan et al., 2023).

This species shows strong invasive potential due to its rapid growth, high seed production, and ability to colonize disturbed forest areas. Its seeds are widely dispersed by wildlife, especially large

mammals such as elephants, which consume its pods and spread seeds through dung (Anoop et al., 2021). This ecological interaction has unintentionally supported its spread across forest landscapes.

Once established, *Senna spectabilis* forms dense stands that suppress native vegetation and reduce natural regeneration. In several forest areas, it has been observed replacing native undergrowth and altering habitat structure (Anoop et al., 2025). It also reduces the availability of forage for herbivores, indirectly affecting wildlife feeding patterns.

Due to these characteristics, *Senna spectabilis* is now recognized as a major invasive threat in forest ecosystems of southern India.

## Wayanad: Local Case of a National Ecological Issue

Wayanad, located in the northern part of Kerala within the Western Ghats, provides a clear example of how national-level invasion processes manifest at the local scale. The region is ecologically rich, supporting diverse flora and fauna, including large herbivores such as elephants and deer (Vinayan et al., 2023)

However, *Senna spectabilis* has spread extensively in parts of Wayanad Wildlife Sanctuary. Studies indicate that it now occupies large forest patches, replacing native vegetation and altering habitat structure (Vinayan et al., 2023). Its spread is strongly linked to wildlife movement, as animals act as natural dispersal agents for its seeds (Anoop et al., 2021).

This creates a complex ecological cycle where natural animal movement unintentionally accelerates the spread of an invasive plant species. As a result, forest regeneration becomes difficult, and native plant diversity declines.

Wayanad therefore represents a critical study landscape where national invasion patterns, regional ecological vulnerability, and species-specific dynamics intersect.

# 2.4 HISTORY OF INVASIVE SPECIES AND *SENNA SPECTABILIS*

## History of Invasive Species

The history of invasive species is closely connected with the movement of people, trade, agriculture, and colonial expansion across the world. For centuries, humans have intentionally and unintentionally transported plants and animals from one region to another for farming, forestry, ornamental gardening, medicine, and commercial purposes. Many of these introduced species remained harmless for a long period of time, while some slowly adapted to new environments and later became invasive (Sankaran et al., 2014).

Invasive species are organisms that are introduced outside their natural geographic range and later spread rapidly in ways that threaten native biodiversity, ecosystems, agriculture, or human well-being (Sandilyan, 2018). The process of invasion usually begins with introduction, followed by establishment, naturalization, and finally expansion into surrounding landscapes (Jayachandran, 2023). In many cases, invasive species initially appear useful or attractive, which is why they are often planted intentionally before their ecological impacts become visible.

In India, the history of biological invasions became closely linked with colonial trade and plantation systems during the British period. Foreign plant species were introduced for timber, shade, fuelwood, ornamentation, and soil stabilization (Sankaran et al., 2014). Several invasive plants currently found in India originally came from tropical regions of Central and South America because these regions share climatic similarities with India, especially with humid states like Kerala (Latha & Venkatesan, 2023). Over time, many of these species escaped from gardens, plantations, and agricultural lands into nearby forests and river systems.

Kerala has a particularly long history of interaction with foreign regions through maritime trade. Ancient trade connections with Europe, the Middle East, and Southeast Asia created pathways for the movement of many alien species into the state (Biju Kumar et al., 2023). Initially, many of these introductions were considered beneficial. Plants with attractive flowers were used in gardens,

while fast-growing trees were planted along roadsides and plantations for shade and timber purposes (Sankaran et al., 2014). However, several of these species later adapted aggressively to Kerala's tropical climate and began spreading uncontrollably.

Among the earliest and most widespread invasive plants in Kerala was *Lantana camara*. The British introduced this species to India in 1807 through the Royal Botanical Garden in Calcutta as an ornamental plant because of its colorful flowers (Chatterjee, 2015). Over time, the species escaped from gardens and spread into forests across the Indian subcontinent. In Wayanad and other parts of the Western Ghats, *Lantana camara* gradually formed dense undergrowth that suppressed the regeneration of native vegetation (Chandran et al., 2023). Tribal communities and forest dwellers later observed how the plant altered forest movement, wildlife habitats, and fire patterns (Sundaram et al., 2012).

Another major invasive plant in Kerala is *Chromolaena odorata*, commonly called Siam Weed or "Communist Pacha." This species was accidentally introduced into Kerala during the 1940s from Assam and Sri Lanka (Prameela et al., 2023). Its rapid spread during the period of political change in Kerala led local communities to nickname it after the Communist movement that was rising during the same time (Prameela et al., 2023). The plant quickly occupied abandoned lands, roadsides, and disturbed forest areas because of its ability to reproduce rapidly and tolerate harsh environmental conditions.

Other invasive species also entered India through unusual historical events. *Mikania micrantha*, a fast-growing climbing vine, was introduced during World War II to camouflage military equipment and camps (Prameela et al., 2023). Similarly, *Parthenium hysterophorus*, commonly known as Congress Grass, entered India accidentally through wheat imports from the United States during the 1950s (Sandilyan, 2018). Aquatic species such as Water Hyacinth (*Eichhornia crassipes*) were introduced because of their attractive flowers and decorative value before becoming severe threats to wetlands and freshwater ecosystems (Biju Kumar et al., 2023).

As time passed, scientists and forest managers began recognizing that invasive species were not isolated environmental problems but long-term ecological threats capable of transforming entire landscapes. Dense invasions reduced native plant diversity, changed soil properties, disrupted food chains, and affected wildlife movement and habitat quality (Sankaran et al., 2014). In Kerala, the

humid climate, heavy rainfall, and recurring disturbances such as floods and land-use changes further accelerated the spread of invasive species across forests and agricultural lands (Prameela et al., 2023).

Among all the invasive plants currently affecting Kerala, one species has emerged as a particularly serious threat to the forests of Wayanad: *Senna spectabilis*.

## History of *Senna spectabilis*

The history of *Senna spectabilis* began far away from India, in the tropical regions of Central and South America where the species naturally evolved (Anoop et al., 2021). The tree is native to countries such as Colombia, Costa Rica, and parts of the West Indies, where it originally grew as a medium to large flowering tree within tropical ecosystems (Datiles & Acevedo-Rodriguez, 2023). Scientists first documented the species in Colombia during the early nineteenth century, and by 1832 it had already entered formal botanical records (Datiles & Acevedo-Rodriguez, 2023).

During the nineteenth century, European botanical networks played a major role in spreading tropical plant species across colonies and trade centers. Specimens of *Senna spectabilis* were collected in Trinidad and Tobago in 1862, and by 1869 the species was being cultivated in the Royal Botanic Gardens of Trinidad (Anoop et al., 2025). Because of its bright yellow flowers, broad canopy, and fast growth, the tree became popular as an ornamental and shade species. Gradually, it spread across tropical regions including South Mexico, Costa Rica, and Puerto Rico (Francis & Liogier, 1991).

The global movement of *Senna spectabilis* continued during the twentieth century. In several African countries, the tree was introduced for practical purposes such as shade, firewood, and boundary marking (Wakibara & Mnaya, 2002). In Tanzania, it was planted in the Mahale Mountains National Park in 1967 to provide shade for people and agricultural fields (Wakibara & Mnaya, 2002). Farmers later began using it as a living fence to reduce crop damage from wild animals. In Uganda, the species was introduced near forest reserves for fuelwood production and land demarcation purposes (Mungatana & Ahimbisibwe, 2010).

At the time of these introductions, the tree was largely viewed as useful and environmentally harmless. Its rapid growth, dense foliage, and ability to survive in tropical climates made it attractive for forestry and plantation purposes. However, in many countries, the tree slowly adapted to local conditions and began spreading outside cultivated areas. Like several other invasive plants, *Senna spectabilis* passed through an early "lag phase," during which its spread remained unnoticed for many years before suddenly accelerating (Vinayan et al., 2023).

In India, *Senna spectabilis* was first introduced into botanical gardens as an ornamental species because of its decorative appearance and shade-producing ability (Singh, 2001). Later, forestry agencies and plantation managers promoted the species in different regions of the Western Ghats. The tree was also believed to be useful in coffee plantations because its wide canopy provided shade for crops growing underneath (Anoop et al., 2025).

Initially, the species did not appear dangerous. For many years, it remained limited to planted locations and attracted little scientific concern. However, researchers later discovered that the tree possessed several characteristics common to invasive plants: rapid growth, abundant seed production, adaptability to disturbed habitats, and efficient dispersal mechanisms through animals and water (Anoop et al., 2021). These traits eventually allowed the species to expand aggressively into forest ecosystems.

The most serious chapter in the history of *Senna spectabilis* would unfold in the forests of Wayanad in Kerala

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# 2.5 ECOLOGICAL CHANGES, SPREAD MECHANISMS, AND INVASIVE DYNAMICS OF *SENNA SPECTABILIS*

## Ecological Impacts of *Senna spectabilis*

Biological invasion is now recognized as one of the greatest threats to global biodiversity. Invasive alien species are considered second only to habitat destruction as drivers of biodiversity loss because they alter ecosystem structure, functioning, and ecological processes (IPBES, 2019;

Prevena, 2021). Rather than simply coexisting with native species, invasive plants actively transform the ecosystems they colonize. For this reason, they are often described as ecological "change agents" that modify the composition, functioning, and stability of natural ecosystems (IUCN, 1999; Bargavi et al., 2025).

In healthy ecosystems, native plants, animals, fungi, microorganisms, and climatic conditions have evolved together over long periods, creating complex ecological interactions that maintain ecosystem stability. The introduction of *Senna spectabilis* disrupts these interactions by competing aggressively for sunlight, water, nutrients, and space. As the species spreads, native vegetation gradually declines, reducing overall plant diversity and altering the natural structure of the forest (Prevena, 2021).

The ecological effects extend far beyond the visible replacement of native plants. Woody invasive species also modify fundamental ecosystem processes, including litter decomposition, soil microbial activity, nutrient cycling, and carbon storage (Linders et al., 2019). As native ground vegetation declines, soil stability decreases, organic matter is reduced, and soil fertility gradually deteriorates. These changes weaken the resilience of the ecosystem and reduce its ability to recover naturally following disturbance (Linders et al., 2019).

Importantly, invasive plants are not merely opportunistic colonizers of already degraded habitats. Research shows that they can actively drive ecosystem degradation by initiating and reinforcing ecological change (Linders et al., 2019). Consequently, even relatively intact forests may experience significant ecological alteration following invasion. In forests invaded by *Senna spectabilis*, studies have documented reduced native plant richness, diminished understory vegetation, and simplified vegetation structure resulting from the formation of dense monospecific stands (Bargavi et al., 2025).

The consequences of these vegetation changes extend throughout the ecosystem. Native plants provide food, shelter, and breeding habitats for numerous insects, pollinators, herbivores, and other organisms. As native vegetation declines, these associated species also decrease, disrupting food webs and weakening ecological interactions. Such cascading effects progressively reduce ecosystem complexity, biodiversity, and resilience, ultimately affecting the functioning of the entire forest ecosystem (Bellard et al., 2016).

# 2.6 SPREAD MECHANISMS AND REPRODUCTIVE BIOLOGY

The rapid spread of *Senna spectabilis* across tropical landscapes is primarily driven by its highly efficient reproductive strategy and multiple modes of seed dispersal, allowing it to colonize both natural and disturbed habitats with remarkable success (Prevena, 2021; Bargavi et al., 2025). Unlike many native tree species that depend on specific environmental conditions for successful regeneration, *Senna spectabilis* possesses several biological traits that enhance its establishment, persistence, and expansion.

**High Seed Production**

One of the major reasons for the invasive success of *Senna spectabilis* is its prolific seed production. Mature trees produce abundant flowers and large quantities of seeds each year, enabling rapid population expansion. Studies have reported a pollen viability of nearly 98%, indicating that almost all pollen grains are capable of successful fertilization (Anoop et al., 2025). This exceptionally high reproductive efficiency results in continuous seed production and facilitates rapid colonization of newly invaded habitats.

**Multiple Seed Dispersal Mechanisms**

The species employs several complementary dispersal mechanisms that enable both local and long-distance spread. One important mechanism is ballistic dispersal, in which mature seed pods split open explosively, projecting seeds away from the parent tree (Bargavi et al., 2025). Following this initial dispersal, wind and rainwater transport the seeds further into surrounding areas, promoting local expansion.

Long-distance dispersal occurs primarily through zoochory, where animals transport seeds across the landscape (Anoop et al., 2020). Birds and mammals consume the fruits and subsequently disperse viable seeds through their droppings. In the Western Ghats, elephants play a particularly significant role because the fruiting season of *Senna spectabilis* coincides with their movement

patterns, enabling seeds to be transported over considerable distances into previously uninvaded forests (Anoop et al., 2020; Prevena, 2021).

The species also spreads through epizoochory, whereby seeds adhere to the fur or feathers of animals and are passively transported across fragmented landscapes (Bargavi et al., 2025). The combination of ballistic dispersal, zoochory, epizoochory, and secondary movement by wind and water enables *Senna spectabilis* to spread efficiently across a wide range of habitats.

**Persistent Soil Seed Bank**

Another important factor contributing to the persistence of the invasion is the longevity of its seeds. Seeds remain viable in the soil for up to three years, forming a persistent soil seed bank that allows new seedlings to emerge long after mature trees have been removed (Kerala Biodiversity Board, 2012; Prevena, 2021). Consequently, a single clearing operation is often insufficient, as dormant seeds continue to germinate over several growing seasons, making long-term management considerably more challenging.

**Coppicing and Regeneration Ability**

In addition to prolific seed production, *Senna spectabilis* possesses a strong capacity for vegetative regeneration. When trees are cut, damaged, or partially removed, vigorous new shoots rapidly emerge from stumps and root systems (Bargavi et al., 2025). Even small root fragments left in the soil can regenerate into new plants, allowing populations to recover quickly after mechanical removal. This strong coppicing ability significantly increases the resilience of the species and contributes to its long-term persistence in invaded landscapes.

## 2.7 PHYSIOLOGICAL AND COMPETITIVE ADVANTAGES

Beyond its reproductive capacity, *Senna spectabilis* possesses several physiological characteristics that enhance its competitive ability and enable it to establish successfully across a wide range of

environmental conditions (Sandilyan, 2023). These biological adaptations improve resource acquisition, increase growth rates, and allow the species to outcompete native vegetation even in relatively stressful habitats.

**Association with Vesicular-Arbuscular Mycorrhiza (VAM)**

One of the major physiological advantages of *Senna spectabilis* is its symbiotic association with vesicular-arbuscular mycorrhizal (VAM) fungi. These fungi form a mutually beneficial relationship with the plant's roots, enhancing the absorption of water and essential nutrients from the soil, while receiving carbohydrates produced through photosynthesis in return.

This association substantially improves the growth performance of the species. Studies have shown that VAM inoculation can increase root growth by approximately 241% and shoot growth by about 213%, resulting in larger and more vigorous plants (Kung'u, 1997). An extensive root system enables greater uptake of water and nutrients, while rapid shoot development allows the tree to capture more sunlight and overshadow neighbouring vegetation.

**Efficient Resource Utilization**

The enhanced root system allows *Senna spectabilis* to exploit soil resources efficiently, even under nutrient-poor conditions where many native species struggle to establish. Although the species does not form nitrogen-fixing root nodules, it utilizes available nitrogen very efficiently, giving it a competitive advantage in resource-limited environments (Kerala Biodiversity Board, 2012; Prevena, 2021). This efficient resource use supports rapid growth and successful establishment in newly invaded habitats.

**Broad Ecological Tolerance**

Another important factor contributing to the success of *Senna spectabilis* is its broad ecological tolerance. The species can survive across a variety of habitats, including sandy soils, degraded lands, black cotton soils, roadsides, scrublands, and forest edges (Prevena, 2021). It is also capable of withstanding prolonged dry periods with relatively little damage, enabling it to persist under drought conditions where many native species experience reduced growth.

Its ability to tolerate diverse environmental conditions allows the species to establish in both natural forests and human-modified landscapes. This ecological flexibility increases its invasive potential by enabling populations to persist under varying climatic and edaphic conditions and rapidly colonize habitats where native vegetation has been weakened by disturbance or environmental stress (Bargavi et al., 2025).

**Allelopathy and Soil Modification**

One of the most important mechanisms through which *Senna spectabilis* suppresses native vegetation is allelopathy, the ability of a plant to release biochemical compounds that inhibit the growth and establishment of neighbouring species (Prajitha & Sudha Bai, 2025). Unlike competition for light or nutrients, allelopathy directly interferes with the physiological processes of surrounding plants, giving *Senna spectabilis* an additional competitive advantage.

**Allelopathic Effects on Native Vegetation**

Allelochemicals are present in the leaves, bark, roots, and other plant tissues of *Senna spectabilis*. As leaves decompose or roots release these compounds into the surrounding soil, the chemicals accumulate in the rhizosphere and influence the growth of nearby vegetation (Bargavi et al., 2025).

These compounds inhibit several essential physiological processes in native plants. They can reduce seed germination, suppress root elongation, interfere with cell division, and limit nutrient uptake, thereby restricting the successful establishment of seedlings. Some studies also suggest that these allelochemicals induce oxidative stress by increasing the production of reactive oxygen species (ROS), which damage plant cells and may even affect DNA integrity (Bargavi et al., 2025).

As a result, native herbs, shrubs, and tree seedlings gradually decline, while *Senna spectabilis* seedlings continue to establish successfully. Over time, invaded areas become increasingly dominated by the invasive species, often developing into dense monospecific stands with greatly reduced plant diversity (Wakibara & Mnaya, 2002).

**Soil Biogeochemical Changes**

The ecological impacts of *Senna spectabilis* extend below ground through alterations in soil biogeochemical processes. In healthy forest ecosystems, soil microorganisms, fungi, insects, and decomposers work together to break down organic matter and recycle nutrients, maintaining soil fertility and ecosystem productivity (Gioria & Pyšek, 2014).

The invasion of *Senna spectabilis* alters this balance by introducing large quantities of leaf litter, bark, flowers, and other organic material with different decomposition characteristics from those of native vegetation (Prevena, 2021). As decomposition patterns change, nutrient release and cycling are also modified, gradually altering soil chemistry and microbial community composition. Microorganisms adapted to native vegetation decline, while those capable of tolerating the altered conditions become more dominant (Gioria & Pyšek, 2014).

Although the species does not fix atmospheric nitrogen, its efficient utilization of available nutrients enables it to maintain rapid growth even in nutrient-poor soils (Kerala Biodiversity Board, 2012; Prevena, 2021). Continuous nutrient uptake by dense populations may further disturb the natural nutrient balance within invaded ecosystems.

The invasion also influences soil organic carbon (SOC), an essential component of soil fertility, moisture retention, and structural stability. As native ground vegetation disappears, protective soil cover is reduced, exposing the soil to erosion, decreasing moisture retention, and lowering overall soil quality (Linders et al., 2019).

**Positive Feedback for Invasion**

The combined effects of altered nutrient cycling, modified microbial communities, changes in soil organic carbon, and allelopathic activity gradually create soil conditions that favour *Senna spectabilis* over native vegetation. Seedlings of the invasive species establish more readily under these altered conditions, while native species experience increasing difficulty in germination and growth. This creates a positive ecological feedback, whereby the invasion modifies the soil in ways that further promote its own persistence and expansion (Gioria & Pyšek, 2014; Bargavi et al., 2025).

These below-ground changes often persist even after the removal of mature trees, making ecological recovery slow and challenging. Consequently, the impacts of *Senna spectabilis* extend beyond the visible vegetation, fundamentally altering the ecological processes that sustain healthy forest ecosystems (Linders et al., 2019).

## 2.8 CHANGES IN FOREST STRUCTURE AND REGENERATION

The invasion of *Senna spectabilis* not only alters species composition but also changes the physical structure of forest ecosystems. As the species spreads, it forms dense stands that modify light availability, suppress native vegetation, and interfere with the natural regeneration of forests (Sajeev et al., 2012; Bargavi et al., 2025). These structural changes gradually simplify the forest ecosystem and reduce its capacity to recover naturally.

### Understory Suppression

One of the most visible impacts of *Senna spectabilis* is the formation of a dense canopy that greatly reduces the amount of sunlight reaching the forest floor (Sajeev et al., 2012; Bargavi et al., 2025). Most native herbs, grasses, shrubs, and young tree seedlings depend on adequate sunlight for photosynthesis and growth. Under dense stands of *Senna spectabilis*, the understory remains in continuous shade, creating conditions that are unsuitable for many native species.

As light availability declines, understory vegetation gradually disappears, resulting in reduced plant diversity and a simplified vegetation structure. The forest floor becomes increasingly dominated by *Senna spectabilis* seedlings, while native ground flora continue to decline (Prevena, 2021).

### Impaired Forest Regeneration

The suppression of native seedlings has significant consequences for forest regeneration. Since young indigenous trees fail to establish and develop beneath dense *Senna spectabilis* canopies, the

natural replacement of older native trees is interrupted (Prevena, 2021). Over time, this weakens the regenerative capacity of the forest and promotes the persistence of dense, monospecific stands of the invasive species.

Evidence from Tanzania demonstrates the importance of this suppression. Following the removal of *Senna spectabilis* from invaded forests, native vegetation regenerated naturally without active planting, indicating that the invasive tree itself had been preventing natural forest recovery (Wakibara & Mnaya, 2002).

**Alteration of Forest Microclimate**

The loss of understory vegetation also alters the forest microclimate. Reduced ground cover changes humidity, soil moisture, leaf litter characteristics, and temperature conditions near the forest floor. These environmental changes further reduce the suitability of the habitat for native plant regeneration while creating conditions that favour the continued establishment and persistence of *Senna spectabilis* (Prevena, 2021).

The combined effects of canopy dominance, understory suppression, disrupted regeneration, and altered microclimatic conditions gradually transform structurally diverse forests into simplified ecosystems dominated by a single invasive species, reducing both ecological complexity and long-term resilience.

## 2.9 FACTORS THAT AID THE SPREAD OF *SENNA SPECTABILIS*

The spread of *Senna spectabilis* is not determined solely by its biological characteristics. Its invasion success is strongly influenced by environmental conditions, landscape features, and human-induced disturbances that create favourable opportunities for establishment and expansion. Understanding these factors is essential for predicting invasion patterns and identifying areas that are most vulnerable to future spread (Prevena, 2021).

**Forest Type**

The susceptibility of forests to invasion varies according to their structure and canopy characteristics. Studies conducted in Wayanad show that deciduous forests, degraded forests, scrublands, secondary woodlands, plantations, and other disturbed habitats are particularly vulnerable to invasion by *Senna spectabilis* (Prevena, 2021). These habitats generally have open canopies that allow greater sunlight to reach the forest floor, creating favourable conditions for seed germination and rapid seedling growth.

Research indicates that the probability of invasion exceeds 75% in many deciduous and scrub forest areas of Wayanad, demonstrating their high ecological vulnerability (Prevena, 2021). Once established, *Senna spectabilis* rapidly forms dense stands that suppress native vegetation and hinder natural forest regeneration.

In contrast, evergreen forests exhibit comparatively lower invasion levels because their dense canopies restrict sunlight penetration to the understory. Since *Senna spectabilis* is a light-demanding species, these shaded conditions act as a natural barrier to its establishment (Prevena, 2021). However, this resistance declines when evergreen forests are disturbed by logging, road construction, tourism, fire, or fragmentation, which create canopy openings that facilitate invasion (Richardson & Pyšek, 2000).

**Human Disturbances**

Anthropogenic disturbances play a significant role in accelerating the spread of *Senna spectabilis*. Activities such as road construction, plantation expansion, agricultural development, deforestation, tourism, and infrastructure development disturb native vegetation and reduce the natural resistance of ecosystems to invasion (Kosaka & Kushwaha, 2010; Bargavi et al., 2025).

Among these disturbances, roads function as important invasion corridors. Ecological modelling has identified distance from roads as one of the strongest predictors of the spatial distribution of *Senna spectabilis* in Wayanad (Prevena, 2021). Roadsides provide disturbed soil, increased light availability, and continuous movement of people, vehicles, livestock, and construction materials, all of which facilitate seed dispersal and the establishment of new populations.

Similarly, forest edges and secondary forests experience greater invasion pressure because they receive more sunlight and undergo higher levels of disturbance than intact forest interiors. These disturbed habitats provide favourable conditions for rapid colonization and subsequent expansion into adjacent forests (Bargavi et al., 2025).

**Hydrological Factors**

Water bodies also contribute significantly to the spread of *Senna spectabilis*. The species commonly establishes near rivers, streams, wetlands, and other moist habitats where environmental conditions favour seed germination and seedling survival (Prevena, 2021).

During periods of rainfall, flowing water acts as an effective dispersal agent by transporting seeds downstream into previously uninvaded areas. Consequently, hydrological networks enhance landscape connectivity and facilitate the gradual expansion of the invasion across forest ecosystems.

**Topography**

Topographic characteristics further influence the distribution of *Senna spectabilis*. In Wayanad, the species is most commonly found at elevations of approximately 750 metres above sea level, with its occurrence declining at higher altitudes (Prevena, 2021). Elevation influences local climatic conditions, while slope affects water movement, soil stability, and seed deposition, collectively shaping habitat suitability for invasion.

**Landscape Connectivity**

The interaction between favourable habitat conditions and landscape connectivity determines the overall pattern of invasion. Fragmented forests, plantation boundaries, abandoned agricultural lands, and disturbed forest margins create continuous pathways through which *Senna spectabilis* can expand across the landscape (Prevena, 2021; Bargavi et al., 2025).

The spread of *Senna spectabilis* therefore reflects the combined influence of species-specific biological traits, suitable environmental conditions, landscape configuration, and human

disturbance. These interacting factors not only determine where invasion occurs but also influence the rate at which the species expands across tropical forest ecosystems.

# 2.10 CLIMATE CHANGE AND FUTURE INVASION RISKS

Climate change is increasingly recognised as a major driver of biological invasions, influencing the distribution, establishment, and spread of invasive species across ecosystems. Rising temperatures, altered rainfall patterns, prolonged droughts, increasing atmospheric carbon dioxide, and more frequent disturbances are changing environmental conditions in ways that often favour invasive plants over native vegetation (Vilà & Hulme, 2017). Owing to its high ecological adaptability, *Senna spectabilis* is expected to remain a significant invasive threat under future climatic conditions.

**Climatic Drivers of Invasion**

Among the various climatic factors, temperature plays a particularly important role in determining the distribution of *Senna spectabilis*. Ecological studies indicate that annual mean temperature (BIO1) and isothermality (BIO3) are the most influential climatic variables governing habitat suitability for the species (Prevena, 2021). These factors largely determine where the species can establish, survive, and expand.

Increasing atmospheric carbon dioxide may further enhance the competitive ability of *Senna spectabilis*. Elevated $CO_2$ concentrations can stimulate photosynthesis, increase biomass production, and promote faster growth in many invasive plant species, allowing them to outcompete native vegetation more effectively (Liu & van Kleunen, 2017).

Climate change also intensifies environmental disturbances such as droughts, heat stress, storms, wildfires, and irregular rainfall patterns. These disturbances weaken native ecosystems, reduce their resilience, and create favourable conditions for invasive species to establish and spread (Vilà & Hulme, 2017).

**Predictive Ecological Modelling**

Predictive ecological modelling has become an important tool for assessing the present and future distribution of *Senna spectabilis*. Studies conducted in Wayanad using Maximum Entropy (MaxEnt) modelling have integrated environmental variables such as temperature, rainfall, elevation, slope, and land cover to identify areas susceptible to invasion (Prevena, 2021).

The modelling results indicate that nearly 66% of Wayanad district currently provides suitable environmental conditions for the establishment and spread of *Senna spectabilis* (Prevena, 2021). Climate projections using the HadGEM2-ES model further suggest that although some lower-elevation areas may become less suitable under extreme warming scenarios, approximately 86% of the Wayanad Wildlife Sanctuary is likely to remain suitable for invasion until 2070 (Prevena, 2021; Anoop et al., 2025).

These findings demonstrate that climate change is unlikely to reduce the invasion risk. Instead, it is expected to alter the spatial distribution of suitable habitats, shifting invasion pressure across the landscape.

**Future Invasion Dynamics**

Future climatic changes may enable *Senna spectabilis* to expand into higher-elevation regions that were previously protected by cooler environmental conditions (Prevena, 2021). As climatic barriers weaken, ecosystems that currently experience relatively low invasion pressure may become increasingly vulnerable.

Climate change and biological invasion often act synergistically. While changing climatic conditions place native ecosystems under increasing stress, invasive species exploit these weakened conditions to establish and spread more rapidly (Vilà & Hulme, 2017). This interaction accelerates biodiversity loss, alters ecosystem functioning, and reduces ecological resilience.

The integration of climate projections with ecological modelling therefore provides valuable information for identifying future invasion hotspots and prioritising monitoring, early detection, and management interventions. Such predictive approaches are essential for reducing the long-

term ecological impacts of *Senna spectabilis* in Wayanad and other tropical forest ecosystems (Prevena, 2021).

# 2.11 DISRUPTION OF ECOLOGICAL INTERACTIONS

The ecological impacts of *Senna spectabilis* extend beyond changes in vegetation and forest structure. As the invasion progresses, it disrupts long-established ecological interactions among plants, pollinators, insects, birds, and other organisms. These disruptions affect ecosystem functioning, reduce biodiversity, and gradually simplify complex ecological networks (Bellard et al., 2016).

**Disruption of Pollination**

Pollination is a fundamental ecological process that enables the reproduction of flowering plants and supports the maintenance of biodiversity. Many native plant species rely on specific pollinators for successful seed production. However, *Senna spectabilis* produces abundant, conspicuous yellow flowers that attract large numbers of pollinating insects (Prevena, 2021).

Because the species flowers profusely and often forms dense stands, pollinators tend to visit *Senna spectabilis* more frequently than neighbouring native plants. Consequently, native species receive fewer pollinator visits, reducing their reproductive success and seed production (Bargavi et al., 2025). Over time, declining regeneration of native plants further strengthens the dominance of the invasive species.

The invasion also alters pollinator foraging behaviour. As pollinators increasingly concentrate on the abundant floral resources provided by *Senna spectabilis*, smaller or less conspicuous native flowers receive less attention. This disrupts specialised plant–pollinator relationships that have evolved over long periods, weakening ecological interactions within the forest (Bargavi et al., 2025).

**Cascading Effects on Food Webs**

The decline of native vegetation has consequences throughout the food web. Many insects depend on indigenous plants for food, shelter, and breeding habitats. As these plants disappear, herbivorous insect populations decline, affecting predators that rely on them, including birds, reptiles, amphibians, and small mammals.

These sequential ecological changes are described as cascading trophic effects, where disturbances at one trophic level progressively affect organisms at higher levels of the food web (Linders et al., 2019). Such disruptions reduce ecosystem stability and weaken the ecological relationships that maintain forest resilience.

**Biotic Homogenisation**

As *Senna spectabilis* becomes increasingly dominant, ecosystems gradually lose their unique native species composition and begin to resemble one another. This process, known as biotic homogenisation, occurs when widespread invasive species replace locally adapted native flora, reducing regional biodiversity and ecological distinctiveness (Vander Zanden, 2005).

A comparable pattern has been observed in Kerala's sacred groves, where invasive species such as the Yellow Crazy Ant disrupt native ecological interactions and reduce ecosystem stability (Sinu & Rajesh, 2023). Although involving different organisms, these examples illustrate how invasive species simplify ecological networks by displacing native species and altering long-established biological interactions.

The disruption of pollination, food webs, and species interactions ultimately reduces ecosystem resilience, making invaded forests less capable of resisting further environmental disturbances and biological invasions.

# 2.12 RESTORATION CHALLENGES

The ecological impacts of *Senna spectabilis* do not end with its removal. Once the species becomes well established, many of the changes it creates within the ecosystem persist, making restoration

a long-term and challenging process. Alterations in vegetation structure, soil properties, ecological interactions, and regeneration processes often continue to influence the ecosystem long after mature trees have been cleared.

**Persistent Soil Seed Bank**

One of the greatest obstacles to restoration is the persistent soil seed bank of *Senna spectabilis*. The seeds remain viable in the soil for up to three years and continue to germinate even after mature trees have been removed (Kerala Biodiversity Board, 2012; Prevena, 2021). Consequently, a single removal operation is rarely sufficient, as new cohorts of seedlings continue to emerge over successive growing seasons.

This persistent regeneration necessitates long-term monitoring and repeated removal of seedlings to prevent reinvasion. Without sustained follow-up management, previously cleared areas can quickly become reinfested.

**Regeneration through Coppicing**

The species also exhibits a strong capacity for vegetative regeneration. Trees that are cut or damaged readily produce new shoots from stumps and surviving root fragments, allowing populations to recover rapidly following mechanical removal (Bargavi et al., 2025). Even small portions of roots remaining in the soil may regenerate into new individuals, reducing the effectiveness of conventional cutting methods.

**Delayed Ecosystem Recovery**

Successful restoration is further complicated by the ecological changes that persist after invasion. Native vegetation often fails to recover rapidly because ecological processes disrupted during the invasion require time to re-establish. Altered soil conditions, reduced native biodiversity, disturbed microbial communities, and weakened ecological interactions continue to influence forest recovery even after the invasive trees have been removed.

As a result, simply eliminating *Senna spectabilis* does not guarantee the restoration of the original ecosystem. Active interventions are frequently required to facilitate ecological recovery and prevent renewed invasion.

**Need for Long-Term Ecological Restoration**

Effective restoration therefore extends beyond the removal of invasive trees. It requires continuous monitoring of regenerating seedlings, restoration of native vegetation, recovery of soil health, and long-term management of the remaining seed bank. These measures are essential for rebuilding ecological processes and improving the resilience of invaded ecosystems.

Without sustained restoration efforts, forests invaded by *Senna spectabilis* may remain in a degraded ecological state for many years, limiting the recovery of native biodiversity and ecosystem functioning.

## 2.13 LIVELIHOODS, CULTURE, AND SOCIAL TENSIONS

Invasive alien species (IAS) affect not only forests and biodiversity, but also the daily lives, culture, emotions, safety, and survival of people. Species such as *Senna spectabilis* and *Lantana camara* create a difficult situation for many communities. People see them as harmful invasive plants that destroy ecosystems, but at the same time many families also depend on them for fuel, income, fodder, timber, and other basic needs. Because of this, invasive species create what researchers call a “resource paradox,” where the same plant is both harmful and useful at the same time (Shackleton et al., 2019; Kannan et al., 2014; Mungatana & Ahimbisibwe, 2012).

The social impacts are especially serious in poor rural areas where people depend directly on forests and natural ecosystems for survival. Biological invasions have already caused huge economic losses around the world. Between 1970 and 2017, invasive species caused global damages worth nearly USD 1.28 trillion. In India alone, the losses are estimated between USD 127.3 billion and 182.6 billion (Bang et al., 2022). Behind these large numbers are real human

struggles — farmers losing crops, women walking long distances for firewood, indigenous communities losing access to sacred forests, and families facing greater poverty and insecurity.

## Livelihood Changes and Economic Struggles

Invasive species deeply affect the livelihoods of rural people. Many farming and forest-dependent communities experience invasive plants as environmental shocks that slowly change their entire way of life (Shackleton et al., 2019).

One of the biggest problems is agricultural damage. Some invasive plants spread very fast and completely cover farmland. For example, *Mikania micrantha*, often called the "mile-a-minute weed," grows aggressively over crops and paddy fields. Farmers struggle to control it because it spreads rapidly and blocks sunlight from reaching crops. This reduces agricultural productivity and increases labor costs because farmers must spend more time removing the weed (Prameela et al., 2023).

In the Western Ghats and other forest regions, invasive species also destroy important non-timber forest products (NTFPs). Thick growths of *Senna spectabilis* and *Lantana camara* cover the forest floor and prevent the growth of useful native plants such as wild tubers, ginger, turmeric, gooseberries, and Indian sarsaparilla. These plants are important for food, medicine, and small household income. When these native plants disappear, poor families lose an important source of support during difficult times (Anoop et al., 2025).

At the same time, some communities have adapted to these invasions and started using invasive plants as alternative resources. In southern India, native bamboo became less available because of over-harvesting and natural flowering cycles. As a result, many local people started using *Lantana camara* for making furniture, baskets, and handicrafts (Kannan et al., 2014). Some families even developed small businesses around these products. Studies showed that households using lantana often had better occupational diversity and improved yearly income compared to households that did not use the plant (Kannan et al., 2014).

A similar situation can be seen in Rwanda and Uganda, where *Senna spectabilis* became an important source of firewood and timber. The wood burns quickly, produces less smoke, and gives

strong heat, making it useful for cooking and household energy needs (Bapfakurera et al., 2024). In Uganda's Budongo Forest Reserve, many people use the tree for timber and building poles (Mungatana & Ahimbisibwe, 2012). For poor households, these invasive trees have become part of their survival system.

However, this dependence also creates hardship. As native trees disappear, women and children often have to walk very long distances — sometimes more than 9 kilometers — to collect suitable firewood. This can take many hours every day, reducing time for education, rest, childcare, or paid work (Dzokom, 2024). In many places, women carry heavy loads of wood through dense invasive thickets under extreme heat and unsafe conditions.

Because invasive species have become connected to local livelihoods, removing them completely can create social conflict. Many poor households fear losing an important source of fuel, fodder, or income. This creates tension between conservation officials and local communities.

To solve this problem, some management programs are trying to turn invasive plants into useful economic products. In Kerala and Tamil Nadu, researchers and forest departments are promoting the idea of converting invasive biomass into paper pulp, organic manure, biogas, and compost (Anoop et al., 2025; Sabu, 2023). This approach allows communities to earn income while also helping remove invasive plants from forests. Such strategies try to balance ecological restoration with human welfare.

## Culture, Identity, and Emotional Connections

Invasive species affect not only the environment but also culture, traditions, memories, and spiritual relationships with the land.

Many indigenous and tribal communities share deep emotional and cultural connections with forests. For them, forests are not simply sources of resources. Forests are part of their identity, history, religion, and ancestral heritage. When invasive plants change these landscapes, people feel as if a part of their culture is disappearing.

For the Soliga tribes of the Western Ghats, who are traditionally known as the "people of the bamboo," the spread of *Lantana* and *Senna* has changed their relationship with the forest

(Sundaram et al., 2012). Thick invasive thickets block old walking paths and prevent access to sacred places, medicinal plants, and wild food sources. Some elders describe these invasions as an insult to ancestral spirits because the forests no longer look or function the way they once did.

Sacred groves in Kerala also face serious threats from invasive species. These groves are small patches of protected forest connected to local beliefs, rituals, and traditional worship. Invasive Yellow Crazy Ants are now spreading inside these groves and disturbing natural ecological interactions such as pollination and insect activity (Sinu & Rajesh, 2023). Slowly, both the ecological and spiritual value of these sacred places are being damaged.

In South Africa, dense invasive trees such as Black Wattle have covered sacred pools used for rituals and ceremonies, making them difficult for local communities to access (de Neergaard et al., 2005; Fox, 2005). This shows that biological invasions can damage not only biodiversity, but also cultural landscapes and spiritual traditions.

At the same time, some invasive species have slowly become culturally accepted by local communities. In parts of southern India, some people now use *Lantana camara* in daily cultural life and local traditions (Kannan, 2011). These examples show how humans slowly adapt emotionally and culturally to environmental change over time.

Another growing issue is the loss of environmental awareness among younger generations. Many young people recognize invasive plants mainly by their colorful flowers or attractive appearance. Because of this, they may see invasive species as “beautiful” rather than harmful (Remmele & Lindemann-Matthies, 2024). This situation is sometimes called the “extinction of experience,” where people lose direct knowledge of native biodiversity and become disconnected from nature (Soga & Gaston, 2016). As a result, public support for invasive species management may weaken.

## Social Tensions, Inequality, and Safety Issues

Invasive species also increase social inequality and create conflict between different groups of people.

Women and children are often the most affected. In many rural communities, they are responsible for collecting fuelwood, fodder, and water. When invasive species spread, these tasks become harder and more dangerous. Women spend more time clearing weeds, searching for native plants, and walking long distances through forests (Dzokom, 2024).

Dense invasive thickets can also create safety risks. Some reports show that these thick forest areas are sometimes used as hiding places for criminals. Women and children collecting fuelwood may face risks of harassment or physical attack in isolated invasive forests (de Neergaard et al., 2005).

Invasive species can also increase conflict between humans and wildlife. In Wayanad, the invasion of *Senna spectabilis* has reduced native food plants for elephants. As a result, elephants move closer to farms and villages searching for food (Vinayan et al., 2023; Anoop, 2019). This leads to crop destruction, property damage, and fear among local residents. Many families live under constant stress because of increasing human-elephant conflict.

Another major issue is conflict between stakeholders. Conservationists and forest officials often want complete eradication of invasive plants to restore biodiversity. However, poor households may oppose these actions because they depend on invasive plants for survival. Some families rely on *Senna* wood for fuel and construction. Others earn income from invasive plant products such as lantana handicrafts. Because of this, local communities may resist large-scale removal programs (Shackleton et al., 2019).

This situation creates what researchers call a “knowing-doing gap.” Scientists may understand the long-term ecological dangers of invasive species, but local communities often focus on immediate daily needs such as food, fuel, and income (Murphy, 2014). Therefore, successful management cannot happen through force alone.

### Community Participation and Inclusive Management

Long-term invasive species management requires cooperation between scientists, governments, forest departments, and local communities. People living close to forests must be included in decision-making processes because they understand local conditions and are directly affected by management actions.

Modern approaches now focus on inclusive and community-based management. Instead of treating local people as obstacles, many programs encourage them to become active participants in restoration work. Community education programs help residents identify invasive plants, monitor forest changes, and restore native habitats.

Providing economic alternatives is also very important. If communities lose fuelwood or income after invasive plant removal, they may oppose restoration efforts. Therefore, some projects support compensation systems, alternative livelihoods, and value-added industries using invasive biomass.

Education also plays a major role in building environmental awareness. Teaching children and young people about native biodiversity can help reconnect future generations with local ecosystems and reduce the "extinction of experience."

Ultimately, invasive alien species are not only environmental problems. They are also social, cultural, economic, and emotional challenges. They change how people live, work, travel, worship, and survive. The story of invasive species is therefore also a story about human adaptation, inequality, resilience, and the struggle to protect both nature and culture at the same time.

## 2.14 GOVERNANCE AND MANAGEMENT OF *Senna spectabilis* AND OTHER INVASIVE ALIEN SPECIES

The governance and management of Invasive Alien Species (IAS) is an important area of study because invasive species create many environmental, economic, and social problems around the world. Managing these species is not the responsibility of one country or one organization alone.

It requires international agreements, national laws, scientific research, and practical management activities in the field to work together.

# Governance

### International Agreements

At the global level, the management of invasive species is mainly guided by the Convention on Biological Diversity (CBD). Under Article 8(h) of the CBD, countries that have signed the agreement are expected to prevent the introduction of harmful alien species and control or remove those that threaten ecosystems and habitats (CBD, 1992; Rana et al., 2003). Because invasive species are becoming a growing threat to biodiversity worldwide, many international conservation programmes now give special attention to this issue. For example, the Kunming–Montreal Global Biodiversity Framework has set a target of reducing the introduction and spread of Invasive Alien Species by 50% before 2030 (Anoop et al., 2025).

### National Legislation and Institutional Mechanisms

In India, the management of invasive species is mainly carried out through the Biological Diversity Act, 2002. The National Biodiversity Authority (NBA) is the main agency responsible for implementing this law and supporting biodiversity conservation across the country (Sandilyan et al., 2018). However, many researchers believe that India still needs stronger and better coordinated policies to effectively manage invasive species across different regions and ecosystems (Bargavi et al., 2025; Rana et al., 2003).

Among different countries, South Africa is often seen as one of the best examples of invasive species management. The country has strong laws such as the National Environmental Management: Biodiversity Act (NEMBA) and the Conservation of Agricultural Resources Act (CARA), which help regulate and control invasive species effectively (Mhlongo et al., 2024; van Wilgen & Wannenburgh, 2016).

### State-Level Governance: Kerala

In Kerala, the management of invasive species is carried out under the Biological Diversity Act, 2002. The Kerala State Biodiversity Board (KSBB) is the main agency responsible for biodiversity conservation and invasive species management in the state (Kerala Biodiversity Board, 2012; Sankaran et al., 2012). Among the invasive species affecting Kerala, *Senna spectabilis* has become a major concern, especially in the Wayanad Wildlife Sanctuary.

## Management

### Prevention, Early Detection and Monitoring

Research shows that preventing invasive species from spreading is usually easier and less expensive than trying to remove them after they become established. For this reason, early detection and monitoring are considered very important management strategies.

### Technological Approaches

Today, scientists use technologies such as Remote Sensing, Geographic Information Systems (GIS), Species Distribution Models (SDMs), and Maximum Entropy (MaxEnt) models to identify areas that are vulnerable to invasion and to predict where invasive species may spread in the future (Adhikari et al., 2015; Prevena, 2021).

### Control and Management Strategies

For invasive tree species such as *Senna spectabilis*, different mechanical control methods are commonly used. Techniques like girdling and debarking are used to stop the movement of nutrients inside the tree and gradually kill it (Gumisiriza et al., 2008; Vinayan et al., 2023). Studies have shown that debarking mature trees during summer can be more effective than simply cutting them down because cut trees often grow back through coppicing and produce several new shoots (Vinayan et al., 2023; Wakibara & Mnaya, 2002). For small saplings, uprooting is usually recommended because it removes the whole plant, including its roots, and reduces the chance of regrowth (Anoop et al., 2025).

Another important management method is biological control. This method uses natural enemies such as insects, fungi, or plant diseases to control invasive species. A well-known example is the use of the rust fungus *Puccinia spegazzinii* to control the invasive weed *Mikania micrantha* (Ellison et al., 2007; Rai et al., 2014). Biological control is often considered a more sustainable method because it can provide long-term control without repeated human intervention.

Chemical control methods using herbicides such as glyphosate can also help reduce invasive plant populations. However, researchers have warned that herbicides can affect other plants, soil microorganisms, and nearby water sources (Anoop et al., 2025; Weidlich et al., 2020). Because of these risks, many conservation programmes prefer to use a combination of management methods rather than depending only on chemicals.

**Sustainable Management and Community Participation**

In recent years, another management approach has become popular. Instead of treating invasive plants as waste, researchers have explored ways to use them for useful purposes. Invasive plants such as *Lantana camara* have been used to make furniture, handicrafts, pulpwood, and organic manure (Kannan et al., 2013; Subedi & Rai, 2014). This approach provides economic benefits to local communities and encourages people to participate in invasive species removal programmes (Anoop et al., 2025; Bargavi et al., 2025).

Researchers also emphasize that public awareness and community participation are important for successful management. The way people view invasive species often affects whether management programmes succeed or fail. In some areas, people may value invasive plants because they provide shade, fuelwood, or other benefits. This can make removal efforts difficult (Kapitza et al., 2019; Mungatana & Ahimbisibwe, 2012). Therefore, educating people and involving local communities in management activities is considered very important (Remmele & Lindemann-Matthies, 2024).

**Management of *Senna spectabilis* in Kerala**

Research shows that *Senna spectabilis* was introduced to the Muthanga forest station in 1986 as an ornamental shade tree (Vinayan et al., 2023). Over the next few decades, the species spread

rapidly and now covers nearly 23% of the Wayanad Wildlife Sanctuary (Anoop et al., 2021; Vinayan et al., 2023). As the invasion increased, native plants began disappearing, natural regeneration declined, and large areas became dominated by *Senna spectabilis*.

Managing the species in Wayanad has been very challenging. Early management programmes carried out between 2013 and 2015 used girdling as a control method. However, many treated trees produced several new shoots, and newly opened spaces in the forest allowed more seedlings to grow (Vinayan et al., 2023; WTI, 2014). Because of this, current management methods recommend a combination of strategies. Small saplings are manually uprooted, larger saplings are mechanically removed, and mature trees are debarked during summer to reduce flowering and seed production (Bargavi et al., 2025; Vinayan et al., 2023).

Another major challenge is that several wild animals help spread the species. Studies have shown that Asian elephants, chital, and Indian porcupines eat the seed pods and later spread viable seeds through their dung across different parts of the forest (Anoop et al., 2021; Muraleekrishnan, 2024). This makes management more difficult because new plants can appear far away from the original invasion site.

Studies using MaxEnt modelling have shown that nearly 66% of Wayanad district is suitable for *Senna spectabilis* invasion, with eastern areas being the most vulnerable (Prevena, 2021). This means that the species may continue spreading into new areas if proper management measures are not taken.

The invasion also has important social impacts. Tribal communities and other forest-dependent people in Wayanad have reported a decline in forest products such as wild tubers, ginger, turmeric, and other useful native plants that were once easily available (Anoop et al., 2025; Ravi, 2022). As a result, the invasion affects not only biodiversity but also the livelihoods and daily lives of local people.

The reduction of native food plants inside forests has also been linked to increasing Human–Elephant Conflict. As food becomes less available within forests, elephants often move into farms and human settlements in search of food (Anoop et al., 2025; Ravi, 2022). This creates difficulties for both wildlife conservation and local communities.

Therefore, researchers believe that managing *Senna spectabilis* is not only about removing invasive trees. It also requires restoring forest areas with native trees, grasses, and other indigenous plant species. Ecological restoration is important because it prevents the return of *Senna spectabilis* and other invasive species such as *Lantana camara* (Bargavi et al., 2025; Latha & Venkatesan, 2023). In the long run, successful management depends on scientific research, regular monitoring, community participation, ecological restoration, and continuous conservation efforts to protect forests, wildlife, and local communities from the impacts of invasive species (Bargavi et al., 2025; Weidlich et al., 2020).

## 2.15 OTHER BIOLOGICAL INVASIONS IN KERALA

Although *Senna spectabilis* is one of the most significant invasive plants affecting the forests of Kerala, it is not the only invasive species threatening ecosystem stability. Several invasive animals and aquatic plants have also spread rapidly across the state, disrupting ecological processes, reducing biodiversity, and placing additional pressure on already stressed ecosystems. These examples demonstrate that biological invasions affect a wide range of terrestrial, freshwater, and coastal habitats.

### Invasive Faunal Species

Invasive animal species alter ecosystems by disrupting food webs, pollination, nutrient cycling, and species interactions. In Kerala, two well-documented examples are the Yellow Crazy Ant (*Anoplolepis gracilipes*) and the Tropical Leatherleaf Slug (*Laevicaulis alte*).

The Yellow Crazy Ant has spread rapidly through several sacred groves and forest ecosystems in Kerala, where it interferes with delicate ecological relationships among insects, plants, and other organisms (Sinu & Rajesh, 2023). Sacred groves are biodiversity-rich forest patches that support numerous native species and preserve important ecological interactions. As Yellow Crazy Ant populations increase, they compete with native insects for food and nesting sites, displace indigenous species, and interfere with pollinator activity. These changes weaken natural ecological networks and reduce ecosystem stability (Sinu & Rajesh, 2023).

Another important invasive faunal species is the Tropical Leatherleaf Slug (*Laevicaulis alte*), which has spread throughout all fourteen districts of Kerala following its introduction through horticultural and agricultural activities (Cyril & Joseph, 2023). The slug feeds on vegetables, ornamental plants, seedlings, and agricultural crops, causing considerable economic losses. In addition, it has been reported as a potential carrier of Rat Lungworm disease, highlighting that biological invasions may also pose risks to public health (Cyril & Joseph, 2023).

These examples demonstrate that invasive animal species can simultaneously affect biodiversity, ecosystem functioning, agriculture, and human well-being, further increasing the ecological stress already created by invasive plants such as *Senna spectabilis*.

## Aquatic Invasive Species

Biological invasions are equally severe in freshwater and coastal ecosystems, where invasive aquatic plants spread rapidly through rivers, wetlands, ponds, irrigation canals, and mangrove habitats. Water bodies provide continuous pathways for dispersal, enabling these species to establish and expand over large areas.

One important example is Red Cabomba (*Cabomba furcata*), an invasive aquatic plant that has become increasingly widespread in Kerala's freshwater ecosystems (Prabhakara Rao & Syamala Rani, 2023). The species reproduces through vegetative fragmentation, where even small plant fragments can develop into new individuals. Water currents transport these fragments through interconnected rivers, ponds, wetlands, and irrigation canals, facilitating rapid spread.

Dense growth of Red Cabomba reduces sunlight penetration into the water, suppressing native aquatic vegetation and disrupting photosynthesis. The invasion also alters oxygen availability and affects fish, aquatic insects, amphibians, microorganisms, and other organisms dependent on healthy freshwater ecosystems. In irrigation canals, excessive plant growth may obstruct water flow and interfere with agricultural activities (Prabhakara Rao & Syamala Rani, 2023).

Coastal wetlands are similarly threatened by Pond Apple (*Annona glabra*), an invasive tree that aggressively colonises mangrove ecosystems (Swedha Madhavan et al., 2023). By competing with native mangrove vegetation, Pond Apple alters the structure and composition of these ecologically

important habitats. Since mangroves provide shoreline protection, carbon storage, nursery grounds for aquatic organisms, and protection against storms and coastal erosion, their degradation can reduce the ecosystem services upon which both biodiversity and local communities depend (Swedha Madhavan et al., 2023).

Together, these examples illustrate that biological invasions are not restricted to terrestrial forests but also threaten freshwater and coastal ecosystems, emphasising the need for integrated management approaches across different habitat types.

## 2.16 HUMAN WELFARE, PUBLIC HEALTH, AND ECOSYSTEM SERVICE LOSS

The impacts of invasive alien species extend beyond biodiversity loss and ecosystem degradation. By altering ecological processes, invasive species also affect ecosystem services, agriculture, public health, and human well-being. As ecosystems become increasingly degraded, their ability to provide essential services such as clean water, fertile soils, climate regulation, pollination, and carbon storage gradually declines, creating significant environmental, social, and economic consequences (Pejchar & Mooney, 2009).

### Loss of Ecosystem Services

Healthy ecosystems provide a wide range of services that support both biodiversity and human societies. These include soil formation, nutrient cycling, water purification, carbon sequestration, flood regulation, pollination, and local climate regulation. Biological invasions disrupt these ecological functions by altering vegetation structure, reducing biodiversity, and modifying natural ecological processes (Pejchar & Mooney, 2009).

The replacement of diverse native vegetation by invasive species simplifies ecosystem structure and weakens ecological resilience. As a result, forests become less effective in maintaining soil fertility, regulating water cycles, storing carbon, and supporting wildlife populations.

## Agricultural Impacts

Invasive species also impose substantial pressures on agricultural systems. Invasive weeds compete directly with crops for sunlight, water, nutrients, and space, leading to reduced crop productivity and increased management costs. Changes in soil quality, water availability, and the spread of invasive pests further increase economic losses for farmers and reduce agricultural sustainability (Pejchar & Mooney, 2009).

## Public Health Concerns

Some invasive species have direct and indirect implications for human health. Certain invasive plants create favourable breeding habitats for mosquitoes and other disease vectors, increasing the risk of vector-borne diseases such as malaria (Stone et al., 2018). Others produce allergenic pollen or release toxic compounds that may affect air quality and cause respiratory or allergic health problems, particularly in disturbed landscapes such as roadsides, wastelands, and abandoned lands.

As discussed earlier, invasive species such as the Tropical Leatherleaf Slug (*Laevicaulis alte*) may also act as carriers of pathogens, demonstrating that biological invasions can influence both environmental and public health (Cyril & Joseph, 2023).

## Economic Costs

The management of invasive species requires continuous investment in surveillance, control measures, ecological restoration, and long-term monitoring. Once invasive species become well established, complete eradication is often no longer feasible, making management an ongoing financial burden (IPBES, 2019).

The cumulative costs of biodiversity loss, reduced agricultural productivity, ecosystem degradation, restoration programmes, and public health risks make biological invasions one of the most expensive environmental challenges worldwide. These long-term impacts highlight the importance of early detection, effective management, and sustained conservation efforts to minimise future ecological and economic losses.

# 2.17 MANAGEMENT AND ECOLOGICAL RESTORATION

The successful management of *Senna spectabilis* requires an integrated and long-term approach because of its high reproductive capacity, persistent soil seed bank, and strong regenerative ability. Once the species becomes established, a single control measure is rarely sufficient. Effective management therefore combines mechanical removal, continuous monitoring, ecological restoration, and community participation to prevent reinvasion and promote the recovery of native ecosystems.

## Mechanical Control

Mechanical methods are commonly used to reduce established populations of *Senna spectabilis*. One of the most effective techniques is girdling, in which a continuous ring of bark is removed from the trunk, usually at a height of one to two metres above the ground. This interrupts the transport of water and nutrients within the tree, resulting in almost complete mortality of mature individuals when carried out correctly (Vinayan et al., 2023).

Mechanical cutting alone is generally less effective because the species regenerates readily from stumps and surviving root fragments. Consequently, repeated follow-up operations are necessary to remove newly emerging seedlings and coppice shoots, preventing the re-establishment of invasive populations (Bargavi et al., 2025).

## Ecological Restoration

The removal of invasive trees represents only the first step in ecosystem recovery. Areas cleared of *Senna spectabilis* remain vulnerable to reinvasion unless native vegetation is allowed or assisted to regenerate. Active ecological restoration therefore includes the regeneration of indigenous plant species, recovery of soil health, management of the remaining seed bank, and continuous ecological monitoring.

Long-term monitoring is particularly important because new seedlings may continue to emerge for several years following removal (Kerala Biodiversity Board, 2012; Prevena, 2021). Early detection

and timely removal of regenerating individuals help prevent the species from re-establishing and reduce future management costs.

### Community-Based Utilisation

The large quantity of biomass produced during removal programmes presents both a challenge and an opportunity. To address this, researchers have proposed the **Kalpa Sasya** approach, which promotes the productive utilisation of invasive plant biomass rather than treating it solely as waste (Biju Kumar et al., 2023).

Under this approach, harvested biomass can be converted into products such as paper pulp, furniture, fuelwood, compost, and organic manure. Such utilisation not only reduces disposal problems but also creates economic incentives for local communities to participate in invasive species management, making large-scale removal programmes more practical and sustainable (Biju Kumar et al., 2023).

### Towards Integrated Management

The long-term management of *Senna spectabilis* depends on integrating control measures with ecological restoration and sustained monitoring. Mechanical removal, restoration of native vegetation, community participation, and regular surveillance should be implemented together to minimise reinvasion and support ecosystem recovery. Without continued management, cleared areas remain highly susceptible to recolonisation, delaying the restoration of biodiversity and ecological functioning.

## 2.18 THEORETICAL FRAMEWORK

#### Sustainable Livelihoods Framework (SLF)

This study is guided by the Sustainable Livelihoods Framework (SLF), which was originally introduced by Chambers and Conway (1992) and later developed and widely applied by the Department for International Development (DFID, 1999). The framework was developed to

provide a comprehensive understanding of how people build and sustain their livelihoods in changing social, economic, and environmental conditions.

The Sustainable Livelihoods Framework adopts a people-centred approach to understand livelihood systems by examining the resources available to individuals and communities, the factors that influence their access to these resources, and the strategies they use to achieve sustainable livelihoods (Chambers & Conway, 1992; DFID, 1999). The framework recognizes that livelihoods are influenced by multiple interconnected factors, including vulnerability conditions, available assets, institutional structures, livelihood strategies, and livelihood outcomes (DFID, 1999).

The framework consists of five major components: Vulnerability Context, Livelihood Assets, Transforming Structures and Processes, Livelihood Strategies, and Livelihood Outcomes (DFID, 1999).

The Vulnerability Context refers to external factors such as shocks, trends, and seasonal changes that influence livelihood conditions and affect people's ability to maintain their livelihoods (DFID, 1999).

Livelihood Assets represent the resources and capabilities that people use to support their livelihoods. The framework identifies five categories of assets: natural capital, human capital, financial capital, social capital, and physical capital. These assets form the foundation of livelihood systems and determine the opportunities available to individuals and communities (DFID, 1999).

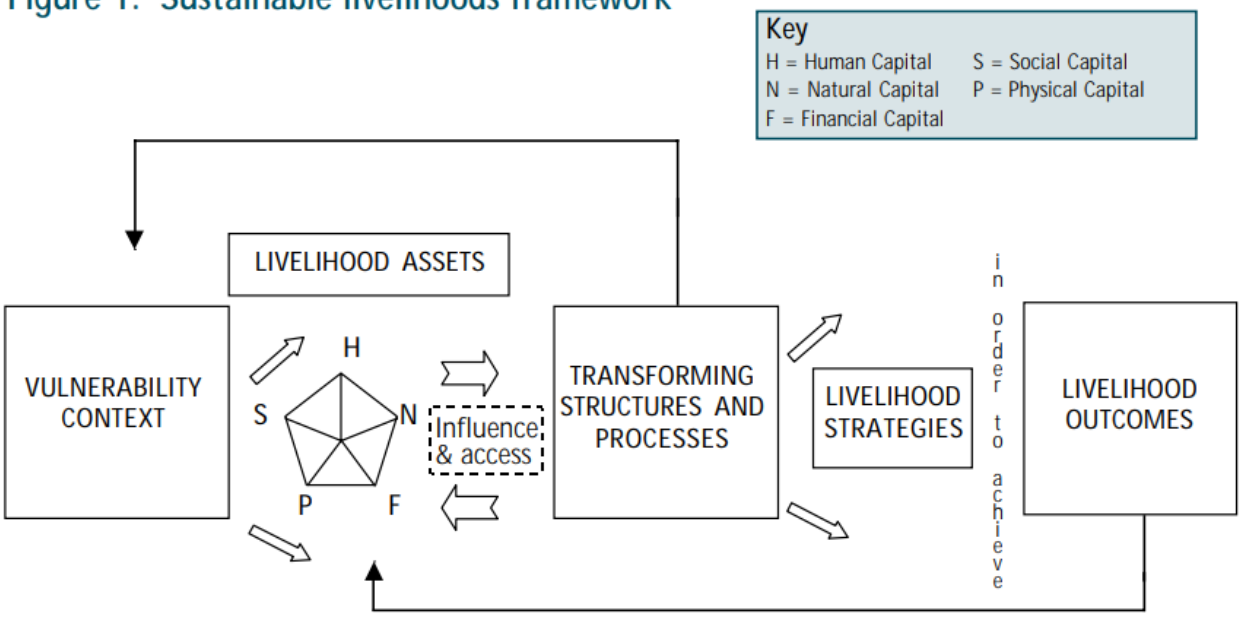
Transforming Structures and Processes include institutions, organizations, policies, laws, and social systems that influence access to resources and shape livelihood opportunities. These structures and processes determine how resources are managed and how decisions affecting livelihoods are developed and implemented (DFID, 1999).

Livelihood Strategies refer to the range of activities and choices through which individuals and households utilize their available assets to secure their livelihoods. These strategies vary depending on available resources, social conditions, and external influences (Chambers & Conway, 1992; DFID, 1999).

Livelihood Outcomes describe the results achieved through livelihood strategies. These include improved well-being, increased income, food security, reduced vulnerability, and sustainable resource use (DFID, 1999).

The Sustainable Livelihoods Framework has been widely used in research related to poverty, natural resource dependence, environmental change, and community resilience. It provides a comprehensive approach for analysing the relationship between people, resources, institutions, and environmental conditions (Scoones, 1998; DFID, 1999).

Figure 1. Sustainable livelihoods framework




(DFID,2001,P.3)

# 2.19 RESEARCH GAP

Several studies in Kerala have examined *Senna spectabilis* from a scientific and ecological perspective, focusing on its distribution, invasion pattern, reproductive characteristics, ecological impacts, and management. These studies have improved the understanding of the species as an invasive plant and its effects on forest ecosystems.

However, limited attention has been given to the social dimensions of the invasion, particularly in the context of Kerala. There is a lack of comprehensive research examining how the spread of *Senna spectabilis* affects forest-dependent communities, including its influence on livelihoods, access to forest resources, food habits, traditional knowledge, cultural practices, and overall well-being. Existing studies rarely connect ecological changes with the everyday experiences of communities living in and around the forests.

Therefore, this study addresses this gap by exploring *Senna spectabilis* not only as an ecological problem but also as a social issue. It examines how the invasion affects biodiversity, wildlife, and the lives of forest-dependent communities in Wayanad, thereby providing a more holistic understanding of its environmental and socio-economic impacts.

# CHAPTER 3

# METHODOLOGY

## 3.1 INTRODUCTION

This chapter explains the research methodology used in this study. Research methodology is the scientific and systematic way of conducting research. It helps the researcher identify the research problem, choose suitable methods, collect data, analyse the data, and draw meaningful conclusions.

According to Dr. Swarooprani K (2022), research methodology is the science of studying how research is carried out in a systematic way. It includes the study of different research methods, principles, and ethical practices used in a particular field of study. It also covers research models, different stages of research, and both quantitative and qualitative research methods. Research methodology helps researchers understand not only the results of research but also the process followed to achieve those results.

Research methodology also explains why a particular method is chosen for a study. It helps researchers understand the strengths and limitations of different research methods and use them effectively to solve the research problem.

This chapter describes the methodology used for the present study. It includes the research design, research objectives, research questions, study area, participants, sampling method, data collection methods, and data analysis techniques. The chapter also discusses the ethical considerations, scope, assumptions, and limitations of the study. These sections provide a clear understanding of how the research was conducted and how the findings were obtained.

## 3.2 TITLE OF THE STUDY

**The invasive threat of senna spectabilis in Wayanad : effects on biodiversity, wildlife, and communities**

## 3.3 RESEARCH QUESTIONS

### General Research Question

What has been the process of invasion of Senna spectabilis in the forests of Wayanad, and how has it shaped biodiversity, wildlife behaviour, livelihoods, food security, and the well-being of local communities? How have restoration efforts been designed and managed to mitigate these impacts?

### Specific Research Questions

How do local communities and other stakeholders perceive the history and spread of Senna spectabilis in Wayanad?

What environmental changes have been observed in forests following the spread of Senna spectabilis, particularly in relation to biodiversity, wildlife movement, and human–wildlife interactions?

How has the spread of Senna spectabilis influenced the livelihoods, resource use, food security, and well-being of forest-dependent communities?

What management and restoration measures have been undertaken to address the spread of Senna spectabilis, and what outcomes and challenges have emerged from these efforts?

## 3.4 DEFINITION OF CONCEPTS

### Invasive alien species

Conceptual definition

The term invasive species is further clarified and defined as “a species that is non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health. [ executive summary of the national invasive species management plan ]

Operational definition

In this study, senna spectabilis will be treated as the primary invasive species. Its invasiveness will be identified through field observations in forested areas of wayanad

**Human-wildlife conflict**

Conceptual definition

Human-wildlife conflict is defined as struggles that emerge when the presence or behaviour of wildlife poses an actual or perceived, direct and recurring threat to human interests or needs, leading to disagreements between groups of people and negative impacts on people and/or wildlife (IUCN SSC, 2022)

Operational definition

Human–wildlife conflict in this study will be identified through the reported experiences of local communities, forest officials, and media documentation. It will include incidents where wildlife, particularly elephants, enter human settlements or farmland due to altered forest composition linked to the invasion of Senna spectabilis.

**Wildlife habitat**

Conceptual definition

Wildlife habitat is where an animal lives and must include all the resources an animal needs to survive and reproduce. An animal's habitat has to provide five essential factors: food, cover, water, space, and interspersion [ Wiggers, E. P. (1989)]

Operational definition

In this study wildlife habitat refers to the forest habitat enclosed within the Wayanad Wildlife sanctuary

**Non timber forest produce**

Conceptual definition

Non-Timber Forest Products' (NTFPs) encompasses all biological materials other than timber, which are extracted from forests for human use. [ Belcher, B. M. (2003) ]
Operational definition

NTFPs in this research will include forest-derived resources traditionally collected by tribal and forest-dependent communities—such as wild berries, tubers, medicinal herbs, mushrooms, and gooseberries. Decline or disappearance of certain NTFPs will be linked to Senna spectabilis invasion when attributed directly by respondents or observed in invaded sites

## 3.5 PILOT STUDY

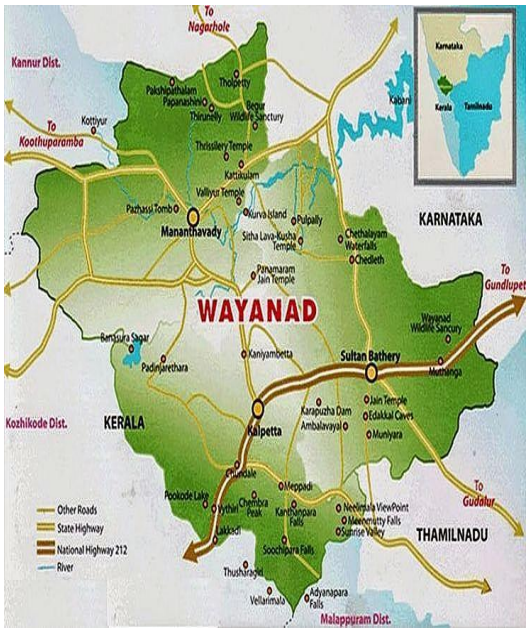
The researcher visited Noolpuzha Grama Panchayat in Wayanad district as part of the pilot study to gain a preliminary understanding of the extent of *Senna spectabilis* invasion in the area. During the visit, the researcher interacted with officials and staff of the Grama Panchayat to obtain a basic understanding of the existing situation. The researcher also met with researchers working on *Senna spectabilis* to gain further insights into the issue and its ecological and social implications. As part of the pilot study, five pilot interviews were conducted using the initial interview guide. The pilot study revealed certain limitations in the research tool, and based on the observations and feedback

obtained, the interview guide was revised and refined to ensure that it was appropriate for the main study and effectively addressed the research questions.

## 3.6 DESCRIPTION OF THE RESEARCH SITE AND PARTICIPANTS

KERALA DISTRICT MAP

MAP OF WAYANAD




Asiazurur. (n.d.).

The present study was conducted in the Muthanga and Tholpetty forest ranges of Wayanad district, Kerala. Located in the Western Ghats, these forests are part of the Wayanad Wildlife Sanctuary within the Nilgiri Biosphere Reserve, a UNESCO World Heritage Site and one of the world's richest biodiversity hotspots (Prevena, 2021; Vinayan et al., 2023). The forests are home to a wide variety of plants and wildlife, including the world's largest contiguous population of Asian elephants, tigers, leopards, dholes, gaur, and many endemic species, making Wayanad one of Kerala's most important forest ecosystems (Anoop et al., 2025; Vinayan et al., 2023).

Wayanad is also home to nearly 37% of Kerala's tribal population. Tribal communities such as the Paniyas, Adiyas, Kattunayakans, Kurichiyans, and Uraali Kurumas have lived in and around these forests for generations and depend on them for food, traditional medicines, Non-Timber Forest Products, and their livelihoods (Balaji & Krishnan, 2017; Wayanad.com, n.d.; Hussain, 2024).

Muthanga and Tholpetty were selected for the present study because these forest ranges have a high spread of *Senna spectabilis* and are home to several forest-dependent tribal settlements. Their rich biodiversity, ecological importance, and close connection between the forest and tribal

communities make them suitable sites for studying the socio-economic implications of *Senna spectabilis*.

The participants for the study were selected based on their knowledge and experience regarding *Senna spectabilis* and its socio-economic impacts. Some participants had been directly affected by the spread of *Senna spectabilis* in their daily lives, while others possessed extensive knowledge through their professional work, research, or involvement in forest restoration activities.

The participants included community members living in and around the forest, Forest Department officials, researchers who have worked on *Senna spectabilis*, representatives of non-governmental organizations (NGOs) involved in ecological restoration, and officials from the Grama Panchayat, including a former Panchayat member and an Accredited Engineer. Their diverse experiences and perspectives provided a comprehensive understanding of the invasion of *Senna spectabilis*, its ecological impacts, and its socio-economic implications for forest-dependent communities.

## 3.6 RESEARCH DESIGN

Research design refers to the overall framework that guides the entire research process. It provides a logical plan for addressing the research problem by outlining the methods to be used for data collection, analysis, and interpretation. A well-developed research design ensures that the study is conducted systematically and that the findings effectively address the research objectives (Creswell & Creswell, 2018). Kothari (2004) defines research design as the conceptual structure within which research is conducted and considers it the blueprint for the collection, measurement, and analysis of data.

The present study adopted a qualitative research design. Qualitative research is concerned with understanding people's experiences, perceptions, and meanings regarding a particular phenomenon in its natural setting. Rather than relying on numerical data, it focuses on obtaining rich, detailed information that helps explain social realities from the participants' point of view (Denzin & Lincoln, 2018). According to Creswell and Creswell (2018), qualitative research is an approach

used to explore and understand the meanings that individuals or groups assign to a social or human problem.

A case study design was adopted for the present study. Yin (2018) defines a case study as an empirical method that investigates a contemporary phenomenon within its real-life context, particularly when the boundaries between the phenomenon and the context are not clearly evident. Case studies enable researchers to gain an in-depth understanding of a bounded case by examining it from multiple perspectives and using different sources of information (Creswell & Poth, 2018).5

In the present study, the invasion of *Senna spectabilis* in the Muthanga and Tholpetty forest ranges of Wayanad is taken as a single case and explored in detail. A single case study design was adopted because the spread of *Senna spectabilis* has brought significant ecological changes to the forest and has affected the livelihoods of forest-dependent tribal communities. By focusing on this single case, the researcher was able to examine in detail the socio-economic implications of the invasion, the experiences of the affected communities, and the perspectives of different stakeholders involved in its management and restoration. This approach enabled a comprehensive understanding of the issue within its real-life context.

## 3.7 SAMPLING STRATEGY

Sampling is the process of selecting a subset of individuals from a population to obtain information about the entire population. It enables the researcher to collect data from a representative group that is relevant to the objectives of the study (Kothari, 2004).

The present study employed purposive sampling, which is a non-probability sampling technique. According to Patton (2015), purposive sampling involves intentionally selecting information-rich participants who have extensive knowledge or experience of the phenomenon being studied. Similarly, Creswell and Poth (2018) state that qualitative researchers purposefully select participants or research sites that can best help them understand the central phenomenon.

Purposive sampling was considered appropriate for the present study because the participants were selected based on their knowledge and experience of *Senna spectabilis* and its socio-economic

implications. The study included individuals who had direct experience with the invasion and its impacts, as well as those who possessed professional knowledge through their work, research, or involvement with the issue.

## 3.8 CRITERIA FOR SELECTION OF PARTICIPANTS

### Inclusion Criteria

- Individuals who have direct experience with the invasion of *Senna spectabilis* and its impacts.
- Individuals who possess knowledge of *Senna spectabilis* through their professional work, research, forest management, ecological restoration, or community involvement.

### Exclusion Criteria

- Individuals who had no knowledge or experience of *Senna spectabilis* or its impacts.
- Individuals who were not associated with the Muthanga and Tholpetty forest ranges or the issue under study.

## 3.9 DATA COLLECTION

### Sources of Data

The present study utilized both primary and secondary sources of data.

### Primary Data

Primary data were collected through semi-structured interviews with participants who had direct experience with *Senna spectabilis* and its impacts, as well as individuals who possessed knowledge of the issue through their work, research, forest management, ecological restoration, and community involvement. The primary data provided firsthand information relevant to the study.

**Secondary Data**

Secondary data for the present study were collected from books, peer-reviewed journal articles, conference proceedings, master's theses, reports, and publications of national and international organizations. The reviewed literature focused on *Senna spectabilis*, invasive alien species, biodiversity conservation, forest ecology, and the tribal communities of Wayanad, providing a comprehensive understanding of the research problem.

## 3.10 METHOD OF DATA COLLECTION

Primary data were collected through semi-structured interviews and observation. The researcher conducted field visits to the Muthanga and Tholpetty forest ranges in Wayanad to collect firsthand information from the selected participants. The interviews were conducted in Malayalam using a semi-structured interview questionnaire, which allowed participants to freely share their knowledge and experiences regarding *Senna spectabilis*. The interviews were audio-recorded with the participants' consent and later transcribed into English. The researcher also made field observations during the visits to better understand the invasion of *Senna spectabilis* and its impacts.

## 3.11 TOOLS FOR DATA COLLECTION

The study employed a semi-structured interview questionnaire and observation as the tools for data collection. The semi-structured interview questionnaire consisted of open-ended questions designed to gather detailed information related to the research objectives. The flexible nature of the questionnaire enabled the researcher to ask probing questions whenever necessary. Observation was also used to understand the presence and spread of *Senna spectabilis*, the surrounding forest environment, and conditions relevant to the study. The information obtained through observation complemented the interview data and enhanced the overall understanding of the research problem.

## 3.12 DATA ANALYSIS

Data analysis is the process of organizing and interpreting collected information to identify meaningful patterns and themes. In the present study, the interview transcripts were analysed using

thematic analysis. The data were carefully reviewed, coded, and grouped into themes based on the research objectives. The identified themes were then interpreted to understand the findings of the study.

## 3.13 ETHICAL CONSIDERATIONS

Ethical principles were followed throughout the study. Participants were informed about the purpose of the research before the interviews, and their voluntary informed consent was obtained. Confidentiality and anonymity were maintained by removing personal identifiers from the data. Participants were free to withdraw from the study at any stage without any obligation. Interview recordings and transcripts were securely stored, and the researcher maintained neutrality and respected the views and experiences shared by all participants.

## 3.14 ASSUMPTIONS, LIMITATIONS AND SCOPE

### 3.14.1 Assumptions of the Study

The study is based on the following assumptions:

- The introduction and spread of *Senna spectabilis* have negatively affected the forest ecosystem of Wayanad by reducing native plant diversity and changing the natural structure of the forest.
- The decline in biodiversity and changes in forest ecology have affected wildlife by reducing the availability of native food plants and suitable habitats.
- The ecological changes caused by *Senna spectabilis* indirectly affect the livelihoods, resource use, food security, and overall well-being of forest-dependent and tribal communities.
- Local communities, forest officials, and other stakeholders have valuable knowledge and experiences that help in understanding the ecological and social impacts of the invasion.
- Managing *Senna spectabilis* requires ecological restoration along with long-term participation from government agencies and local communities.

### 3.14.2 Limitations of the Study

Like all research, this study has certain limitations.

- The researcher faced limitations in interacting with tribal communities due to permission-related restrictions from the Forest Department and the Tribal Development Department. As a result, the number of respondents from the tribal communities was limited.
- Due to this restriction, the study mainly depended on the views of forest officials, experts, local residents, and available secondary sources to understand the impacts on tribal communities.
- Language differences between the researcher and some respondents created communication challenges during data collection. In some cases, translation was required, which may have affected the depth of responses.
- The study was conducted within a limited time frame, making it difficult to observe seasonal variations in the spread of *Senna spectabilis* and its ecological impacts.
- Since the study focused only on selected areas of Wayanad, the findings may not represent all regions affected by *Senna spectabilis*.

### 3.14.3 Scope of the Study

The study explores the ecological and social impacts of *Senna spectabilis* in Wayanad, with particular attention to biodiversity, wildlife, and forest-dependent communities. It contributes to understanding how an invasive species can alter ecosystems and influence human livelihoods.

Although the study is based in Wayanad and focuses on *Senna spectabilis*, the invasion process observed in this research follows patterns that are common to many invasive alien species. Characteristics such as rapid spread, competition with native species, habitat alteration, biodiversity loss, and impacts on local communities are seen in invasive species across different ecosystems.

Therefore, the findings of this study can provide useful insights for understanding and managing invasive species in other regions as well. The study may also serve as a reference for future research, conservation planning, ecological restoration, and invasive species management in similar forest ecosystems.

# CHAPTER 4

# THE CASE OF SENNA IN WAYANAD

# 4.1 ABOUT WAYANAD

Wayanad is a district in the northern part of Kerala, located in the Western Ghats of India. It covers an area of about 2,131 km² and lies between 11°26′54″ to 11°58′52″ North latitude and 75°46′11″ to 76°25′08″ East longitude. The district is bordered by Coorg (Karnataka) in the north-west, the Nilgiri region (Tamil Nadu) in the south-east, the Deccan Plateau in the east, and the Malabar plains in the west. Because of its geographical location, Wayanad forms an important link between the forests of Kerala, Karnataka, and Tamil Nadu (Anoop et al., 2025).

The landscape of Wayanad is mainly a gently sloping plateau with an average elevation of 800–900 metres above sea level. Along the western side are high mountain peaks such as Chembra Peak, Vellarimala, and Banasura, which rise above 2,000 metres. One of the unique features of Wayanad is the presence of small rolling hills and low-lying swampy valleys known as "Vayal." These swampy areas gave the district its name, "Vayal Nadu," meaning "the land of swamps." These valleys also support many perennial streams and are an important part of the district's natural landscape (Anoop et al., 2025).

Most of Wayanad is drained by the Kabini River, an important tributary of the Cauvery River. The district receives rainfall from both the southwest monsoon (June–September) and the northeast monsoon (October–December), with an average annual rainfall of about 2,322 mm. Due to the influence of the Western Ghats, the western part of the district receives much higher rainfall than the eastern part, creating different climatic conditions across the region (Anoop et al., 2025).

Forests cover nearly 40% of Wayanad, making it one of the most important forested districts in Kerala. These forests are part of the Brahmagiri–Nilgiri–Eastern Ghats Landscape, which is well known for its rich biodiversity. The district contains evergreen forests, moist deciduous forests, dry deciduous forests, and high-altitude grasslands, providing a wide range of habitats for plants and animals (Anoop et al., 2025).

Wayanad is globally important because it supports the world's largest continuous population of Asian elephants. The combination of forests, grasslands, and swampy Vayal areas provides an ideal habitat for elephants, especially during the dry season. The district also supports many other wildlife species, including gaur, tigers, leopards, deer, and several endemic species of plants and

animals. The Wayanad Wildlife Sanctuary, which is connected to protected forests in Karnataka and Tamil Nadu, plays an important role in wildlife conservation and allows free movement of animals across state boundaries (Anoop et al., 2025).

Because of its unique geography, climate, and biodiversity, Wayanad is one of the most ecologically important regions of the Western Ghats. The district plays a significant role in biodiversity conservation, ecosystem functioning, and the protection of important wildlife habitats, making it a valuable landscape for both ecological research and conservation efforts (Anoop et al., 2025).

# 4.2 HISTORY OF *SENNA SPECTABILIS* IN WAYANAD

The history of *Senna spectabilis* in Wayanad reflects a gradual transformation of the forest landscape resulting from changes in forest composition, human interventions, and management practices over several decades. The present distribution of the species is connected with a series of events that occurred before and after its introduction into the region. During the field study, community members, environmentalists, researchers, and forest officials shared their observations regarding the transformation of Wayanad's forests and the changing relationship between local communities and forest ecosystems. These field observations correspond with scientific studies documenting the introduction, establishment, and expansion of *Senna spectabilis* within the Wayanad Wildlife Sanctuary (Vinayan et al., 2023).

### 4.2.1 Wayanad before the Introduction of *Senna spectabilis*

According to the respondents, the forests of Wayanad were once characterised by extensive natural vegetation and high biological diversity. An MGNREGA Accredited Engineer explained that the landscape consisted of dense forests containing several native tree species, including jackfruit, mango, and fig. These forests supported a diverse understorey consisting of grasses, herbs, shrubs, climbers, and medicinal plants, which contributed to the richness of the forest ecosystem.

A member of the Kattunaika community described the forest as an integral part of their daily life and identity. According to him, the forest served as their home, market, hospital, and playground.

He recalled that people depended on forest resources such as wild tubers, medicinal plants, honey, edible fruits, and other materials required for their livelihood. He explained that before the presence of invasive species such as *Senna spectabilis* and *Lantana camara*, people could move freely through the forest, which was open, diverse, and rich in natural resources.

Respondents explained that major changes in the forest landscape began during the 1970s. An MGNREGA Accredited Engineer stated that the establishment of the Gwalior Rayons paper mill at Mavoor in Kozhikode increased the demand for forest resources. According to him, large areas of natural forest were cleared to obtain raw materials required for paper production. These cleared areas were later converted into teak (*Tectona grandis*) plantations mainly for commercial purposes.

An Ex-Panchayat Member explained that the conversion of natural forests into teak plantations changed the environmental characteristics of the region. According to him, teak plantations influenced soil moisture conditions and increased soil erosion due to changes in rainfall interaction with the forest floor. He explained this through his observation that dry teak leaves placed on wet soil absorb moisture, illustrating the changes he associated with teak-dominated landscapes.

The respondents also identified the decline of bamboo forests as another important event in the changing forest landscape. According to them, bamboo flowering occurred after several decades, followed by the death of extensive bamboo stands. The disappearance of bamboo cover resulted in visible changes in the vegetation structure of the forest.

According to the respondents, these changes altered the earlier forest landscape of Wayanad. The replacement of natural vegetation with plantations and the decline of certain native forest components created a different ecological setting compared to the original forest system.

### 4.2.2 Introduction of *Senna spectabilis* under the Social Forestry Programme

Following changes in forest conditions, afforestation programmes were initiated to increase vegetation cover in degraded areas. An environmentalist explained that during this period, *Senna spectabilis*, a tree species native to Tropical America, was selected under the Social Forestry Programme due to its rapid growth, broad canopy, and attractive yellow flowers. The species was considered suitable for increasing greenery and was also valued for ornamental purposes.

A responder explained that local authorities introduced *Senna spectabilis* with the expectation that it would support vegetation recovery in degraded areas and provide shade. According to him, the species was introduced as a useful tree, and its future invasive behaviour was not anticipated during the initial plantation period.

Scientific records reported by Vinayan et al. (2023) provide details regarding the official introduction of the species. According to the authors, the Social Forestry Wing of the Kerala Forest Department introduced *Senna spectabilis* into the Wayanad Wildlife Sanctuary in 1986. The initial seedlings were raised at Ponkuzhy in the Muthanga Forest Range, where fewer than fifteen trees were planted near the Muthanga Forest Office compound. The primary purpose of this initial plantation was to provide shade for the office premises (Vinayan et al., 2023).

An environmentalist who participated in the study explained that Ponkuzhy later became a centre for distributing *Senna spectabilis* seedlings to different locations in Wayanad. According to him, environmental workers and local volunteers planted these seedlings along roadsides, residential areas, and private lands as part of plantation activities.

A researcher explained that the appearance of the species also influenced its acceptance among people. The bright yellow flowers enhanced its ornamental value and increased its popularity in different locations. Due to these visible characteristics, the species continued to be accepted by officials and local communities during the early period following its introduction.

The respondents explained that the initial plantation of *Senna spectabilis* was carried out as part of restoration and greening efforts. At that time, it was regarded as a beneficial plantation species rather than a species with invasive potential (Vinayan et al., 2023).

### 4.2.3 Establishment, Expansion, and Recognition of *Senna spectabilis* as an Invasive Species

After its introduction, *Senna spectabilis* remained undetected as a major ecological concern for several years. The species gradually established itself within the landscape, and its increasing presence became noticeable only after significant natural regeneration occurred.

An environmentalist who participated in the study explained that several *Senna spectabilis* trees planted in private lands were later removed due to agricultural activities and construction.

However, some trees survived, matured, and contributed to the spread of the species into surrounding areas. According to him, these surviving trees played an important role in the early expansion of *Senna spectabilis* in Wayanad.

The gradual establishment of the species is supported by scientific observations. Vinayan et al. (2023) reported that *Senna spectabilis* remained in a lag phase after introduction, during which its expansion occurred slowly without receiving major attention from forest managers. Chandran et al. (2023) observed that the trees started flowering approximately seven years after planting, and natural regeneration around the original plantation areas became noticeable after about fifteen years. These stages contributed to the gradual establishment of the species within the Wayanad Wildlife Sanctuary.

For approximately twenty-five years following its introduction, *Senna spectabilis* was not recognised as a major ecological threat. However, by the early 2010s, researchers and forest managers began observing dense populations of the species across forest areas, leading to increased recognition of its invasive nature (Vinayan et al., 2023).

In 2012, the Kerala Forest Research Institute classified *Senna spectabilis* as a medium-risk invasive species in Kerala forests (Sajeev et al., 2012). Subsequent studies documented a continuous increase in its distribution within the Wayanad Wildlife Sanctuary. Mapping studies estimated that the invaded area covered approximately 14.6 km² in 2013, which increased to nearly 55 km² by 2017. By 2023, the species was estimated to occupy approximately 123 km², covering nearly one-third of the sanctuary area (Vinayan et al., 2023).

The present field study also reflected the increasing extent of invasion. A biologist working in the Wayanad Wildlife Sanctuary explained that the sanctuary covers approximately 344.56 km², of which nearly 6,000 hectares are currently affected by *Senna spectabilis*. He recalled that when he joined the Wildlife Department in 2015, the affected area was less than 600 hectares. According to him, the invaded area has increased almost tenfold within the last decade, making *Senna spectabilis* one of the major ecological challenges currently faced by the sanctuary.

The biologist further explained that local communities have started referring to *Senna spectabilis* as “Rakshasa Konna,” reflecting the concern associated with its increasing presence in the region.

The historical development of *Senna spectabilis* in Wayanad demonstrates the transition of the species from an introduced plantation tree to an established invasive species. The increasing recognition of its ecological significance marked an important stage in the management history of the Wayanad Wildlife Sanctuary

## OVERWHELMING SPREAD AND PERSISTENCE OF SENNA

Rotherham (2005)

**The Return Of The Giant Hogweed**

" Turn and run,
Nothing can stop them,
Around every river and canal their power is growing.
Stamp them out,
We must destroy them.
They infiltrate each city with their thick dark warning odour.
Still they're invincible,
Still they're immune to all our herbicidal battering

Waste no time, They are approaching.
Hurry now, we must protect ourselves and find some shelter
Strike by night They are defenceless.
They all need the sun to photosensitize their venom."

- Heracleum mantegazzianum

The poem *"The Return of the Giant Hogweed"* mentioned by Rotherham (2005) describes the

overwhelming spread and persistence of an invasive plant species. The emotions expressed in the poem closely reflected my experience during the field visit to Wayanad. As I walked through the forest landscape, witnessing the widespread presence of *Senna spectabilis*, I experienced a similar feeling of observing a species that had established itself beyond its original boundaries. The rapid spread, dominance over native vegetation, and difficulty in controlling *Senna spectabilis* created a sense of how an invasive species can gradually transform an ecosystem. The poem's portrayal of an unstoppable invasion connected deeply with my field observations, where *Senna spectabilis* appeared as a powerful ecological force altering the forest environment. (Rotherham, 2005)

## 4.3 ECOLOGICAL CHANGES, SPREAD, AND INVASIVE DYNAMICS OF *SENNA SPECTABILIS*

The continued presence of *Senna spectabilis* in the forests of Wayanad is associated with several ecological characteristics that support its survival, regeneration, and expansion. During the field study, biologists, researchers, and environmentalists identified various ecological processes that influence the behaviour of the species within forest ecosystems. These include climatic influences, reproductive characteristics, disturbance events, biological interactions, and changes occurring within forest habitats.

### 4.3.1 Influence of Climate Change on the Spread of *Senna spectabilis*

Respondents identified changing climatic conditions as one of the environmental factors influencing the growth and establishment of *Senna spectabilis* in Wayanad forests. A biologist working at the Wayanad Wildlife Office explained that variations in temperature and rainfall patterns have created conditions favourable for the species. According to him, these changes

provide an advantage to *Senna spectabilis*, enabling it to establish successfully in different forest areas.

A researcher further explained that increasing atmospheric carbon dioxide levels may influence the growth performance of the species. According to him, higher carbon dioxide availability acts as a natural fertilising factor, promoting faster growth and improving the competitive ability of *Senna spectabilis* compared to certain native plant species.

The respondents explained that climatic changes do not independently cause invasion but create environmental conditions that support the continued survival and expansion of *Senna spectabilis* within the forest ecosystem.

### 4.3.2 Bamboo Gregarious Flowering and Canopy Opening

A researcher explained that bamboo gregarious flowering influences the establishment of *Senna spectabilis* by creating suitable conditions within the forest. According to him, bamboo flowering results in the simultaneous death of large bamboo populations, leaving open areas within the forest.

A biologist from the Wayanad Wildlife Office explained that these openings allow greater sunlight availability on the forest floor. According to him, the increased exposure creates favourable conditions for the growth of *Senna spectabilis* in these locations.

The respondents clarified that bamboo flowering does not directly result in invasion. Instead, the ecological changes following bamboo mortality create opportunities for the invasive species to establish in newly available spaces.

### 4.3.3 Allelopathic Behaviour of *Senna spectabilis*

Allelopathic behaviour was identified as an important ecological characteristic of *Senna spectabilis* during the field study. A biologist from the Wayanad Wildlife Office explained that the species influences surrounding soil conditions through chemical compounds released during the decomposition of fallen leaves.

According to him, these substances interfere with the germination and growth of native plant species. As a result, native seedlings may experience difficulty in establishing beneath areas dominated by *Senna spectabilis*.

The respondent explained that this process contributes to reduced regeneration of native vegetation and creates challenges for ecological restoration, as altered soil conditions limit the natural recovery of native plant communities.

### 4.3.4 Persistence of Seeds in the Soil

The ability of *Senna spectabilis* seeds to remain viable for extended periods was identified as an important factor supporting the persistence of the species. A biologist from the Wayanad Wildlife Office explained that the seeds can survive in the soil for approximately five to ten years.

According to him, these dormant seeds form a seed bank, allowing new plants to emerge even after mature trees are removed. Therefore, controlling the species requires continuous observation and repeated management activities rather than only removing existing trees.

The respondent emphasised that the presence of a persistent seed bank is one of the major challenges in achieving long-term control of *Senna spectabilis*.

### 4.3.5 High Germination Capacity

Another reproductive characteristic identified during the field study was the high germination capacity of *Senna spectabilis*. A biologist from the Wayanad Wildlife Office explained that the species has an estimated germination rate of approximately 93 percent.

According to him, this high success rate allows a large proportion of seeds to develop into new plants under suitable conditions. He explained that this reproductive ability supports the rapid establishment of the species within areas where environmental conditions are favourable.

### 4.3.6 Forest Fires as Disturbance Events Facilitating the Spread of *Senna spectabilis*

During the field study, a researcher explained that forest fires contribute to conditions that favour the establishment of *Senna spectabilis*. According to him, fires may occur naturally or due to

human activities, but they result in the removal of existing vegetation and disturbance of forest areas.

The respondent explained that after fire events, the absence of established vegetation provides opportunities for *Senna spectabilis* to occupy available spaces before native plants recover. Therefore, fire-affected areas require timely management to reduce the possibility of further establishment of the species.

Forest fires were identified as important disturbance events that increase the vulnerability of forest areas to invasion by *Senna spectabilis*.

### 4.3.7 Limited Natural Control by Herbivores and Other Organisms

The absence of effective natural control mechanisms was identified as one of the reasons behind the continued spread and persistence of *Senna spectabilis* in the forests of Wayanad. Respondents explained that unlike many native plants, *Senna spectabilis* is rarely consumed by animals, which reduces the natural limitation on its growth and survival.

A researcher highlighted that very few animal species feed on *Senna spectabilis*. Because of this limited consumption, the plant does not face strong biological pressure from herbivores that could otherwise restrict its expansion. As a result, once established in an area, the species can continue growing and producing seeds with minimal interference from natural predators.

An environmentalist further explained that *Senna spectabilis* is considered unpalatable to many animals because of its toxic nature. Animals generally avoid feeding on its leaves and bark, allowing mature trees to grow undisturbed. He also observed that areas dominated by mature *Senna* trees often show reduced vegetation growth beneath them. The ground layer under these trees becomes relatively empty, with fewer smaller plants and reduced visible biological activity compared to areas with native vegetation.

The respondents therefore emphasized that the limited interaction between *Senna spectabilis* and local fauna contributes to its ability to dominate invaded areas. Since fewer organisms consume or naturally regulate the species, it gains an advantage over native plants and continues to establish itself within the forest landscape.

### 4.3.8 Wildlife-Mediated Seed Dispersal

The field study identified wildlife as a potential contributor to the movement of *Senna spectabilis* seeds across forest areas. A researcher explained that some wild animals have recently started feeding on parts of the species, resulting in the unintentional transportation of seeds through animal movement.

Another researcher reported that studies conducted on deer droppings revealed approximately seventy to one hundred *Senna spectabilis* seeds in a single sample. According to him, this indicates that seeds remain capable of passing through animals and reaching new locations within the forest.

The respondents considered this development significant because wildlife movement can contribute to the establishment of the species in areas beyond existing invaded sites.

### 4.3.9 Threat to Vayals

A biologist from the Wayanad Wildlife Office highlighted the increasing presence of *Senna spectabilis* in the vayals of the Wayanad Wildlife Sanctuary. According to him, the sanctuary contains approximately 171 vayals covering nearly 1,500 hectares.

The respondent described vayals as open marshy grasslands that function as the “Jeevanadi” or lifeline of the forest. According to him, these areas serve as important water sources for wildlife, especially during the summer season. He further explained that their ecological importance extends beyond the sanctuary, as wildlife from neighbouring protected areas such as Mudumalai, Nagarhole, and Bandipur depend on these habitats during dry periods for water and grazing.

The biologist expressed concern that the presence of *Senna spectabilis* within these grassland ecosystems may alter their existing characteristics. According to him, continued establishment of the species in vayals could reduce open grazing spaces and affect wildlife dependent on these habitats.

**REFLECTIONS ON SENNA**

As I walked through the forest, I found it difficult to identify any tree other than Senna. Everywhere I looked, there were Senna trees. Some stood tall, others were regenerating, but together they dominated the landscape. The forest felt dry. The diversity that one expects from a tropical forest seemed absent. The richness of species had been replaced by repetition.

As an outsider who had seen only a small portion of this transformation, I felt a deep sense of sadness. If witnessing a tiny fragment of this change affected me so strongly, I wondered how painful it must be for those who had lived through the transformation and watched it happen before their eyes.

Many people referred to the tree as "Rakshasa Konna"

Yet I often found myself thinking about the strange injustice behind that name. A plant was carrying the blame for a problem it had not created on its own. Human decisions, policies, and interventions had allowed it to spread. The consequences were being borne by the forest, by local communities, and even by the tree itself, which had become a symbol of destruction. In many ways, everyone involved seemed to be paying the price for choices made long ago.

(Field notes – 30/12/2025 )

# 4.4 LIVELIHOOD DISRUPTIONS, CULTURAL LOSS, AND SOCIAL TENSIONS AMONG FOREST-DEPENDENT COMMUNITIES

For the tribal communities of Wayanad, the forest has always been an inseparable part of life. It has provided food, materials, income, cultural resources, and a sense of belonging that has been carried across generations. Their relationship with the forest was not limited to collecting resources; it was built through years of knowledge, familiarity, and a deep understanding of their surroundings.

Field interactions with community members revealed that the spread of *Senna spectabilis* has affected this relationship in multiple ways. The decline of naturally available forest resources has created challenges in everyday survival, reduced livelihood opportunities, disturbed traditional practices, and created new social pressures within communities.

The changes experienced by these communities show that the impact of invasive species is not limited to the disappearance of plants. It has gradually entered into the daily lives of people who depended on the forest for generations.

### 4.4.1 Decline of Traditional Forest Foods and Nutritional Security

Among the forest-dependent communities, the Kattunaika community has been one of the most closely connected with forest resources. Traditionally, the forest provided a wide variety of naturally available foods, especially wild tubers, which formed an important part of their traditional diet.

Community members from the Kattunaika community explained that earlier, wild tubers collected from the forest were an important source of food. These resources provided nutritional support and were part of their traditional knowledge system, where generations had learned which plants could be collected, prepared, and consumed.

However, with the decline of Non-Timber Forest Products (NTFPs), these traditional food resources have become increasingly difficult to obtain. The reduction of forest availability has directly affected their food practices and nutritional intake.

A Kattunaika community member expressed this change through their lived experience:

> "We, the Kattunaika community, were the most dependent on the forest. We used to eat many wild tubers collected from the forest. But now, because non-timber forest products are less available, we do not get enough of these tubers. As a result, our intake of nutrients has reduced."

The respondent further explained the present condition of food dependence:

> "At present, we mostly depend on ration rice. We are able to eat a proper, full meal only once a day."

These statements reveal the seriousness of the transformation. Resources that were once obtained directly from the forest have now become difficult to access, forcing families to depend more on externally supplied food. The loss of forest-based food sources has therefore become a question of everyday survival and nutritional security.

### 4.4.2 Decline of Forest-Based Livelihoods and Economic Dependence

For many tribal families, forest products were not only sources of household consumption but also provided opportunities for income generation. Collection of honey and other forest products supported small-scale economic activities within local communities.

Respondents explained that earlier, people collected different forest products and sold them within local societies. These activities allowed them to earn an income while continuing their traditional relationship with the forest.

However, the decline in availability of these resources has severely affected these livelihood opportunities. Honey collection, which was once an important forest-based activity, has reduced drastically.

A community member explained:

> "Honey collection has reduced drastically, from almost 100% to just 25%."

Along with honey, other forest food products have also decreased. As these resources became less available, people who once depended on forest collection for income were forced to search for alternative employment.

Many community members now depend on MGNREGA work as a major source of livelihood. This represents a significant change from a traditional forest-based livelihood system to dependence on wage-based employment.

The transition reflects not only economic hardship but also a gradual separation from occupations and skills that were closely connected with their identity and way of life.

### 4.4.3 Forest Resources and Cultural Identity

The importance of forests among tribal communities extends beyond food and income. The forest is deeply connected with their cultural practices, rituals, and traditional ways of life.

Community members explained that several important ceremonies depend on resources collected from the forest. During puberty ceremonies, turmeric collected from the forest is traditionally applied to the girl as part of the ritual. Similarly, during death ceremonies, specific forest climbers are used as ropes to prepare a bed for carrying the deceased.

These practices demonstrate that forest resources carry cultural and emotional meanings beyond their physical use. They represent traditions passed through generations and reflect the close relationship between communities and their natural surroundings.

The decline of forest resources therefore affects not only material availability but also cultural continuity. When these resources disappear, communities lose access to materials that are deeply connected with their memories, customs, and traditional practices.

### 4.4.4 Changing Frest Access and Emerging Social Tensions

Another important concern shared by respondents was the change in traditional systems of forest access. Earlier, each tribal family and community had specific areas associated with them, which had been inherited and maintained across generations.

Community members explained that they traditionally collected NTFPs only from their own designated areas. This system helped maintain a balance between families and ensured that forest resources were used according to established practices.

However, the spread of *Senna spectabilis* has altered this traditional arrangement. As useful forest resources declined and many areas became less productive, people were forced to search for resources beyond their usual collection areas.

One respondent explained:

> "Earlier, each tribe and each family had its own specific land, which had been passed down through generations. We used to go only to our own land to collect non-timber forest products ."

The respondent further described the changes brought by the decline of resources:

> "As Senna has spread rapidly, useful NTFP resources have declined and the land has become barren. As a result, we are forced to go to other families' lands."

This change has created social pressure and tensions within the community. As the respondent highlighted:

> "This creates social pressure and conflicts that are often invisible to outsiders."

These conflicts may not always appear openly, but they represent the disruption of traditional systems that previously guided relationships between families, land, and forest resources.

### 4.4.5 Changing Relationship Between Communities and the Forest

The experiences shared by respondents reveal a deeper transformation in the relationship between tribal communities and the forest. Earlier, the forest provided multiple necessities—food, materials, income opportunities, and cultural resources. People possessed the knowledge required to collect and use these resources sustainably.

However, the decline of forest products has changed this relationship. Communities that once depended on the forest for several aspects of life are now increasingly dependent on external sources of food and employment.

The loss of forest resources has therefore created consequences that extend beyond ecological concerns. It has affected livelihood security, traditional knowledge, cultural practices, and social relationships. For forest-dependent communities, the disappearance of these resources represents not only the loss of materials but also the weakening of a way of life that has existed for generations.

## 4.5 HUMAN–ANIMAL CONFLICT

Human–animal conflict emerged as one of the most frequently discussed issues during the field study. Almost every respondent, regardless of their profession or role, spoke about the increasing encounters between wildlife and people in different parts of Wayanad. Community members, researchers, local representatives, and officials all described it as a major challenge affecting both forest-dependent communities and farmers living close to the forest.

Respondents explained that the problem has become more severe over the years. They associated this increase with the changes taking place inside the forest, particularly the decline of natural food resources and the spread of invasive plant species. As food becomes less available within the forest, wild animals increasingly move towards agricultural lands and nearby human settlements in search of food.

### 4.5.1 Increasing Human–Animal Conflict in Wayanad

An MGNREGA-accredited engineer explained that the degradation and drying of forests, together with the spread of teak plantations and invasive species such as *Senna spectabilis*, *Chromolaena odorata*, and *Lantana camara*, have reduced the natural habitat and food available for wildlife. According to him, this has forced wild animals to move closer to human settlements, making human–animal conflict a serious and growing concern across the region.

During the interview, he shared that 10 to 20 people had been attacked by tigers. He also stated that around 157 people had lost their lives due to elephant-related incidents during the previous three years, reflecting the seriousness of the issue.

A former Panchayat member also spoke about the increasing conflict between people and wildlife. According to him, the shortage of food inside the forest has contributed to more frequent encounters between wild animals and nearby communities. He recalled that at least 100 people had lost their lives due to human–animal conflict during the last ten years.

The respondents consistently described human–animal conflict not as an occasional incident but as an issue that has become part of everyday life for many people living near the forest.

### 4.5.2 Impact on Agriculture and Crop Damage

The increasing movement of wild animals into agricultural areas has created serious difficulties for farmers living near the forest. During the field study, respondents repeatedly explained that crop damage has become a common problem, affecting both agricultural production and the livelihoods of farming families.

A former Panchayat member explained that many different wild animals now enter farmlands. According to him, the problem is not limited to elephants or tigers. Deer, wild pigs, monkeys, and even caterpillars cause damage to crops at different stages of cultivation.

Among these, respondents highlighted the increasing number of monkeys as a major concern for coffee farmers. They explained that monkeys feed on ripe coffee cherries and damage coffee

plants, leading to considerable losses during the harvesting season. Since coffee is one of the major plantation crops in Wayanad, such damage directly affects the income of farming households.

The respondents explained that repeated crop losses have made farming increasingly difficult. Even after months of cultivation, there is no certainty that the harvest will reach the farmers. This uncertainty has become a growing concern for people who depend on agriculture for their livelihood.

### 4.5.3 Farming and Labour Challenges

One of the researchers approached the issue from a broader perspective by explaining how farming functions within rural communities. According to him, agriculture has always been a collective activity rather than the responsibility of a single individual.

He explained that large-scale farming depends on the coordinated efforts of many people, with each person carrying out a specific responsibility. Along with cultivation, protecting crops from wildlife has become an essential part of farming.

The respondent stated that the increasing spread of *Senna spectabilis* has indirectly affected this system. As the invasive plant suppresses the growth of grasses and small shrubs that normally serve as food for wild animals, the availability of natural food inside the forest declines. Consequently, animals increasingly enter agricultural lands in search of food, creating additional challenges for farmers.

According to the respondent, this has made farming more difficult than before. Farmers now have to manage cultivation while also protecting their crops from repeated wildlife intrusion. As a result, farming has become more uncertain and labour-intensive.

### 4.5.4 Migration and Changes in Livelihood

The respondents also explained that the challenges faced in agriculture have gradually influenced people's livelihood decisions. According to the researcher, repeated crop losses and the increasing risk from wild animals discourage many people from continuing farming.

He explained that when agriculture becomes uncertain, people begin searching for alternative sources of income. Over time, some families choose to migrate in search of safer and more stable employment opportunities.

The respondent described this process as a chain of interconnected events. He explained that the spread of an invasive species reduces natural food resources inside the forest, which contributes to increased human–animal conflict. This, in turn, affects agriculture, encourages migration, reduces the availability of agricultural labour, and ultimately weakens farming activities within the community.

The field data suggest that migration is therefore not an isolated issue but one of the many consequences experienced by communities living in areas affected by ecological change.

### 4.5.5 Community Responses and Compensation

During the interviews, respondents explained that incidents of crop damage and attacks by wild animals are regularly reported to the local Panchayat and the Forest Department. Community members approach these institutions seeking assistance and compensation for the losses they experience.

A former Panchayat member shared that numerous complaints have been registered over the years regarding human–animal conflict. Although compensation is provided by the Forest Department, respondents pointed out that it often takes a long time to reach the affected families.

For people who depend primarily on agriculture, such delays create additional difficulties, as the financial loss caused by damaged crops or other incidents must often be managed long before compensation is received.

The respondents felt that while compensation provides some relief, timely support is equally important for farming families who rely on agriculture as their primary source of livelihood.

# 4.6 GOVERNANCE, PEOPLE'S PERSPECTIVES, AND REFLECTIONS ON SOCIAL FORESTRY

The field study also provided insights into how some respondents understood forest governance and the idea of social forestry. Rather than focusing only on the spread of *Senna spectabilis*, these discussions explored the role of human decisions in shaping forest landscapes. The respondent reflected on the relationship between people, forests, and governance, questioning whether forests can truly be created through planned interventions.

**LIVING WITH THE INVASION**

When I first began this study, I expected to find people speaking passionately about Senna spectabilis as a major environmental problem. Instead, what I encountered was something very different. For many people, Senna was no longer a curiosity, a crisis, or even a topic of discussion. It had become part of their everyday reality. They had lived with it for so long that it seemed to have been accepted almost like fate.

There was something deeply ironic about this reality. The very institutions entrusted with protecting the forest had, knowingly or unknowingly, played a role in introducing the species. In an attempt to address one environmental problem, another was created. Without fully understanding the long-term consequences, one mistake had been used to cover another. Yet, it was not the policymakers or planners who bore the greatest burden. It was the forest and the people who depended on it.

Among all those affected, it was the forest-dependent communities who seemed to have lost the most. For them, the forest was never something separate from life. It was life itself. It was their kitchen, their pharmacy, their marketplace, their place of worship, and their home. Everything they needed came from the forest.

Families would spend days inside the forest collecting resources. Sometimes they stayed there for two or three days at a stretch. They moved through the forest without fear because it belonged to them as much as they belonged to it. Before entering, they would offer prayers to the forest deities, asking for protection and blessings. Their relationship with the forest was not merely economic; it was spiritual, cultural, and deeply personal.

Today, much of the forest they grew up with exists only in memory.

The plants they once recognized are disappearing. The familiar trees that shaped their childhood landscapes are becoming scarce. The fruits they gathered, the medicinal plants they relied upon, the tubers that sustained them, and the countless resources that once supported everyday life are no longer easily available.

There was a time when many families depended almost entirely on the forest and needed little from outside. Today, their lifestyles have changed dramatically. Health problems are increasing. Traditional diets have been replaced by dependence on ration supplies and purchased food. Many people feel that these foods do not provide the same strength, nutrition, or satisfaction that forest foods once offered. Hunger and food insecurity have become part of daily life for some households.

( Field notes 30/12/2025 )

### 4.6.1 Social Forestry and People's Participation

One researcher explained that social forestry was originally introduced as a programme intended to benefit local communities. Since forests directly influence the lives and livelihoods of people living around them, he believed that communities themselves should play an important role in deciding how such programmes are planned and implemented.

However, according to the respondent, decisions are often taken by officials and institutions rather than by the communities who are most closely connected with the forest. He felt that, over time,

these systems of representation become distant from local realities, resulting in decisions that may not fully reflect the experiences and needs of the people.

The respondent viewed this as one of the reasons why forest management programmes sometimes fail to achieve their intended purpose.

### 4.6.2 Human Intervention and Natural Forests

During the discussion, the respondent distinguished between naturally occurring forests and forests created through planned afforestation programmes. He explained that a natural forest develops on its own through ecological processes, whereas afforestation involves deliberate human intervention.

According to him, the spread of *Senna spectabilis* should not be understood only as the aggressive behaviour of an invasive species. Instead, he believed that its rapid expansion indicates that changes had already taken place within the forest ecosystem, creating favourable conditions for its establishment.

Rather than asking only how *Senna spectabilis* spreads, the respondent felt that greater attention should be given to understanding what changes within the forest made such large-scale invasion possible.

### 4.6.3 Repeated Cycles of Forest Management

Another important idea shared by the respondent was the repeated cycle of human intervention in forests. He observed that different species are introduced with the intention of solving one problem, but over time those same interventions may create new environmental challenges.

According to him, management practices often involve removing one species, introducing another, and later removing that as well when new problems arise. He viewed this as a continuous cycle that reflects the long-term consequences of decisions made without fully understanding the complexity of natural ecosystems.

### 4.6.4 Restoration and Livelihood

The respondent also pointed out an interesting contradiction in the present restoration efforts. Many local people are now employed in removing *Senna spectabilis*, a species that was once deliberately introduced through afforestation programmes.

He observed that restoration activities have created employment opportunities for local communities. At the same time, he felt that these jobs exist because people are now trying to correct the consequences of earlier management decisions.

This observation reflects the respondent's perspective on how environmental problems and livelihood opportunities have become closely connected through the restoration process.

## 4.7 RESTORATION INITIATIVES AND SUSTAINABLE FOREST RECOVERY

The rapid spread of *Senna spectabilis* has made forest restoration one of the most important conservation priorities in Wayanad. Field findings showed that restoration is no longer viewed simply as the removal of an invasive tree. Instead, it is understood as a long-term effort to recover the ecological health of the forest while protecting the livelihoods of communities that depend on it. Respondents explained that years of invasion have altered the forest to such an extent that restoring native vegetation now requires careful planning, scientific guidance, and continuous follow-up.

Discussions with respondents also revealed that restoration has gradually evolved into a collaborative process involving research institutions, government departments, conservation organisations, and local communities. Each institution contributes in a different way, from developing management techniques and conducting field experiments to implementing restoration programmes on the ground. Community members have also become active participants in this process, contributing their knowledge of the landscape while creating new livelihood opportunities through restoration work.

The findings further indicate that restoration is not limited to removing *Senna spectabilis*. It also includes restoring native vegetation, monitoring treated areas, and ensuring that the forest is able to regenerate naturally over time. Together, these activities represent an integrated approach aimed at supporting the gradual recovery of invaded forest ecosystems.

### 4.7.1 Management Approaches for the Control of *Senna spectabilis*

Managing *Senna spectabilis* remains one of the greatest challenges faced during restoration. Field findings consistently showed that the species possesses a remarkable capacity to survive and regenerate, making its control far more difficult than that of many other invasive plants. Respondents explained that once the tree becomes established, it cannot be eliminated through a single intervention. Instead, different management techniques have been developed and evaluated over the years to identify methods capable of reducing its spread without causing further damage to the surrounding environment.

One of the earliest approaches involved cutting the trees. Although this initially appeared to be a practical solution, field experience showed that it produced only temporary results. Respondents explained that new shoots frequently emerged from the remaining stump or root system, allowing the tree to grow again within a short period. Because of this ability to regenerate, cutting alone was not considered an effective long-term management strategy.

Another technique adopted during restoration was debarking, in which the bark surrounding the standing tree is carefully removed. Respondents explained that this interrupts the movement of water and nutrients within the stem, eventually causing the tree to die. However, the success of this method depends on careful execution. If the bark is only partially removed or the treatment is incomplete, the tree may continue to survive. This makes debarking a labour-intensive method that requires both experience and regular supervision.

Chemical treatment has also been explored as a possible method of controlling *Senna spectabilis*. Although respondents acknowledged that herbicides are capable of killing the tree, they explained that this approach is generally avoided in natural forests. The use of chemicals may affect nearby

vegetation, soil organisms, and wildlife, creating additional ecological concerns. For this reason, respondents considered chemical treatment unsuitable for large-scale restoration within protected forest ecosystems.

Among all the approaches discussed during the field study, uprooting was consistently identified as the most effective method of managing *Senna spectabilis*. Respondents explained that this method removes the entire plant, thereby reducing the chances of regeneration from the remaining root system. Uprooting is generally carried out during the monsoon season when the soil becomes soft, making it easier to remove the roots completely. Although physically demanding, respondents regarded this method as the most reliable approach currently available for controlling the spread of the species.

### 4.7.2 Government and Institutional Initiatives

The field study showed that the management of *Senna spectabilis* is being supported through the combined efforts of several institutions, each contributing to different aspects of restoration. Rather than relying on a single agency, respondents described restoration as a coordinated effort involving scientific research, policy support, and field-level implementation.

An important contribution has come from the Kerala Forest Research Institute (KFRI), which has studied the biology of *Senna spectabilis* and evaluated different management techniques. Respondents explained that the findings generated through these studies have helped shape present restoration practices by identifying methods that are both effective and environmentally appropriate. This scientific support has provided an important foundation for restoration activities currently being undertaken in invaded forest areas.

Respondents also explained that the Wildlife Conservation Society (WCS) later became involved in restoration programmes. One of the important observations highlighted during these efforts was the need to remove even very small *Senna* seedlings. According to the respondents, overlooking young plants allows fresh infestations to develop, making careful inspection of restored sites an important component of management.

The discussions further revealed that both the Tamil Nadu and Kerala governments adopted a restoration model that allowed paper mills to utilise the removed *Senna spectabilis* wood for the production of paper pulp. According to respondents, the Tamil Nadu model combined the removal of the invasive species with subsequent ecological restoration of the cleared areas. Kerala later adopted a similar approach, enabling the wood obtained during restoration to be put to productive use instead of being discarded.

Respondents reported that approximately 5,000 to 10,000 tonnes of *Senna* wood were supplied to paper mills in Kerala under this initiative. This approach not only supported large-scale removal efforts but also provided a practical means of managing the substantial quantity of biomass generated during restoration.

Field findings also highlighted the occupational challenges associated with this work. Respondents explained that the sap and fine dust released while handling *Senna* trees can cause severe allergic reactions. Skin contact with the sap may result in swelling, while exposure to dust often causes irritation. These experiences emphasise the need for appropriate protective equipment and safe working practices during restoration activities.

### 4.7.3 Community-Based Restoration Practices

One of the most significant findings that emerged during the field study was the active participation of local communities in forest restoration. Rather than depending entirely on external agencies, the ongoing restoration programme has deliberately involved people living close to the forest. Respondents explained that community participation is considered essential because local people possess a deep understanding of the landscape, including areas that are heavily invaded, natural access routes, and the seasonal changes within the forest. This local knowledge has become an important resource in planning and implementing restoration activities.

Field findings showed that the Keystone Foundation, in collaboration with the Forest Department, has adopted a community-based approach to the restoration of areas invaded by *Senna spectabilis*. The restoration team currently consists of 30 local community members supported by two ecologists. According to respondents, local residents were selected not only to generate employment but also because of their familiarity with the forest ecosystem. Their long-standing

relationship with the forest enables them to identify changes in vegetation and locate newly invaded areas more efficiently than people unfamiliar with the terrain.

Respondents explained that restoration work is carried out directly inside the invaded forest. Depending on the condition and size of the trees, workers either remove the bark from standing trees or uproot young plants. These activities require considerable physical effort, particularly in densely invaded areas where movement itself has become difficult. Respondents noted that restoration work often demands patience and careful observation, as each treated area must be handled systematically to prevent further spread of the species.

Another important aspect highlighted during the discussions was the sense of ownership created through community participation. Respondents felt that involving local people has strengthened their connection with forest conservation. Instead of being passive observers of environmental degradation, community members have become active participants in restoring the landscape on which many of their livelihoods and cultural traditions depend. In this way, restoration has become both an ecological and a community-centred process.

### 4.7.4 Monitoring and Experimental Restoration

Field findings revealed that restoration does not end with the removal of *Senna spectabilis*. Respondents consistently emphasised that continuous monitoring is essential to ensure that treated areas remain free from regeneration. Without regular follow-up, new shoots and seedlings can quickly establish themselves, reducing the effectiveness of earlier restoration efforts. As a result, monitoring has become an integral component of the restoration programme rather than a separate activity.

Respondents described one of the experimental restoration techniques that was carried out at Tholpetty in 2024 by KPPL. The trial was designed to evaluate whether additional treatment of the remaining stump could reduce the chances of regeneration after the tree had been cut.

During the experiment, 60 Senna trees were selected for treatment. After each tree was felled, the remaining stump was carefully scraped, and the exposed surface was tightly covered with soil.

According to respondents, this procedure was intended to prevent the regeneration of new shoots from the remaining plant tissue.

The restoration team revisited the site three months later to inspect the treated trees. Any new shoots that had emerged were removed immediately. Respondents explained that repeated follow-up eventually caused the treated trees to dry completely and die. This experiment demonstrated that successful restoration depends not only on the initial treatment but also on regular observation and timely intervention whenever regeneration occurs.

Respondents further reported that approximately 16,000 Senna trees have been treated through similar restoration efforts. Each restored site continues to be monitored for six months to ensure that regeneration is identified and managed at an early stage. According to respondents, this period of observation is essential because the success of restoration can only be confirmed after repeated inspections demonstrate that the invasive species has not re-established itself.

### 4.7.5 Ecological Rehabilitation Through Native Species

The field findings showed that the removal of *Senna spectabilis* is only the first step in the restoration process. Respondents explained that once the invasive trees are removed, the cleared areas cannot be left vacant. If these spaces remain open, they become vulnerable to fresh invasion by *Senna* or other invasive species. For this reason, restoration efforts also focus on re-establishing native vegetation that naturally belongs to the forest ecosystem.

To support this objective, the Keystone Foundation has established a nursery dedicated to raising native plant species for restoration activities. According to respondents, the nursery currently maintains 115 native species, which are propagated specifically for planting in areas cleared of *Senna spectabilis*. The respondents explained that these species were selected because they are naturally found in the forests of Wayanad and contribute to the recovery of the ecosystem.

Among the native species being raised are Thanni (*Terminalia bellirica*), Karimarudhu (*Terminalia elliptica*), Ungu (*Pongamia pinnata*), Pathiri (*Stereospermum colais*), and Soap Nut (*Sapindus trifoliatus*). Respondents explained that introducing these native species is expected to

gradually restore the diversity and structure of the forest that existed before the spread of *Senna spectabilis*.

Respondents also pointed out that planting native species alone does not guarantee successful restoration. Since the programme is still in its early stages, young seedlings require continuous care and observation after planting. Their survival is regularly assessed to ensure that the restored areas develop into self-sustaining forest ecosystems over time.

### 4.7.6 Community Observations on Changing Forest Conditions

Beyond organised restoration activities, respondents shared their observations about the changes they have witnessed inside the forest over the years. These observations reflected how the invasion of *Senna spectabilis* has altered people's interaction with the forest and affected their ability to access resources that were once readily available.

Respondents explained that entering certain parts of the forest has become increasingly difficult because of the dense growth of invasive plants, particularly *Senna spectabilis* and *Chromolaena odorata*. Areas that were once easily accessible are now heavily overgrown, making movement through the forest more challenging than before.

Many respondents recalled that local communities once entered the forest to collect a variety of resources, including honey, bamboo shoots, mushrooms, and firewood. These resources formed an important part of everyday life and supported household needs. According to the respondents, many of these forest products have now become difficult to obtain from invaded areas.

The respondents also observed noticeable changes in the physical appearance of the forest. In some locations, *Senna spectabilis* forms dense stands that dominate the landscape, while in other places it creates more open conditions that expose the forest floor to increased sunlight. According to respondents, these changes have affected the condition of the soil and contributed to the gradual transformation of the forest environment.

Respondents further noted that the shortage of natural food resources inside the forest has altered wildlife movement, particularly in buffer areas and along riverbanks. They observed that animals

increasingly move towards areas occupied by people in search of food. These observations reinforce the wider ecological changes taking place within the forest landscape.

### 4.7.7 Restoration as a Source of Livelihood

The field study also showed that restoration has created new employment opportunities for local communities. While the primary objective of the programme is ecological recovery, respondents explained that it has also generated a regular source of income for people living near the forest.

According to respondents, planning for the present restoration project began in June 2024, after which local community members were recruited to carry out restoration activities. At present, the programme provides permanent employment for 30 workers, allowing them to participate directly in conservation while earning a stable daily wage.

Respondents explained that the restoration team works from 8:30 a.m. to 4:00 p.m. every day except Tuesday, which is observed as a weekly holiday. They shared that many workers use this day to travel to a nearby market in Karnataka, where household supplies are available at lower prices.

At present, each worker receives ₹500 per day for restoration work. Respondents mentioned that the workers have requested an increase to ₹600 per day, considering the physically demanding nature of the work carried out inside the forest.

Although restoration was initiated to address the spread of *Senna spectabilis*, the programme has also provided local communities with an opportunity to contribute directly to the protection of the forests on which many of them have depended for generations. Respondents viewed this participation as an important outcome of the restoration process, as it combines environmental conservation with local employment and community involvement.

# 4.8 THE FOREST THROUGH THEIR EYES: A KATTUNAIKA COMMUNITY NARRATIVE

The conversations with members of the Kattunaika community in Muthanga revealed far more than information about forests or invasive species. They revealed a way of life that had been shaped by the forest over generations. Rather than beginning their stories by talking about the spread of *Senna spectabilis* or the changes they now witness, they first spoke about the forest they had known since childhood. Their memories were not simply descriptions of a landscape; they were memories of home, family, identity, and belonging. Every story reflected a deep emotional attachment to the forest and the life it once sustained.

One elderly community member began by saying,

> "I was born in the forest and grew up with it. From my childhood, the forest was not something outside my life. It was our home, our market, our hospital, our playground."

For the Kattunaika community, the forest was never seen as a place separate from life. It was the centre around which everyday living revolved. It provided food when families were hungry, medicine when someone fell ill, materials to build shelters, and space where children learned about life from their parents and elders. Unlike people who looked at the forest as a resource, the community spoke about it as though they were describing a member of their own family.

As he reflected on his childhood, he paused for a moment and quietly added,

> "Every path, every hill, every stream had a story."

These stories were not written in books or recorded anywhere. They were carried in memory. Every familiar path reminded them of journeys taken with parents and grandparents. Every stream brought back memories of fishing together as children. Hills, trees, and open grasslands were not anonymous parts of the landscape; each carried experiences that connected one generation to the next. Listening to these memories, it became evident that the community's knowledge of the forest had been built not through formal education but through living with it every day.

The respondents remembered a forest that looked very different from what stands today. They described a landscape that was open, healthy, and full of life. Vast grasslands stretched across the forest, creating open spaces where people could move freely and wildlife could graze without disturbance. After every fire season, fresh green grass would naturally emerge from the soil, covering the landscape once again. Watching deer and other animals feeding on these grasslands was an ordinary part of everyday life.

One respondent recalled,

> "In those days, the forest was open and beautiful. There were large grasslands everywhere. After the fire season, fresh green grass would sprout from the soil. The animals would come and feed on it. The forest floor was not crowded with plants like Manja Konna or Lantana. You could walk freely through the forest."

The way they described the forest reflected abundance rather than scarcity. Walking through the forest was effortless because the old paths remained open and familiar. The forest was remembered as a place where people, plants, and animals shared the same landscape without the barriers that now exist.

Food formed one of the strongest memories shared by the community. Their lives were closely connected with the seasonal rhythm of the forest, and almost every season brought different foods that supported their families. Long before purchased food became common, the forest itself met most of their nutritional needs.

One elder smiled while remembering those days.

> "Earlier, there were forest tubers everywhere. We used to collect and eat many kinds of kizhangu. There were Nooru, Galasu, Binni, Ekku, Saalu and many other forest foods. We ate wild fruits, honey and fish. Rice was not our main food then. Forest food was our food."

This simple statement reflected an entire food culture. Their meals depended on what the forest naturally provided. Different varieties of tubers were collected according to the season, while wild

fruits, fish from forest streams, and honey completed their daily diet. Food was not purchased from markets; it was gathered through knowledge that had been passed down across generations.

The respondents often connected these food habits with their health. They believed that living close to nature and eating forest foods had helped earlier generations remain physically strong.

One elderly man remembered his mother with great affection and said,

> "We were healthy. Our elders lived long lives. My mother lived for almost a hundred years. We did not depend on hospitals or injections. People were afraid of hospitals in those days because they did not know much about them. Still, people remained healthy because they lived with nature."

For them, health was closely associated with the forest itself. Their understanding was not based on scientific explanations but on lived experience. The forest provided nutritious food, medicinal plants, and a lifestyle that they believed kept people healthy for many decades.

Honey occupied a particularly important place in their lives. It was much more than a forest product collected for consumption. Honey collection was described as a tradition that connected families across generations.

One respondent explained,

> "When we were young, we would go to the forest with our parents. Sometimes we walked ten or twenty kilometres inside the forest. Honey collection was part of our life and our tradition."

They remembered collecting different varieties of honey, including Vander Then and Cheru Then. The honey produced by small bees was especially valued because it was believed to possess medicinal properties. It was commonly given to children and used as a traditional remedy whenever someone became unwell. The respondents did not separate food from medicine; many forest products fulfilled both purposes.

Beyond honey, the forest supplied a remarkable diversity of useful plants. Community members recalled collecting Kurunthotti, Chunda, Soap Kaayi, Cheenikka, Moovila, Orila, Sadavari,

Kalpasham, Poopal, Wild Turmeric, and Nellikka, each serving different purposes within everyday life. Some were consumed as food, others were used to prepare traditional medicines, while a few supported both nutritional and medicinal needs. They also remembered collecting the tender shoots of Kadumudunga, known locally as Chappu Mola Koombu, which was prepared as food during particular seasons.

The respondents explained that their traditional knowledge extended beyond household use. The tribal society had official permission to collect several forest products for medicinal purposes. Ayurvedic companies placed orders through the society, and community members gathered the required materials from the forest before supplying them.

One elder reflected on those years with a mixture of pride and sadness.

> "Earlier, these plants were available in abundance. We collected them in large quantities. What was once taken in tons is now available only in kilograms."

The statement required no further explanation. It reflected not only the abundance they once experienced but also the profound sense of loss that remained with them.

During these conversations, one thing became increasingly clear. The community did not remember the forest as a collection of trees or natural resources. They remembered it through relationships—with parents who taught them forest paths, with elders who passed on traditional knowledge, with children who accompanied them on long journeys, and with generations who depended on the same landscape for life itself. Every memory they shared carried the feeling that the forest was not simply where they lived. It was where they belonged.

For the Kattunaika community, the relationship with the forest was not limited to collecting food or medicinal resources. The forest was also a space where families spent their time together, where knowledge was shared between generations, and where everyday life unfolded naturally. Their memories reflected a time when entering the forest was not considered a separate activity; it was simply a part of living.

Community members recalled that when they went into the forest for collecting forest products, they often remained there for several days. These journeys were not short visits. Families would

build temporary shelters inside the forest and stay there while collecting what they needed. Men, women, and children travelled together during these periods. Even their dogs and cats accompanied them.

These experiences created a strong connection between family life and the forest. Children learned by observing their parents—understanding which plants could be collected, where different resources were found, and how to move through the forest. Knowledge was not taught through formal lessons; it was gained through participation and experience.

For them, spending time inside the forest was not a difficult task or something to be avoided. It was a familiar way of life. The forest provided comfort and familiarity because it was the place where they had grown up.

One community member explained this feeling in a simple way:

> "Others may feel comfortable in towns and cities. We feel comfortable in the forest."

He further explained that while many people go to cities and other places for relaxation, their own way of finding happiness was different.

> "You may go to towns and cities to relax. We go to the forest."

Even today, when there is no work, some community members continue to walk through the forest paths. Sometimes they go to streams to catch fish, and sometimes they simply walk through the forest. These walks are not only connected with collecting resources but also with the emotional comfort they receive from being in a familiar landscape.

The relationship between the community and the forest was also deeply spiritual. Entering the forest was not considered an ordinary movement from one place to another. It was an act that required respect and acknowledgement of the natural world around them.

Before entering the forest, they offered prayers to their deities and asked for protection. They prayed that no wild animal would cross their path and believed that the forest had its own guardian

spirits who watched over them. Among these beliefs, Mariamma was remembered as one of the important deities associated with their lives.

The community believed that every hill and every place within the forest carried its own sacred presence. The forest was not empty space; it was a place filled with spiritual meaning. Entering it required humility and respect.

This spiritual relationship was closely connected with their cultural practices. Their festivals, songs, and dances carried memories from their ancestors and continued to represent their identity as a community. Women played an important role in preserving traditional songs and performing dances during gatherings. Men participated through drum performances, creating an atmosphere where music, movement, and memory came together.

The respondents explained that these traditions were not newly created practices but something inherited from earlier generations. Through songs, dances, and celebrations, stories and values were carried forward within the community.

However, while remembering the forest of their childhood, the community also expressed a deep sense of sadness when comparing it with the forest they see today. The memories of abundance gradually shifted into memories of loss.

One respondent reflected:

> "When I think about those days, the forest that stands before my eyes is very different from the forest we see today."

This difference was not described only through visible changes. The respondents spoke about changes they felt while walking through familiar places, changes that affected the relationship they had maintained with the forest throughout their lives.

They remembered a time when the forest felt open and accessible. Paths that were once used regularly became difficult to move through. Places where families once collected food and materials became unfamiliar. The landscape that had supported generations began to feel different.

The community members expressed this change with a strong emotional comparison:

> "Today, when I look at the forest, it feels closed and choked. Sometimes it looks like a disease spreading everywhere."

For them, the change was not just about the appearance of trees or plants. It represented the gradual transformation of a place that had shaped their entire existence.

They explained that the most painful part was that the damage was not always visible from outside. According to them, the deeper areas of the forest revealed greater changes.

> "Even worse than what we can see from outside, the real damage is inside the forest. If we go deep into the forest now, there is almost nothing left in many places."

This statement reflected their experience of witnessing a forest that once provided abundance becoming increasingly difficult to recognise. The loss was not only ecological; it was personal. They were witnessing changes in the same landscape where they had grown up, where their parents had taught them, and where generations of their community had lived.

For the Kattunaika community, the forest was not remembered simply as something they used. It was remembered as something they belonged to. Their memories revealed a relationship built through years of walking, collecting, praying, celebrating, and living together with the forest.

As one respondent expressed:

> "For us, the forest is like a mother."

This sentence captured the depth of their connection. The forest was seen as something that had cared for them, provided for them, and shaped their identity. Therefore, changes in the forest were experienced not only as environmental changes but also as changes affecting their own lives and memories.

As the Kattunaika community continued sharing their memories, the conversation gradually moved from the forest they once knew to the changes they have witnessed over the years. Their descriptions were not only about plants disappearing or landscapes changing; they were about losing things that had been part of their everyday existence for generations.

One of the biggest changes they noticed was the increasing presence of Manja Konna (Senna spectabilis) in the forest. They remembered a time when this yellow-flowering tree was not a part of their surroundings. According to them, it was around fifteen years ago that they began noticing it spreading in their forests. Slowly, it expanded into different areas and became increasingly visible across the landscape.

A community member explained:

> "The biggest change we have seen is the arrival of manja konna, the yellow-flowering tree. Around fifteen years ago, we started noticing it spreading in our forests. Today it has occupied large areas. It grows everywhere, especially on dry land. Slowly it spread deeper and deeper into the forest."

For the community, the change was experienced through the disappearance of familiar plants that had once supported their daily lives. They remembered many plants that were once commonly collected but gradually became difficult to find.

They explained that plants such as Kurunthotti, Chunda, Nellikka, and Wild Turmeric had reduced significantly. Many forest tubers that were once collected as food were also no longer available in the same way. These were not just plants known by name; they were part of their everyday food practices, traditional knowledge, and connection with the forest.

The loss of these plants created a strong emotional impact because the community had grown up knowing the forest through these resources.

One respondent described the contrast:

> "There was a time when even a single blade of grass would sprout in the forest. Now many places are covered by manja konna."

The community also shared their observations about what happens beneath these trees. They felt that the areas where Manja Konna grows have become empty, with very little life remaining underneath.

They explained that people believe its flowers, leaves, fruits, and bark are poisonous. They also observed that honey bees do not prefer it. According to their experience, the forest floor beneath these trees does not support the same diversity that they remembered from earlier times.

The changes were also felt in their movement through the forest. Earlier, people could walk through familiar paths and reach different areas easily. Today, they explained that dense growth of invasive plants, including Kongini kaad, has made movement difficult in many places. Old paths that were once regularly used have become blocked.

This change has affected not only people but also the animals that share the forest. Community members explained that earlier, animals had sufficient food available inside the forest. With fewer food plants available, animals increasingly move towards human areas in search of food.

They particularly spoke about elephants entering agricultural areas. According to them, elephants do not come only because of water availability, as many people believe. They explained that even during summer, streams, ponds, and water sources remain available inside their forests. The major problem, according to their experience, is the availability of food.

One community member explained:

> "People often say that elephants come because there is water outside. But that is not true in our forests. Even during summer, there are streams, ponds and water sources. The real problem is food."

They observed that once elephants enter farms and find crops that are easily available, they return repeatedly. This has changed the relationship between people and wildlife, creating fear and difficulty in everyday life.

The changes in the forest have also affected the availability of grazing areas. Community members explained that fodder availability has reduced, making it difficult for families who once depended on cattle. Some people who kept livestock had to sell them because maintaining animals became difficult without sufficient grazing resources.

The same changes affected forest-based income. Earlier, products collected from the forest contributed to household needs. Honey, medicinal plants, and other collected materials provided

support to families. As these resources became harder to find, forest collection alone was no longer enough to sustain livelihoods.

Because of these difficulties, many families gradually began depending more on wage-based work. Community members explained that some people now work under MGNREGA, while others take up work such as farm labour, road work, or other daily wage activities.

For many families, this represented a major change from the way earlier generations lived. Their identity and skills were closely connected with the forest, but changing conditions forced them to look for other forms of income.

The community also explained how these changes affected traditional practices. Earlier, materials required for daily activities and rituals were collected directly from the forest. Certain climbers and natural materials were used for different purposes, including tying and carrying. As these materials became difficult to obtain, people started purchasing alternatives from outside.

This change was not only about replacing one material with another. For the community, these forest materials carried cultural meaning because they connected daily practices with their relationship to nature.

Women in particular experienced these changes in their everyday responsibilities. Since women were traditionally involved in household activities such as cooking and managing family needs, changes in the availability of forest resources created additional difficulties for them.

Community members explained that although Senna wood is available in large quantities, it is not always preferred as firewood. When used for cooking, especially inside traditional kitchens, the smoke can cause discomfort. Women who spend more time near cooking fires experience problems such as eye irritation and burning sensations.

For women, the difficulty was not only finding firewood but also dealing with the health discomfort caused by the available alternatives. Even when certain resources are easily available in the surroundings, they cannot always be used safely for household purposes.

Through these experiences, it became clear that changes in the forest were felt differently by different members of the community. For elders, it represented the loss of a landscape they had

known since childhood. For families, it affected food and income. For women, it created additional challenges in managing everyday household responsibilities while trying to continue traditional practices.

When reflecting on the forest of the past, the community members returned repeatedly to memories of abundance.

They remembered collecting honey, gathering **amla**, finding forest tubers, collecting medicinal plants, and sleeping inside the forest surrounded by the sounds of nature. They remembered a time when people, animals, and plants existed together as part of the same living system.

Today, their memories carry both love and sadness. The forest remains an important part of who they are, but they feel that the relationship they once had with it is becoming increasingly difficult to maintain.

One statement captured the depth of this feeling:

**""There is no peace left in the forest anymore."**

*(Kaadinu ullilekku poyal oru saadhanavum illa.)*."

> For a community whose entire life has been connected with the forest, these words represent more than the absence of resources. They express the feeling of entering a familiar place and finding that the things that once defined it are slowly disappearing.

The forest that once fed them, supported them, and guided their way of life continues to hold emotional importance. They still return to it, still respect it, and still consider it part of their identity. But as each year passes, they feel that the forest of their childhood is becoming a memory that exists only in their stories.

# 4.9 WOMEN'S EXPERIENCES: RESPONSIBILITIES, STRUGGLES, AND CHANGING EVERYDAY REALITIES

The experiences shared by the Kattunaika community also revealed that changes in the forest have affected men and women differently. While the entire community depends on the forest in various ways, women experience these changes through their everyday responsibilities inside the household and community. Their relationship with the forest is closely connected with cooking, caring for family members, maintaining traditional practices, and passing knowledge from one generation to another.

Women have traditionally played an important role in collecting and managing materials required for daily life. Their knowledge was not limited to identifying resources but also included understanding how different materials could be used, preserved, and prepared. Many household practices depended on resources collected from the forest, and women carried the responsibility of transforming these materials into food, medicines, and items needed for everyday activities.

One of the difficulties experienced by women is related to the availability and use of firewood. Although Senna wood is found in large quantities in many areas, community members explained that it is not always suitable for household cooking. Women, who are mainly responsible for cooking, are the ones who experience the direct effects of using such wood.

They explained that when Senna wood is burned inside traditional kitchens, the smoke causes irritation and discomfort, especially affecting the eyes. The burning sensation and irritation create difficulties during cooking, making a daily household activity physically uncomfortable. Since women spend considerable time near cooking fires, they are the ones who repeatedly experience these problems.

For many women, the challenge is not only the discomfort caused by certain types of firewood but also the increasing difficulty in finding suitable materials for household needs. Earlier, many resources required for daily life were collected directly from the forest. Women had detailed

knowledge about these materials and their uses. As these resources became difficult to obtain, they had to adjust their traditional practices and depend more on alternatives from outside.

The changes have also affected women's role in preserving cultural practices. Many traditions within the community involve materials collected from the forest, and women often play an important role in preparing and maintaining these customs. When traditional materials become unavailable, women are required to find alternatives while trying to preserve the meaning of these practices.

The respondents explained that certain materials used during important cultural occasions were once collected directly from the forest. Women were familiar with these materials and their preparation because such knowledge was passed down through generations. However, as these resources became less accessible, some traditional practices slowly changed.

Women also remain important carriers of cultural memory through songs, dances, and community gatherings. Traditional songs performed by women are not merely forms of entertainment; they represent stories, memories, and knowledge inherited from earlier generations. Through these practices, women continue to maintain a connection between the past and the present.

The changing relationship with the forest has therefore affected women not only physically but also emotionally. Many of the activities they performed as part of everyday life were connected with the forest, and changes in resource availability have altered the way these responsibilities are carried out.

Their experiences show that environmental changes are not experienced equally by everyone. For women, the impacts appear through small but continuous changes in daily routines—the difficulty of preparing food, the replacement of traditional materials, and the challenge of maintaining cultural practices in a changing environment.

Through their experiences, it becomes clear that women are not only affected by changes in the forest but are also central to understanding how these changes influence family life, cultural continuity, and community identity.

## ADAPTING TO SENNA

As I spent more time in the field, I began to see how people were adapting to this new reality.

One day, I entered a house and noticed stacks of cut wood piled beside it. Curious, I asked what kind of wood it was.

"Senna," they replied.

"We use it as firewood now."

They explained that burning Senna produces heavy smoke. The smoke irritates the eyes, causes redness, and can make breathing uncomfortable. Some people even experience skin allergies after handling it. Yet despite these problems, they continue to use it because it is one of the few resources that is now abundantly available and legally accessible.

In another settlement in Muthanga, I noticed that many houses had been constructed using Senna wood. Chicken coops were built from it. Fences were made from it. Even supports for agricultural crops were fashioned from Senna poles.

What struck me was not merely the presence of the wood, but what it represented.

People had begun to adapt.

When alternatives disappear, survival often means making use of whatever remains. Communities that once depended on diverse forests are now finding ways to live with an invasive species. They have transformed it into fuel, building material, fencing, and livelihood.

Even the work of removing Senna has become a source of employment. People now earn wages by cutting, uprooting, transporting, and managing the very species that has contributed to the transformation of their environment.

Perhaps this is the most complex part of the story.

Senna spectabilis is not merely an invasive tree. It is a symbol of environmental change, policy failure, adaptation, resilience, and survival. It tells a story of forests that have changed, communities that have endured, and people who continue to find ways to live within a landscape that is no longer the one they once knew.

( Field Notes -30/12/2025 )

# CHAPTER 5

# THEMATIC ANALYSIS AND DISCUSSIONS

# 5.1 INTRODUCTION

Data analysis is a crucial stage in research as it helps to organize, interpret, and derive meaningful insights from the collected information. In this study, thematic analysis was adopted as the method for analysing the qualitative data. Thematic analysis involves systematically examining interview data by identifying, developing, and organizing important themes and patterns that emerge from the responses of participants. The process included a detailed review of the transcripts prepared from the in-depth interviews to understand the experiences, perspectives, and meanings expressed by the respondents. Through this method, recurring ideas and concepts within the data were grouped into relevant themes and sub-themes. As explained by Bryman (2008), themes and sub-themes represent repeated patterns or significant ideas within qualitative data and provide a framework for categorizing and interpreting research findings**.**

The researcher carefully reviewed the interview transcripts to identify recurring experiences, ideas and patterns shared by the participants. The identified information was then organised into major themes and analysed in detail. This chapter presents the major themes that emerged from the study, including:

➢ Creeping of *Senna spectabilis* into the Life of People

➢ Senna and Culture: Changing Relationship Between People and the Forest

➢ Senna and Conflicts: Changing Resource Use and Social Relations

➢ The Forest That Once Fed, Healed and Sustained Well-being

➢ Senna and Women: The Unequal Burden of Forest Invasion

# 5.2 ANALYSIS AND DISCUSSIONS

## A HARMLESS INTRODUCTION: THE BEGINNING OF AN ECOLOGICAL CRISIS

Every ecological crisis has a beginning. The invasion of *Senna spectabilis* in Wayanad did not happen overnight. It developed slowly through a series of human decisions that changed the forest over many years. So, understanding the spread of *Senna spectabilis* is not just about understanding an invasive species. It is about understanding how a healthy and stable ecosystem gradually became vulnerable to invasion.

There was a time when Wayanad was known for its rich forests and exceptional biodiversity. The forest was much more than a collection of trees. It was a living ecosystem where every plant, animal and microorganism had its own place and purpose. Native trees such as jackfruit, mango, fig and many other indigenous species formed a dense canopy. Different varieties of grasses covered the forest floor, while shrubs, herbs and climbers grew beneath them. Tiny ants, insects, reptiles, birds and countless other organisms depended on these plants for food and shelter. Larger mammals relied on the grasslands, streams and native vegetation for survival. Every living organism was connected to another, creating a natural balance that had developed over centuries. The forest sustained itself without human intervention because every part of the ecosystem supported the other.

Over time, this balance began to change. The forest was no longer seen only as a living ecosystem but also as a valuable economic resource. Trees were increasingly valued for the timber they could provide and the industries they could support. As commercial interests grew, the ecological value of the forest received less attention. The people who made these decisions may not have seen their long-term consequences, but the forest and the communities that depended on it continue to experience those effects today.

A major turning point came when large areas of native forest were cleared for paper production through Gwalior Rayons. In place of these natural forests, teak plantations were established. Although trees were planted again, a plantation could never replace a natural forest. A natural

forest contains hundreds of species that depend on one another, while a monoculture plantation supports only a small part of that ecological diversity. As a result, the original structure of the forest changed, making the ecosystem less resilient than before.

The forest underwent another important change when bamboo reached the end of its natural life cycle. After flowering, the bamboo died, leaving large open spaces across the forest. Under normal conditions, these gaps would have slowly recovered through natural regeneration, allowing native vegetation to return over time. Instead, another human intervention was introduced to restore these areas.

That intervention was social forestry.

At first, social forestry appeared to be a practical solution. Its aim was to increase green cover and restore degraded land. However, this study raises an important question. If social forestry was introduced for the benefit of local communities, were those communities involved in deciding how their forests should be restored?

The findings suggest that meaningful community participation was limited. Decisions about afforestation were mainly taken through administrative systems. Forest-dependent communities, who had lived with these forests for generations and understood their seasonal changes, native vegetation and ecological behaviour, had very little role in deciding what should be planted. Instead, restoration decisions were largely made by institutions responsible for forest management.

As a result, a programme introduced in the name of communities gradually became a top-down process. Decisions were made on behalf of the people rather than together with them. Those with administrative authority decided how the forest should be restored, while the people whose lives were closely connected to the forest had little influence over those decisions.

It was during this period that *Senna spectabilis* was introduced. The species was not planted with the intention of harming the forest. It was introduced as part of an effort to restore degraded landscapes. In 1986, the Kerala Forest Department planted fewer than ten *Senna spectabilis* trees at the Muthanga Forest Station because the species was known for its fast growth and attractive yellow flowers. At that time, very little was known about its invasive nature or its ability to

dominate native ecosystems. What appeared to be a harmless and practical decision would later become one of the biggest ecological challenges in Wayanad.

## GOVERNANCE FAILURES AND THE UNINTENDED CONSEQUENCES OF CONSERVATION

The spread of *Senna spectabilis* also highlights an important challenge in forest governance. The findings of this study show that ecological restoration is not only about planting trees or increasing green cover. It also depends on how decisions are made, who takes part in those decisions and whether long-term ecological impacts are considered from the beginning. When these elements are missing, even well-intended conservation efforts can produce outcomes that are very different from what was originally expected.

One of the main concerns identified in this study is the limited involvement of forest-dependent communities in restoration planning. These communities have lived alongside the forests for generations and have developed a deep understanding of the landscape through continuous interaction with it. Their knowledge of native vegetation, seasonal changes and wildlife behaviour is based on lived experience and forms an important part of sustainable forest management. However, this knowledge was not given sufficient importance during the planning and implementation of restoration programmes. Decisions were mainly taken through administrative systems, leaving local communities with very little influence over the process.

This reflects a broader challenge in environmental governance. Conservation programmes are often designed and implemented through institutional structures, while the people who interact with the forest every day remain on the outside of the decision-making process. As a result, valuable local knowledge is not fully used, even though it could contribute to better ecological outcomes. The findings of this study suggest that successful restoration requires collaboration between scientific expertise, government institutions and local communities rather than relying on only one source of knowledge.

Another important issue identified through this study is the need for a stronger precautionary approach in ecological restoration. Environmental decisions, especially those involving biodiversity-rich ecosystems, require careful planning that extends beyond immediate objectives. Restoration strategies should consider not only short-term benefits but also their possible long-term ecological effects. Without such planning, actions intended to improve an ecosystem may unintentionally create new environmental problems.

The findings also show that restoration should focus on rebuilding ecosystems rather than simply increasing tree cover. A restored forest is not measured only by the number of trees it contains but by the recovery of its ecological functions. Native plant diversity, healthy wildlife habitats, natural regeneration and balanced ecological interactions are all essential parts of successful restoration. These aspects should guide restoration planning if long-term conservation goals are to be achieved.

The study further reveals that management challenges continued even after the invasive nature of *Senna spectabilis* became evident. Several control methods were introduced with the intention of reducing its spread. Mechanical girdling and the application of kerosene were among the approaches used to eliminate the trees. However, instead of producing the expected results, these methods often encouraged regeneration. Scientific studies have shown that damaged trees produced multiple coppice shoots, while the openings created during removal allowed large numbers of seedlings to establish. These outcomes demonstrate that management strategies must be based on a thorough understanding of the biology and regeneration behaviour of invasive species. Otherwise, control measures may unintentionally increase the problem they are meant to solve.

The study also points to institutional challenges in managing invasive alien species. Different organisations often work with different priorities, resulting in inconsistent management approaches. While some agencies focus on removing *Senna spectabilis* from protected forests, others continue to recognise its economic value in different contexts, particularly as a source of firewood. Such differences make coordinated management more difficult and reduce the overall effectiveness of conservation efforts. Addressing invasive species therefore requires clear policies, better coordination among institutions and a common long-term management strategy.

The findings of this study suggest that ecological restoration is a continuous process rather than a single intervention. It requires scientific research, regular monitoring, adaptive management and meaningful community participation throughout every stage of implementation. When restoration is guided by these principles, the chances of achieving lasting ecological recovery become much greater.

Ultimately, the experience of *Senna spectabilis* in Wayanad provides an important lesson for future conservation programmes. Effective restoration is not only about repairing damaged landscapes but also about improving the way environmental decisions are made. Strong governance, informed planning, scientific understanding and active participation from local communities are all essential if similar ecological challenges are to be avoided in the future.

The Sustainable Livelihoods Framework also explains that institutions and governance systems play an important role in shaping people's livelihoods. It states that Structures and Processes include the policies, laws, organizations, and institutions that influence how natural resources are managed and how decisions affecting people's livelihoods are made (DFID, 1999). This is clearly reflected in the case of *Senna spectabilis* in Wayanad.

The nature and functioning of institutions, especially the Forest Department, played an important role in both the introduction and management of *Senna spectabilis*. The hierarchical nature of the department resulted in a top-down decision-making process, where the species was introduced without public consultation or participation. The views of local communities, who depend on forests for their livelihoods, were not considered. Moreover, the species was introduced without properly studying how it would affect the ecosystem and the people who depend on it. This shows that the institutions were not fully responsive to ecological and social realities. Therefore, the *Senna spectabilis* invasion is not only an ecological problem but also an institutional one.

The framework also explains that institutions and policies influence how effectively environmental problems are managed. International agreements such as the Convention on Biological Diversity (CBD), national laws like the Biological Diversity Act, 2002, and institutions such as the Kerala State Biodiversity Board and the Kerala Forest Department provide the legal and institutional framework for managing invasive alien species. However, despite these policies and legal provisions, *Senna spectabilis* continues to spread in Wayanad. This shows that there are gaps

between policy and implementation. It also reflects the limitations of institutions in responding effectively to such a complex environmental problem. As a result, the livelihoods of forest-dependent communities continue to be affected.

## THE PARADOX OF INVASIVENESS: WHEN DESTRUCTION BECOMES A LIVELIHOOD

One of the most striking findings of this study is the contradiction created by the spread of *Senna spectabilis*. The species damaged the forest resources that many communities once depended on, yet today it also provides them with temporary employment through its removal. This is the paradox at the centre of the invasion. The same tree that reduced traditional livelihoods has become a source of income for many of the people affected by it.

Before the spread of *Senna spectabilis*, many families living around the forest depended on it for their daily needs. They collected honey, medicinal plants, tubers, fruits and other forest products. These resources supported both their household needs and their income. Their relationship with the forest was built over generations, and their livelihoods were closely connected to the health of the ecosystem.

As the invasion expanded, this relationship slowly changed. Areas that once provided useful forest resources became increasingly difficult to access or less productive. Native vegetation declined, and many forest products became harder to find. As a result, communities that had relied on these resources for generations found it more difficult to continue their traditional way of life. Their dependence on the forest remained, but the forest could no longer support them in the same way.

The effects were felt beyond the communities alone. The invasion also affected natural grasslands and marshy *vayals*, which are important feeding grounds for wildlife. As these habitats became occupied by *Senna spectabilis*, the availability of food for grazing animals declined. Since many wild animals move across the larger forest landscape in search of food and water, changes in these habitats can influence wildlife far beyond a single protected area.

To restore these invaded areas, different removal programmes have been introduced. Many local people now work in these programmes, cutting trees, removing bark and clearing invaded sites.

This work provides wages and creates employment opportunities. However, the livelihood available today exists because an earlier livelihood was lost.

This is the central paradox revealed by the study. People are now earning an income by removing the same species that reduced the forest resources on which they once depended. Their work is helping restore the ecosystem, but it is also a response to a problem they did not create.

This does not mean that restoration programmes are unnecessary. On the contrary, removing *Senna spectabilis* is an essential step in helping native ecosystems recover. At the same time, the findings highlight the importance of creating long-term livelihood opportunities alongside ecological restoration. Temporary employment alone cannot replace the lasting relationship that communities once had with a healthy forest.

Ultimately, the story of *Senna spectabilis* is not only about an invasive tree. It is also about how changes in the environment can reshape people's lives in unexpected ways. The invasion changed the relationship between forests and the communities that depended on them, creating new forms of work while weakening older ways of living. As restoration continues, equal attention must be given to rebuilding both the ecosystem and the livelihoods that have long been connected to it.

## CREEPING OF SENNA INTO THE LIFE OF PEOPLE

Senna has not just creeped into the forest; it has slowly creeped into the lives of the people. What first began as the spread of an invasive tree has gradually entered every part of their existence. It has changed their daily routines, food habits, traditions, relationships, livelihoods and even the way they think about the forest. It is difficult to imagine how a single tree could bring such a deep transformation to an entire community. Who would have thought that introducing something which never belonged to this forest would slowly unwind problems that were never there before.

For the tribal communities, this is not a problem that lasts for a few months or a few years. This lingers through their whole life. They have watched the forest of their childhood slowly change before their own eyes. The places where they once walked with joy have become unfamiliar. The plants they grew up collecting have disappeared one after another. They can clearly see the loss

happening, yet they remain helpless because the change is beyond their control. It is like watching someone you love slowly disappear while being unable to save them.

The invasion of Senna spreads silently. It does not destroy everything in a single day. Instead, it slowly replaces life with emptiness, just as a disease slowly spreads through a healthy body. Every year it occupies a little more space, and every year the community loses a little more of what once made the forest their home. As Senna continues to spread through the forest, its effects also spread through the lives of the people. What was once only an ecological problem has now become a social, cultural and emotional one.

The elders still remember the forest as it once was. They remember walking into it without fear, knowing that it would always provide what they needed. They remember abundance, not scarcity. They remember a forest that fed them, healed them, protected them and gave meaning to their lives. Today, those memories remain, but the forest they remember is slowly disappearing. The pain they carry is not only the loss of resources; it is the loss of a way of life that had existed for generations.

**Senna and Culture**

For the tribal communities, the forest has never been just a collection of trees. It is a part of who they are. Their lives, beliefs, traditions and identity have always been closely connected to it. Every generation has grown up with the forest, learning from it, depending on it and respecting it. This is how important the forest was for them.

One elder described this relationship in the simplest yet most powerful words: "For us, the forest is like a mother." Others may feel comfortable in towns and cities, but they feel comfortable only in the forest. Even today, when there is no work, they still walk through the forest paths because simply being inside the forest gives them happiness. This shows that their relationship with the forest has never been limited to livelihood alone. It is a place where they feel a sense of peace, comfort and belonging.

Their connection with the forest is also deeply spiritual. Before entering the forest, they pray to their deities and ask for protection. They believe that the Almighty will protect them from danger and that the forest has its own guardian spirits and sacred presence. Mariamma is one such deity.

Every hill and every place in the forest is respected. They enter the forest only after offering their prayers. For them, entering the forest is not an ordinary act; it is an act of faith and respect.

From childhood onwards, children accompanied their parents into the forest. Walking ten or even twenty kilometres inside the forest was a normal part of life. It was through these journeys that they learnt about the forest, its seasons and the many resources it provided. The forest was where knowledge was passed from one generation to the next, making it an inseparable part of their lives.

Their cultural practices are also deeply rooted in the forest. During puberty ceremonies, turmeric collected from the forest is traditionally applied to a girl's body as part of the ritual. At the time of death, specific forest climbers are used as ropes to weave a bed for carrying the deceased. Their festivals, songs and dances are also connected to the forest and their traditional way of life. Women perform traditional dances while singing songs inherited from their ancestors, while men dance to the rhythm of drums. These traditions have continued from one generation to another because the forest has always remained at the centre of their lives.

However, the spread of Senna has slowly begun to weaken this relationship. As it expanded across the forest, many native plants that formed an important part of their traditions became increasingly difficult to find. Kurunthotti became scarce. Chunda became scarce. Nellikka reduced. Wild turmeric reduced. Many other useful forest plants also disappeared. As these resources declined, practising traditions that depended on them also became increasingly difficult. The invasion of Senna has therefore affected not only the forest but also the cultural life that has always existed within it.

One elder remembered the old forest with deep emotion. They remembered carrying honey home after long walks inside the forest. They remembered collecting forest tubers, amla and medicinal plants without difficulty. They remembered sleeping inside the forest and waking up to the sounds of birds. They remembered a forest where plants, animals and people lived together in harmony. Those memories remain alive, but the forest they remember is slowly fading away.

Today, when they walk through the forest, they see change everywhere.

**"There is no peace left in the forest anymore."**

These words express much more than the absence of forest products. They reflect the pain of watching a way of life slowly disappear. The forest that once shaped their traditions, protected their beliefs and preserved their culture is no longer the same. They still enter the forest with the same faith, respect and love, but each year it becomes harder to find the resources that once formed the foundation of their lives. This shows that the invasion of Senna is not only changing the ecology of the forest; it is slowly eroding the culture that has lived within it for generations.

**Senna and Conflicts**

The spread of Senna has changed more than the physical landscape of the forest. It has quietly disturbed the social balance that had existed within tribal communities for generations. The conflicts seen today are not simply disagreements between people. They are the result of a forest that can no longer provide what it once did. When the forest began losing its native resources, the stability that depended on those resources also began to disappear. What was once peaceful has slowly become unstable.

Traditionally, every tribe and every family had its own customary forest area. These were not boundaries marked on maps or protected by legal documents, yet everyone knew where they began and ended. These customary lands had been passed down through generations and were accepted and respected by the entire community. Families collected non-timber forest products only from their own areas, and this unwritten system allowed everyone to live without conflict.

The same understanding existed during honey collection. When a family found a beehive, they would leave a mark on it. That mark was enough for everyone else to know that the hive had already been claimed. Nobody disturbed it. There was no need for arguments because mutual respect and trust guided these practices. The forest had enough to provide for everyone, and therefore there was little reason for competition.

However, the creeping of Senna slowly changed this balance. As the invasion spread, useful non-timber forest products declined and many customary forest areas became almost barren. The places where families had collected resources for generations no longer had enough to meet their needs. The forest they depended on was no longer able to support them in the same way.

When resources become scarce, people cannot simply stop searching for food and other essentials. Hunger cannot be ignored; it has to be satisfied somehow. Families who could no longer find enough resources within their own customary areas were forced to enter the customary lands of other families in search of what remained. This was not because they wished to break tradition. It was because they had no other choice.

As more people began entering the lands of others, conflicts slowly emerged. These are not always loud or visible conflicts, but they persist within the community. The unwritten understanding that had kept peace for generations is gradually being challenged by the scarcity of resources. A system that once worked naturally is becoming increasingly difficult to maintain because the forest itself has changed.

This reveals an important reality. The invasion of Senna has not only reduced biodiversity or altered the ecology of the forest. It has also disrupted customary systems of resource use that had remained stable for generations. A tree that first entered the forest has now entered the social life of the community. As the forest continues to lose its native resources, relationships within the community also begin to change. In this way, the effects of Senna extend far beyond the environment, quietly creating tensions that were once unknown and transforming a community that had long lived in balance with its forest.

This is also similar to what the Sustainable Livelihoods Framework explains about Social Capital. The framework states that social capital includes the relationships, social networks, trust, cooperation, and collective action that help people support one another and respond to different challenges (DFID, 1999). This is reflected in the case of *Senna spectabilis* invasion in Wayanad.

The findings of this study show that the invasion of *Senna spectabilis* has affected not only the environment but also the social relationships within and between communities. As access to forest resources has declined, people have had to depend more on one another, while at the same time facing increased competition for the limited resources that remain. Managing the invasion also requires cooperation between local communities, the Forest Department, and other institutions involved in conservation and restoration.

The study further shows that where there is trust, cooperation, and community participation, people are more willing to take part in restoration activities and the management of invasive species. However, weak coordination, limited participation, and poor cooperation between communities and institutions reduce the effectiveness of these efforts. Therefore, the findings support the Sustainable Livelihoods Framework, which explains that strong social capital can improve people's ability to respond to environmental challenges, while weak social capital can increase their vulnerability and reduce the success of conservation initiatives.

## SENNA AND WOMEN

Every crisis leaves its deepest scars on certain sections of society. The findings of this study show that, within the tribal communities, women bear a greater share of the burden created by the spread of Senna. While the invasion affects the entire community, its impacts are not experienced equally. Hidden behind the ecological changes is a gendered reality, where women are forced to carry responsibilities with fewer resources and fewer choices.

Participants explained that women are largely responsible for collecting food for their households. Earlier, they depended on the forest areas surrounding their settlements, where useful forest foods and other resources were easily available. Men, however, often travelled much deeper into the forest. If they could not find a resource in one place, they had the freedom to move further inside or search elsewhere until they found what they needed.

Women did not have the same opportunity. They depended mainly on the resources available within the areas they could safely access. These were the places from which they collected food for their families every day. Unfortunately, these are also the areas where the spread of Senna has become most visible. As native plants disappeared from these forest patches, the amount of food women could collect also began to decline.

At first, one may wonder why women could not simply walk deeper into the forest in search of resources, just as men did. However, the findings suggest that this is not a realistic option. Women do not have the luxury of safety to travel deeper into the forest in search of food and other resources. Their movement is naturally restricted by concerns for safety as well as their responsibilities within the household. As a result, when the nearby forest changes, women are left

with very few alternatives. The burden of the ecological change therefore falls more heavily on them.

For a mother or caregiver, returning home without enough food for the family is more than the loss of forest resources. It becomes a daily source of stress and worry. Every useful plant that disappears means another resource that can no longer be taken home. In this way, the spread of Senna has increased not only the physical difficulty of collecting food but also the invisible emotional burden carried by women.

Another important finding of this study is related to the use of Senna as firewood. Many women explained that they collect Senna because it is the only firewood that is now available in abundance. They can collect as much as they need because it grows almost everywhere. However, burning Senna creates another problem. Participants reported that the smoke causes eye irritation and, in some cases, allergic reactions. Since women are the ones who spend the most time cooking, they are also the ones who are exposed to this smoke every day and therefore experience these health problems more frequently.

This reveals a cruel irony. The same invasive tree that has reduced the availability of the forest resources on which women once depended has now become the resource they are forced to depend upon. Senna has replaced many useful native species, yet it has become the main source of firewood simply because nothing else remains in abundance. Women therefore continue to live with the impacts of Senna at every stage of their daily lives. It reduces the food they can collect, increases the burden of caring for their families and finally follows them into their kitchens, where even preparing a meal exposes them to discomfort. The invasion of Senna has therefore affected women in ways that are often unseen, making them one of the most vulnerable groups within the community.

# THE FOREST THAT ONCE FED, HEALED AND SUSTAINED WELL-BEING

There was a time when tribal families never had to depend on the outside world for their food or medicine. Everything they needed came from the forest. It was the forest that fed them, healed them and supported their well-being. Their daily lives were closely connected to what the forest provided. Food was not something they bought. Medicine was not something they searched for in hospitals. The forest itself took care of their needs. As long as the forest remained healthy, the people also remained healthy. Today, that relationship has slowly begun to break. With the creeping of Senna, the forest is no longer able to provide what it once did, and the effects are now felt in the food, health and overall well-being of the community.

The elders remember a forest that was rich in food. Forest tubers were found everywhere. They collected and ate many kinds of *kizhangu*, including nooru, galasu, binni, ekku, saalu and many other forest foods. They also ate wild fruits and honey. Rice was not their main food then. As one elder said, **"Forest food was our food."** This simple statement reflects how deeply their lives depended on the forest. Their meals came directly from nature, providing them with a wide variety of food throughout the year. The forest did not just satisfy their hunger; it naturally provided a balanced and nutritious diet.

Their health was also closely connected to this way of life. The elders explained that they rarely depended on hospitals or injections. Even though many people were afraid of hospitals because they knew very little about them, they remained healthy because they lived with nature. This does not simply show the absence of hospitals. It shows that the forest itself supported their health through nutritious food, clean surroundings and natural resources that had sustained generations.

The forest was also their natural source of medicine. From childhood, they accompanied their parents into the forest and learnt about the many useful plants that grew there. They collected kurunthotti, chunda, soap kaayi, cheenikka, moovila, orila, sadavari, kalpasham, poopal, wild turmeric, nellikka and many other medicinal plants. Kadumudunga was another important plant, and its tender shoot, *chappu mola koombu*, was eaten. Some plants were used as medicine, some were eaten as food and some were sold through the tribal society for the preparation of Ayurvedic

medicine. This shows that the forest was not only a source of nutrition but also the foundation of their traditional healthcare system.

Honey also held an important place in their lives. Honey collection was part of their daily life and tradition. They collected different varieties of honey, including *vander then*, *cheru then* and others. The honey collected from small bees was considered highly medicinal. It was given to children and used to treat different health problems. Honey was therefore much more than a forest product. It was both food and medicine, passed down through generations as part of their traditional knowledge.

However, this way of life has slowly begun to disappear. As Senna spread across the forest, many native plants and forest foods became difficult to find. The Kattunaika community, which depended the most on the forest, has been greatly affected. The forest tubers that once formed an important part of their daily food are no longer easily available. Honey collection has also reduced drastically, from almost one hundred percent to nearly twenty-five percent. Many other forest food products have also declined. With every resource that disappears, the community loses another part of the system that once supported its food, health and well-being.

As the forest continued to change, the food habits of the community also changed. Earlier, they depended on a wide variety of forest foods that naturally provided the nutrients their bodies needed. Today, much of that diversity has been replaced by ration rice. A community that once depended on the richness of the forest now depends mainly on a single staple food. This is not just a change in what people eat; it is a change in the quality of their nutrition and overall well-being.

The participants shared that many families are able to eat a proper meal only once a day. Food is often not sufficient, and buying food from the market is not always possible because of financial limitations. Earlier, when the forest provided food freely, this burden did not exist. Today, the disappearance of forest foods has made even meeting basic food needs a daily challenge. The loss of forest resources has therefore not only reduced food availability but has also affected the nutritional security of the community.

The effects are seen beyond food alone. Earlier, many families earned an income by selling non-timber forest products through their tribal society. As these products became scarce with the spread

of Senna, this source of income also declined. Many families have now been forced to search for other ways of earning a living, with several depending on MGNREGA for employment. This decline in livelihood further affects their ability to access sufficient and nutritious food, creating a cycle where the loss of forest resources affects both income and well-being.

The findings show that the impact of Senna is far greater than the disappearance of a few plant species. The forest once provided food, medicine and livelihood together, creating a system that naturally supported the well-being of the community. Today, that system is slowly breaking apart. As forest foods become scarce, traditional medicine becomes difficult to access, livelihoods become uncertain and food security continues to decline. The community is forced to depend on alternatives that can never fully replace what the forest once provided.

The forest that once fed them, healed them and supported their well-being is slowly losing its ability to do so. This is perhaps one of the deepest impacts of Senna. It has not only changed the forest landscape but has also weakened a way of life that had sustained generations. What is being lost is not simply food or medicinal plants; it is a complete system of living where the well-being of the people and the well-being of the forest were inseparable.

The experiences of the respondents also reflect the concept of Livelihood Outcomes described in the Sustainable Livelihoods Framework. According to the framework, livelihood outcomes represent the final impacts of environmental and livelihood changes on people's lives, including their income, food security, well-being, reduced vulnerability, and livelihood sustainability (DFID, 1999).

The findings of this study show that the invasion of *Senna spectabilis* has affected livelihood outcomes in several ways. The decline of native vegetation and forest resources has reduced the availability of many products that forest-dependent communities traditionally collected for food, medicine, and income. At the same time, the spread of the invasive species has contributed to changes in wildlife movement, increasing incidents of crop raiding and causing further economic losses for local households. These changes have reduced livelihood security and increased the vulnerability of many families.

The study also shows that the impacts are not limited to economic losses. For many tribal communities, forests are closely linked to their culture, traditions, and identity. As native plant species disappear and forest ecosystems change, people experience the loss of culturally important resources and a weakening of their traditional relationship with the forest. Thus, the invasion affects both material well-being and cultural well-being.

The findings further suggest that effective management of *Senna spectabilis* and the restoration of native vegetation can improve livelihood outcomes. Ecological restoration can increase the availability of forest resources, improve biodiversity, reduce Human–Elephant Conflict, and create better livelihood opportunities for forest-dependent communities. Therefore, restoring native ecosystems is essential not only for ecological recovery but also for improving the long-term well-being and livelihood sustainability of forest-dependent communities.

## SENNA AND HUMAN–ANIMAL CONFLICT

The spread of Senna has not remained limited to changes within the forest. Slowly, its effects have started reaching the lives of people living around the forest. One of the important issues that emerged during the study was the increasing conflict between humans and wildlife. For communities living close to forests, encounters with wild animals have become a growing concern and a part of their everyday struggles.

Human–animal conflict is often understood as animals entering human spaces. However, the issue is much deeper than this. It reflects the changes taking place inside the forest itself. When the forest changes, the lives of animals also change. When animals are unable to find enough food and space within the forest, they naturally move towards areas where food is available. This brings them closer to farms and human settlements, creating conflict between people and wildlife.

The spread of Senna is part of this larger change happening within the forest. As Senna expands, it occupies areas where many native plants, grasses and smaller vegetation once grew. These plants supported the forest ecosystem by providing food and shelter for different forms of life. When these resources reduce, the balance within the forest is disturbed. The animals that once depended on the forest for their needs are forced to search for alternatives outside it.

This shows that the impact of Senna does not end with the disappearance of native plants. The change in vegetation creates a chain of effects that slowly moves from the forest to human spaces. Reduced food availability inside the forest influences animal movement, and this movement affects the people who live close to the forest.

Therefore, human–animal conflict should not be seen as an isolated problem. It is connected to the larger changes happening in the forest landscape. The increasing encounters between humans and wildlife reflect a changing relationship between the forest, animals and the communities that have lived alongside them for generations.

## Increasing Human–Animal Conflict in Wayanad

Human–animal conflict has become a growing concern among communities living close to the forest. What was once an occasional encounter has gradually become a regular challenge affecting everyday life. People living near forest areas now have to deal with increasing risks from wildlife movement, especially in areas where human settlements and forests exist close together.

The seriousness of this issue is reflected in the increasing number of wildlife-related incidents reported in the region. Encounters with elephants, tigers and other wild animals have created fear and uncertainty among communities. For people whose lives are closely connected with the forest and surrounding lands, these incidents have changed their sense of security.

The growing conflict shows how changes in the forest environment are affecting the relationship between humans and wildlife. The boundary between forest spaces and human spaces has become increasingly difficult to maintain, creating challenges for both communities and wildlife

## Senna and Crop Damage

The increasing movement of wildlife into agricultural areas has created serious challenges for farming communities. Crop damage has become one of the major concerns for people whose livelihoods depend on agriculture. The loss is not limited to the destruction of crops; it affects the time, labour and resources invested by farmers throughout the cultivation process.

Farmers face damage from different types of animals, including wild pigs, deer and monkeys. Among these, monkey attacks have become a major concern, especially for coffee farmers. The destruction of coffee plants and loss of ripe coffee cherries directly affects household income, making farming more uncertain.

For farmers, the impact of wildlife damage goes beyond economic loss. After months of hard work, there is always uncertainty about whether the harvest will reach them. This has slowly changed the way people experience farming. Agriculture, which was once a dependable livelihood, has become more stressful and unpredictable.

The connection between Senna and crop damage can be understood through the changing relationship between forests and agricultural lands. As wildlife movement increases due to changes in the forest environment, the pressure on farmlands also increases. Thus, the impact of Senna extends beyond the forest by indirectly affecting agricultural practices and the livelihoods of farming families.

## Farming and Labour Challenges

The increasing conflict with wildlife has changed the way farming is carried out. Earlier, farming was mainly focused on cultivation, where different members of the community contributed through their roles and responsibilities. Today, farmers have to take on an additional challenge: protecting their crops from wildlife.

The time and effort required for farming have increased because farmers must constantly remain alert about possible crop damage. Protecting fields has become as important as cultivating them. This has added more pressure, especially for families who already depend on agriculture for their livelihood.

The problem is not only the physical loss of crops but also the uncertainty created by repeated wildlife disturbances. Farmers invest labour, money and time into cultivation, but the final outcome is no longer predictable. As a result, farming has become more difficult, demanding and less secure than before.

The changes caused by Senna have therefore affected farming indirectly. By influencing the forest conditions that shape wildlife movement, Senna has added another layer of difficulty to agricultural life. What was once a process of growing food has now become a continuous struggle between cultivation and protection.

## Senna, Livelihood Changes and Migration

The difficulties created by wildlife conflict have gradually affected the livelihood choices of communities. When crop losses become frequent and farming becomes uncertain, people are forced to look for other ways to support their families. The problem therefore extends beyond agriculture and begins to affect the larger livelihood system of the community.

For many families, farming is not only a source of income but also a way of life connected to their land. However, repeated losses and increasing challenges make it difficult to continue depending only on agriculture. As a result, some people begin searching for alternative employment opportunities to secure their income.

Migration can be understood as part of this larger chain of changes. It is not simply a personal decision but a response to increasing difficulties created by environmental and livelihood pressures. When the forest changes, wildlife movement changes, agriculture becomes uncertain and people are pushed towards new ways of survival.

In this way, the effects of Senna move beyond ecological changes and enter the social and economic lives of communities. A change that begins within the forest slowly influences the decisions people make about their work, livelihood and future.

## Community Responses and Compensation

When human–animal conflict affects their lives and livelihoods, communities seek support from local institutions such as the Panchayat and the Forest Department. Incidents of crop damage and other losses are reported in the hope of receiving assistance and compensation.

Although compensation provides some support, the process often takes time. For families depending on agriculture, the loss occurs immediately, while financial assistance may come much

later. During this period, households have to manage the damage on their own, creating additional pressure.

Compensation can provide temporary relief, but it does not fully address the deeper challenges created by increasing human–animal conflict. The loss of crops, uncertainty in farming and fear of wildlife encounters continue to affect the daily lives of communities.

The findings show that addressing human–animal conflict requires more than providing compensation after losses occur. It requires understanding the ecological changes that are increasing these conflicts and finding ways to restore a balance between forests, wildlife and the people who live alongside them.

# COMMUNITY AND RESTORATION

One of the most striking findings of this study is the changing relationship between the community and restoration. The spread of Senna has taken away many of the forest resources that once supported people's everyday lives. Yet today, the same plant has become the reason some people are able to earn a livelihood. This is perhaps one of the most unfortunate realities revealed through the study.

The restoration programme has created employment for thirty local community members, who now spend their days removing Senna and helping restore the forest. On the surface, this appears to be a livelihood opportunity. But looking deeper, it reflects a painful reality. The community is now earning because of the very problem that has affected their lives. The forest that once fed them now gives them work only because it first lost its ability to do so.

There is another contradiction hidden within this process. The people removing Senna are not the people who brought it into the forest. They did not create this problem, yet they now carry the responsibility of removing it. They are spending their time, strength and labour trying to correct a change that was never their mistake. It is unfortunate that a community already affected by the invasion must also bear the burden of repairing its consequences.

Earlier, people entered the forest to collect honey, medicinal plants, tubers and other resources that naturally supported their lives. Today, many enter the same forest carrying tools instead of baskets, not to collect what the forest offers, but to remove what has taken those resources away. Their relationship with the forest has changed in a way that few could have imagined.

This does not reduce the importance of restoration. Restoring the forest is necessary. However, the findings remind us that restoration is not only about bringing back trees and biodiversity. It is also about recognising the people whose lives changed with the forest. The community is not simply participating in restoration; they are rebuilding a landscape that they themselves have lost.

Perhaps the greatest irony is this: Senna first reduced their traditional livelihood, and now Senna itself has become a source of livelihood. A community that once depended on a healthy forest now depends, at least in part, on the work created by its damage. This shows how deeply the invasion has entered people's lives. It has not only changed the forest; it has changed the very way people survive from it.

This is also similar to what the Sustainable Livelihoods Framework explains about Livelihood Strategies. The framework states that livelihood strategies are the different activities and choices people adopt to earn a living and cope with changing social, economic, and environmental conditions (DFID, 1999). This is reflected in the case of *Senna spectabilis* invasion in Wayanad.

As the spread of *Senna spectabilis* has reduced the availability of native vegetation and affected forest resources, many people have been forced to change their livelihood strategies. Some households have reduced their dependence on forest resources, while others have increasingly relied on wage labour or other alternative sources of income. These changes were not made by choice but as a way of coping with the loss of livelihood opportunities caused by the invasion.

The findings of this study also show that some people have started using *Senna spectabilis* itself as a livelihood resource. The wood is collected and used as fuelwood and, in some cases, for making simple furniture and other wood products. These activities provide some additional income while also helping to remove the invasive species to a certain extent. However, these are mainly coping strategies rather than sustainable livelihood options.

Thus, the findings of this study are consistent with the Sustainable Livelihoods Framework, which explains that livelihood strategies are not fixed but change as people adapt to environmental pressures and changing livelihood conditions.

# CHAPTER 6

# FINDINGS, SUGGESTIONS

# AND CONCLUSION

# 6.1 INTRODUCTION

This chapter presents the findings and suggestions of the study titled "The Invasive Threat of *Senna spectabilis* in Wayanad: Effects on Biodiversity, Wildlife, and Communities." The study focuses on understanding the spread of *Senna spectabilis* and its impact on the forest ecosystem, biodiversity, wildlife, and the lives of local communities. The study explores the experiences and observations of community members regarding the changes caused by the invasion, supported by information from secondary sources. A case study approach was used to understand the ecological and social impacts of *Senna spectabilis* in Wayanad.

The major findings of the study are presented in the following sections.

# 6.2 FINDINGS

The findings of the study show that the spread of *Senna spectabilis* has created significant changes in the forest landscape of Wayanad. The invasion has affected native plant diversity, wildlife habitats, and the availability of forest resources used by local communities. The data collected from the participants highlights that the increasing dominance of *Senna spectabilis* has created ecological challenges and influenced the relationship between communities and the forest. The major findings of the study are discussed under different themes and sub-themes.

# 6.3 RESEARCH QUESTIONS

## How do local communities and other stakeholders perceive the history and spread of *Senna spectabilis* in Wayanad?

The findings show that local communities and other stakeholders have a similar understanding of the history and spread of *Senna spectabilis* in Wayanad. They do not see it as a problem that appeared suddenly. Instead, they believe it was a slow process that happened over many years. Although the respondents included tribal communities, environmentalists, researchers and forest officials, their views were largely similar. They explained that the spread of *Senna spectabilis* was the result of earlier human activities in the forest rather than a natural process. According to them,

a tree that was once introduced to restore degraded forests has now become one of the biggest environmental challenges in Wayanad.

Most respondents linked the history of *Senna spectabilis* to the period after large-scale deforestation in Wayanad. They explained that many natural forests were cleared for commercial purposes, which disturbed the balance of the ecosystem. To restore these degraded areas, the Forest Department started social forestry and afforestation programmes. As part of these programmes, *Senna spectabilis* was planted because it grew fast, spread quickly and covered open land within a short period. Respondents said that no one knew the tree would later become invasive. At that time, it was considered a useful species that could help restore damaged forests.

Several respondents also pointed to Ponkuzhi as the place where the first nursery of *Senna spectabilis* was established in Wayanad. According to an environmentalist, seedlings from this nursery were later distributed and planted in different places, including roadsides, government offices, nearby settlements and private lands. Respondents explained that these plantations were carried out with good intentions. The tree was accepted by many people because it grew easily and produced bright yellow flowers. Their views are supported by earlier studies, which explain that *Senna spectabilis* was introduced through social forestry programmes before its invasive nature was fully understood (Vinayan et al., 2023).

The respondents explained that the spread of *Senna spectabilis* was slow in the beginning and therefore went unnoticed for many years. They said that many trees planted on private land were later removed for farming, construction and other land uses. However, some trees remained and continued to grow. As these trees matured, they produced a large number of seeds, which gradually spread into nearby forest areas. One respondent explained that a single mature tree can produce thousands of seeds, making it easy for the species to spread once suitable conditions are available. From the respondents' point of view, the invasion did not happen immediately after the tree was introduced. Instead, it slowly increased over time until it became a serious problem across the forest.

The findings also show that respondents did not blame the spread of *Senna spectabilis* on a single reason. Instead, they believed that several human and environmental factors worked together to help the species spread. Researchers explained that climate change, forest fires, bamboo flowering,

open canopy areas and the absence of natural predators created favourable conditions for the plant to grow rapidly. According to them, these changes weakened the growth of native plants and gave *Senna spectabilis* a better chance to establish and spread. This shows that respondents see the invasion not only as the spread of one invasive tree but also as a sign that the forest ecosystem has already undergone major ecological changes.

Even though respondents agreed on the overall history of the invasion, each stakeholder group explained it from its own experience. Environmentalists mainly spoke about the past decisions that led to the introduction of the species through social forestry programmes. Forest officials focused more on the increasing spread of the tree and the difficulties of controlling it. Researchers explained the invasion using ecological factors such as seed production, rapid regeneration and changing climate conditions. Tribal communities, on the other hand, described the history through their own experiences of living in the forest and watching it change over the years. Despite these different perspectives, all stakeholder groups agreed that *Senna spectabilis* has changed from a useful plantation tree into a major threat to the forests of Wayanad.

Another important finding from the interviews is the change in the way people now look at *Senna spectabilis*. Many respondents said that the species is now commonly called **"Rakshasa Konna"**, meaning a dangerous or destructive tree. This shows how people's understanding has changed over time. A tree that was once planted with the hope of restoring forests is now widely seen as a species that threatens biodiversity, wildlife and the livelihoods of forest-dependent communities.

Overall, the findings answer the first research question by showing that local communities and other stakeholders see the history and spread of *Senna spectabilis* as a long-term problem created through human intervention. They believe that the species was introduced with the intention of restoring degraded forests, but its invasive nature was not recognised at that time. As the years passed, it spread slowly across the landscape and became difficult to control. Although different stakeholder groups explain the invasion from different perspectives, they all agree that *Senna spectabilis* has become one of the most serious environmental challenges facing the forests of Wayanad today.

## What environmental changes have been observed in forests following the spread of *Senna spectabilis*, particularly in relation to biodiversity, wildlife movement, and human–wildlife interactions?

The spread of *Senna spectabilis* has brought major changes to the forest ecosystems of Wayanad. The findings from the field interviews show that the invasion has affected the composition of forest vegetation, reduced the availability of native species, influenced wildlife movement patterns, and increased interactions between humans and wildlife. Respondents explained that the changes are not limited to the presence of an invasive tree but have affected the overall functioning of the forest and the relationship between forest-dependent communities, wildlife, and natural resources.

### Changes in biodiversity and forest vegetation

Respondents observed that forests before the spread of *Senna spectabilis* had a greater diversity of native plants, grasses, tubers, medicinal species, and other forest resources. The forest provided food, shelter, and resources for both wildlife and local communities. However, after the expansion of *Senna*, many native plants have become less available in several forest areas.

A Kattunaika community member explained that the forest of the past was open and rich with grasslands. During the post-fire season, fresh green grass used to grow, attracting animals for grazing. The forest floor contained many edible tubers, wild fruits, medicinal plants, and other useful species. However, according to him, after the spread of *Manja Konna* (*Senna spectabilis*), the forest became dense and difficult to move through. Plants such as *Kurunthotti*, *Chunda*, *Nellikka*, wild turmeric, and several forest tubers have reduced considerably.

The respondent explained that earlier, forest food was an important part of their daily life. They collected different varieties of tubers such as *Nooru, Galasu, Binni, Ekku,* and *Saalu*, along with honey, fish, fruits, and medicinal plants. These resources were not only used for consumption but were also collected for traditional medicine and income generation. However, many of these resources are now difficult to find because of changes in forest vegetation.

An environmentalist also explained that *Senna spectabilis* affects the growth of other plants because of its invasive nature. According to the respondent, almost no vegetation grows below a

*Senna* tree. The area beneath the tree becomes empty, with fewer small plants and reduced biological activity. This creates a condition where *Senna* dominates the landscape and reduces the diversity of species that normally exist in a natural forest.

The biologist from the Wayanad Wildlife Sanctuary explained that the rapid spread of *Senna* is supported by several ecological characteristics. The tree produces a large number of seeds, with one mature tree producing thousands of seeds. These seeds remain viable in the soil for several years and form a seed bank, allowing new plants to emerge even after removal efforts. The species can also regenerate through roots and stem portions, making complete removal difficult.

The respondents also identified certain environmental conditions that support the expansion of *Senna*. Forest fires create open spaces where sunlight reaches the ground, allowing the invasive species to establish quickly. Similarly, bamboo flowering and large-scale bamboo death create gaps in the forest canopy, providing suitable conditions for *Senna* growth. Climate change, including changes in temperature, rainfall patterns, and increased carbon dioxide levels, was also mentioned as a factor supporting its rapid spread.

**Changes in wildlife movement and habitat use**

The spread of *Senna spectabilis* has also changed the availability of habitats and food resources for wildlife. Respondents explained that earlier forests had sufficient natural food sources, allowing animals to remain within forest areas. However, with the decline of native plants and grasslands, animals are increasingly moving outside forests in search of food.

A Kattunaika community member explained that earlier animals had access to large grasslands and diverse vegetation inside the forest. These areas supported grazing animals and maintained a natural balance between plants, animals, and people. However, after the spread of invasive plants such as *Senna spectabilis* and *Lantana camara*, these open areas have reduced. The forest has become more closed and many traditional animal pathways have been affected.

The biologist from the Wayanad Wildlife Sanctuary highlighted the importance of *vayals* (marshy grasslands) for wildlife. These ecosystems act as important feeding and water areas, especially during dry summer months. Animals from neighbouring forest landscapes such as Mudumalai, Nagarhole, and Bandipur also depend on these areas. However, the spread of *Senna* into *vayals*

creates a threat by converting these open grasslands into dense woody vegetation. This can reduce grazing areas and affect wildlife that depend on these habitats.

Respondents observed that animals such as elephants, deer, wild pigs, monkeys, and other species have changed their movement patterns due to reduced food availability inside forests. The community members explained that elephant movement towards human settlements has increased, mainly because natural food sources have declined. They also clarified that water availability is not the main issue, as forests still have streams and water sources even during summer. According to them, the major reason for increasing animal movement outside forests is the shortage of food.

The increase in monkey populations was also mentioned by respondents. They explained that monkeys increasingly enter agricultural areas and damage crops, especially coffee plants, because food resources within forests have reduced.

**Changes in human–wildlife interactions**

The ecological changes caused by *Senna spectabilis* have directly affected interactions between forest-dependent communities and wildlife. As forests lose their natural food resources, animals are moving closer to human settlements, increasing the frequency of conflicts.

The former panchayat member explained that human–wildlife conflict has increased significantly over the last decade. According to him, conflicts involving elephants, wild pigs, monkeys, deer, and other animals have become more common. Many people approach the panchayat to register complaints related to crop damage and animal attacks. Although compensation is provided by the Forest Department, respondents reported that the process is often delayed.

The decline of forest resources has also affected the livelihood of communities dependent on forests. The Kattunaika community, which traditionally depended on forest products, has experienced major changes. Earlier, they collected honey, medicinal plants, tubers, fruits, and other non-timber forest products. However, respondents reported that these resources have reduced significantly after changes in forest vegetation.

The reduction in honey availability was specifically mentioned by respondents. The former panchayat member explained that honey collection has declined drastically, from almost complete

availability in the past to a much smaller quantity today. Since forest products no longer provide enough income, many community members have shifted towards other forms of employment such as MGNREGA work and daily wage labour.

The changes in forest resources have also affected traditional practices and cultural connections with the forest. The Kattunaika community explained that many traditional activities, rituals, and daily practices depended on materials collected from forests. Plants used for food, medicine, and cultural purposes have become difficult to obtain, causing gradual changes in their traditional lifestyle.

The findings reveal that the spread of *Senna spectabilis* has resulted in significant environmental changes in Wayanad forests. The invasion has reduced native biodiversity by replacing diverse vegetation with dense *Senna* growth, affected wildlife habitats by reducing food availability and altering movement patterns, and increased human–wildlife interactions due to animals entering human-use areas in search of resources.

The impact of *Senna spectabilis* extends beyond ecological changes. It has affected the livelihood, food systems, and cultural relationship of forest-dependent communities with their environment. Thus, the invasion represents both an ecological challenge and a social issue, influencing biodiversity conservation, wildlife behaviour, and human dependence on forests.

## How has the spread of *Senna spectabilis* influenced the livelihoods, resource use, food security, and well-being of forest-dependent communities?

The spread of *Senna spectabilis* has brought significant changes to the lives of forest-dependent communities in Wayanad, particularly among the Kattunaika community, whose everyday life has traditionally been closely connected with forest resources. The findings from the interviews show that the invasion has affected their access to forest products, traditional food systems, livelihood opportunities, and overall relationship with the forest. The changes observed are not limited to economic losses but also include impacts on nutrition, health, cultural practices, and their sense of connection with the forest.

**Changes in traditional resource use and forest dependency**

Forest-dependent communities in Wayanad have traditionally relied on forests for food, medicine, livelihood materials, and cultural practices. A Kattunaika community member explained that the forest was once their main source of survival. The forest was not considered a separate place but was part of their daily life. They collected food, medicine, and other useful materials directly from the forest.

Earlier, communities collected different varieties of wild tubers such as *Nooru, Galasu, Binni, Ekku,* and *Saalu*. These tubers formed an important part of their traditional diet. Along with tubers, they collected wild fruits, honey, fish, medicinal plants, and other forest products. These resources were available in abundance and supported their food needs throughout the year.

The community members also collected several medicinal plants such as *Kurunthotti*, *Chunda*, *Soap kaayi*, *Cheenikka*, *Moovila*, *Orila*, *Sadavari*, wild turmeric, *Nellikka*, and other forest species. Some of these plants were used for their own health needs, while others were collected through tribal societies and supplied to Ayurvedic companies. According to respondents, materials that were earlier collected in large quantities are now available only in very small amounts.

The spread of *Senna spectabilis* has contributed to this decline by occupying forest spaces where native plants and useful species once grew. Community members explained that after the spread of *Manja Konna* (*Senna spectabilis*), many plants they depended on became difficult to find. Species such as *Kurunthotti*, *Nellikka*, wild turmeric, and several forest tubers have reduced significantly.

**Impact on livelihood opportunities**

The reduction in forest resources has directly affected the livelihood opportunities of forest-dependent communities. Earlier, collection of honey, medicinal plants, and other non-timber forest products (NTFPs) provided both food and income. However, respondents reported that these activities have declined due to the reduced availability of forest resources.

Honey collection was one of the important traditional livelihood activities of the Kattunaika community. The former panchayat member explained that honey availability has reduced

drastically compared to the past. Different varieties of honey, including small bee honey that was considered valuable for medicinal purposes, are now difficult to obtain.

Similarly, forest products that were previously collected and sold through community systems are no longer available in sufficient quantities. Because of this decline, many community members have shifted towards wage-based employment. Respondents mentioned that people now depend more on activities such as MGNREGA work, forest-related temporary employment, agricultural labour, and other daily wage activities.

A community member explained that earlier people could spend several days inside the forest collecting resources because the forest provided everything needed for survival. Today, forest collection alone cannot support a family, forcing people to search for alternative sources of income.

**Changes in food security and nutrition**

The spread of *Senna spectabilis* has also affected the traditional food security of forest-dependent communities. Earlier, forest foods played an important role in maintaining their nutrition. Wild tubers, fruits, honey, and other collected resources provided a diverse diet and reduced dependence on external food sources.

The former panchayat member explained that the Kattunaika community was highly dependent on forest foods, especially wild tubers. However, due to the decline of non-timber forest products, these traditional foods are becoming unavailable. As a result, the community has become increasingly dependent on ration supplies, especially rice.

According to the respondent, many families who earlier had access to diverse forest foods now depend mainly on ration rice. He explained that some families are able to have a complete meal only once a day, showing how the loss of forest resources has affected their nutritional security.

The community members also reflected on how their food habits have changed over time. Earlier, forest foods were considered their main source of nutrition, and they believed that their traditional lifestyle supported better health. The reduction of these resources has therefore affected not only food availability but also their traditional knowledge related to collecting, preparing, and using forest foods.

**Impact on health and well-being**

The decline of forest resources has influenced the overall well-being of forest-dependent communities. Respondents explained that the forest was traditionally connected with physical health, emotional well-being, and cultural identity.

A Kattunaika community member described the forest as their home, market, and hospital. According to him, people earlier depended on medicinal plants collected from the forest for treating health problems. They also believed that their traditional diet and active lifestyle helped maintain good health.

However, the reduction of forest foods and medicinal plants has weakened this relationship. The loss of access to traditional resources has increased dependence on external systems for food and healthcare. The community members expressed that the forest, which once provided everything needed for life, now provides much less.

The changes have also affected their emotional and cultural connection with the forest. Earlier, people could move freely through forest paths, stay inside forests for collecting resources, and participate in activities connected with their traditions. Respondents explained that invasive plants have blocked pathways and reduced access to areas that were once familiar parts of their lives.

**Changes in cultural practices and traditional knowledge**

The spread of *Senna spectabilis* has also affected cultural practices associated with forest use. Many traditional activities depended on plants and materials collected from the forest. Respondents explained that materials used for rituals, daily activities, and traditional practices have become difficult to obtain.

The community members described that their songs, dances, beliefs, and rituals are deeply connected with the forest. Before entering the forest, they traditionally pray to their deities and seek protection. However, as forest resources decline, some practices connected with forest collection and traditional knowledge are gradually disappearing.

The decline of plant diversity has therefore affected not only material resources but also the cultural relationship between the community and the forest.

The findings show that the spread of *Senna spectabilis* has significantly influenced the livelihoods, resource use, food security, and well-being of forest-dependent communities in Wayanad. The invasion has reduced the availability of important forest resources such as tubers, honey, medicinal plants, and other non-timber forest products. This has weakened traditional livelihood systems and increased dependence on wage labour and external food supplies.

The decline of forest resources has also affected nutrition, health practices, cultural traditions, and the emotional connection communities share with forests. For communities such as the Kattunaikas, the impact of *Senna spectabilis* is therefore not only an ecological issue but also a social and cultural challenge that has changed their traditional way of life.

## What management and restoration measures have been undertaken to address the spread of *Senna spectabilis*, and what outcomes and challenges have emerged from these efforts?

The spread of *Senna spectabilis* in Wayanad has resulted in various management and restoration efforts involving government agencies, research institutions, non-governmental organisations, and local communities. The findings show that controlling *Senna* is a complex process because of its rapid regeneration capacity, large seed production, and ability to spread even after removal attempts. The restoration efforts have therefore focused not only on removing the invasive species but also on restoring native forest vegetation and involving local communities in conservation activities.

### Efforts for removal and control of *Senna spectabilis*

The respondents explained that several methods have been attempted to remove *Senna spectabilis*. However, complete removal has remained difficult due to the biological characteristics of the plant. An environmentalist explained that initial attempts showed that simply cutting the tree was

not effective because new shoots emerged from the remaining parts of the plant. Even after cutting with heavy machinery such as JCB, portions of the plant remain in the soil and regenerate.

Different methods such as cutting, debarking, applying chemicals, and uprooting have been tested. According to the environmentalist, debarking can be effective if done carefully, but it requires proper execution. Chemical treatment can kill the tree but creates concerns because it may also affect surrounding plants, animals, and the soil environment. At present, uprooting is considered one of the more effective methods, especially during the monsoon season when the soil becomes soft. However, respondents highlighted that this method requires continuous monitoring and repeated removal because new plants can emerge from existing seeds in the soil.

The Kerala Forest Research Institute (KFRI) studied different approaches for controlling *Senna*. Later, organisations such as the Wildlife Conservation Society (WCS) became involved in removal activities. Respondents explained that these organisations emphasised removing even small *Senna* plants before they become mature trees and produce large quantities of seeds.

**Community-based restoration efforts**

The findings show that recent restoration approaches have increasingly involved local communities. The Keystone Foundation, in collaboration with the Forest Department, has initiated restoration work focused on removing *Senna spectabilis* and recovering native forest ecosystems.

According to the respondents from Keystone, the project has employed 30 local community members and two ecologists for restoration activities. Local people were selected because of their knowledge of the landscape and their understanding of forest conditions. The restoration team uses different methods, including debarking and uprooting, depending on the condition and size of the tree.

A specific restoration experiment was conducted at Tholpetty in 2024, where a method involving cutting the tree, scraping the stump, and covering it with soil was tested. After three months, new shoots were removed, causing the tree to gradually dry and die. According to the respondents, this method showed positive results, and the team has treated around 16,000 trees so far. The treated areas are monitored continuously for several months to ensure that the trees do not regenerate.

**Restoration of native vegetation**

The management efforts have also focused on restoring native forest species after *Senna* removal. The Keystone Foundation has established a nursery to support ecological restoration. The nursery grows around 115 native plant species, including Thanni (*Terminalia bellirica*), Karimarudhu (*Terminalia elliptica*), Ungu (*Pongamia pinnata*), Pathiri (*Stereospermum colais*), and Soap nut (*Sapindus trifoliatus*).

These native species are planned to be replanted in areas cleared of *Senna* to rebuild the original forest structure. Respondents explained that restoration does not end with removing *Senna*, as continuous monitoring is necessary to ensure the survival of newly planted native species and prevent the re-establishment of invasive plants.

**Utilisation of removed *Senna* biomass**

Another approach adopted in the management process has been the utilisation of removed *Senna* wood. Respondents explained that the Tamil Nadu government followed a model where paper mills were allowed to remove *Senna* trees and use the wood for paper pulp production. Kerala also adopted a similar approach, where approximately 5,000–10,000 tonnes of *Senna* wood were supplied to paper mills.

This approach helped reduce the amount of removed biomass while also creating employment opportunities. However, respondents highlighted that working with *Senna* wood has health risks. The sap and dust released during cutting can cause allergic reactions, skin irritation, swelling, and breathing-related problems among workers.

**Outcomes of restoration efforts**

The restoration initiatives have produced some positive outcomes. One major outcome has been the creation of employment opportunities for local communities. Through restoration projects, local residents have received regular work opportunities in invasive species removal and forest restoration activities.

The involvement of local communities has also strengthened participation in forest management. Respondents explained that local people understand the landscape, know the locations where *Senna* has spread, and can contribute valuable knowledge to restoration activities.

Another important outcome is the beginning of native forest recovery. Through the establishment of nurseries and planting of native species, restoration efforts are attempting to move forest areas back towards their original ecological condition. The focus has shifted from only removing the invasive species to rebuilding biodiversity and restoring ecosystem functions.

**Challenges in management and restoration**

Despite these efforts, respondents identified several challenges in controlling *Senna spectabilis*. The major challenge is the biological nature of the species. Its large seed production, long-lasting seed bank, and ability to regenerate from roots and stems make complete removal extremely difficult.

The environmentalist explained that even after mature trees are removed, seeds already present in the soil can produce new plants years later. Therefore, restoration requires continuous removal and monitoring over a long period.

Another challenge is the scale of infestation. According to the biologist from the Wayanad Wildlife Sanctuary, *Senna spectabilis* has spread across approximately 6,000 hectares of forest area. Managing such a large area requires significant financial resources, manpower, and long-term planning.

The restoration process also faces ecological challenges. Removing *Senna* creates open spaces, but these areas can again become suitable for invasive species if native vegetation does not recover quickly. Therefore, restoration requires careful planning to ensure that cleared areas are occupied by native plants.

Health risks for workers involved in removal activities are another concern. Respondents reported that contact with *Senna* sap and dust can cause allergies and skin problems, creating occupational risks for those engaged in cutting and removal work.

The findings show that management of *Senna spectabilis* in Wayanad has involved multiple approaches, including mechanical removal, debarking, uprooting, experimental control methods, utilisation of removed biomass, and restoration of native vegetation. Recent efforts have increasingly focused on community participation and ecological restoration rather than only removal.

Although these initiatives have created employment opportunities, improved local involvement, and started the process of forest recovery, controlling *Senna* remains a major challenge. The species' rapid regeneration, extensive seed bank, large area of spread, and continuous monitoring requirements make long-term management necessary. The findings indicate that successful restoration will require sustained efforts combining scientific methods, local knowledge, and continuous involvement of communities and conservation organisations.

# 6.3 SUGGESTIONS

- Any programme that affects local communities, such as social forestry or restoration projects, should be planned carefully with proper ecological and social studies before implementation.
- Species selection for plantations should be done wisely. Before introducing any species, its long-term impact on native biodiversity, ecosystems, and local livelihoods should be tested and evaluated.
- Communities should be included in decision-making processes. Their knowledge, experiences, and concerns should be considered while planning and implementing restoration activities.
- Restoration should focus on both ecological recovery and community well-being. Conservation efforts should also provide suitable livelihood opportunities for affected people.
- Government departments, NGOs, research institutions, and local communities should work together because invasive species management is a large-scale issue that cannot be solved by one organisation alone.
- Restoration programmes should be planned at the landscape level because invasive species do not follow administrative boundaries.

- More funds should be allocated for long-term restoration, monitoring, and maintenance rather than only for short-term removal activities.
- Pilot studies should be conducted before large-scale implementation of any ecological intervention to understand possible risks and improve management strategies.
- Regular monitoring should be included in restoration programmes to evaluate ecological recovery and make necessary changes over time.
- Future environmental policies should focus on prevention, early detection, and careful planning to avoid similar ecological problems in the future.
- Awareness programmes should be strengthened among communities, decision-makers, and institutions to promote sustainable management of natural resources.

# 6.4 CONCLUSION

This study shows that invasive alien species are not only an ecological problem but also a social and livelihood concern. The invasion of *Senna spectabilis* in Wayanad has affected forest ecosystems, native biodiversity, and the daily lives of communities that depend on forests. The changes caused by this invasive species have influenced the availability of forest resources, traditional practices, and the relationship between people and their surrounding environment.

The study highlights that managing invasive species requires more than simply removing the invasive plants. Restoration should be a long-term process that focuses on recovering native vegetation, improving ecosystem health, and supporting the communities connected with these landscapes. A successful restoration programme should consider both ecological recovery and the needs of local people.

The findings also show the importance of careful planning before implementing any environmental programme. Activities such as social forestry, plantation development, and introduction of new species should be carried out only after proper scientific evaluation and understanding of possible future impacts. Decisions that affect forests and communities should be made with proper knowledge, planning, and involvement of local people.

Community participation is one of the most important aspects of sustainable restoration. Local communities have a close connection with forests and possess valuable knowledge about their

surroundings. Their experiences and suggestions should be included in conservation planning. At the same time, the livelihood challenges faced by communities due to invasive species management should be recognised and addressed.

The management of *Senna spectabilis* requires cooperation between government departments, research institutions, NGOs, and local communities. Since ecological problems do not follow human-made boundaries, joint efforts and coordinated action are necessary for effective restoration. Long-term funding, continuous monitoring, and regular evaluation are important to ensure that restoration efforts achieve their goals.

Overall, this study emphasises that restoring ecosystems affected by invasive species is a combined ecological and social responsibility. The experience of *Senna spectabilis* in Wayanad shows that conservation efforts can succeed only when scientific knowledge, community participation, and proper planning work together. Sustainable restoration should aim not only to protect biodiversity but also to maintain the well-being of the people who are closely connected with these ecosystems.

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# ANNEXURE

**Title:** The Invasive Threat of *Senna spectabilis* in Wayanad: Effects on Biodiversity, Wildlife, and Forest-Dependent Communities

## RESEARCH QUESTION

### General research question

What has been the process of invasion of Senna spectabilis in the forests of Wayanad, and how has it shaped biodiversity, wildlife behaviour, livelihoods, food security, and the well-being of local communities? How have restoration efforts been designed and managed to mitigate these impacts?

### Specific research question

How do local communities and other stakeholders perceive the history and spread of Senna spectabilis in Wayanad?

What environmental changes have been observed in forests following the spread of Senna spectabilis, particularly in relation to biodiversity, wildlife movement, and human–wildlife interactions?

How has the spread of Senna spectabilis influenced the livelihoods, resource use, food security, and well-being of forest-dependent communities?

What management and restoration measures have been undertaken to address the spread of Senna spectabilis, and what outcomes and challenges have emerged from these efforts?

## SEMI-STRUCTURED INTERVIEW SCHEDULE

Part 1: History of *Senna spectabilis* in Wayanad

1. Since when have you noticed the widespread growth of *Senna spectabilis* (Manjakkonna) in your area?
2. What changes have you observed in the growth and spread of *Senna spectabilis* during the last 10–20 years?
3. Do you remember any specific reason for the introduction or spread of *Senna spectabilis* in this area?

Part 2: Changes in Nature and Wildlife

1. What changes have you observed in native plants and trees in areas where *Senna spectabilis* has spread?
2. Have you noticed any changes in the number, feeding behaviour, or movement of wildlife such as wild boar, deer, and birds?
3. How has the spread of *Senna spectabilis* affected elephant movement and human–elephant interactions in your area?
4. Have you noticed any changes in the presence of honeybees and butterflies?
5. Do you think changes in climate, such as increased or decreased rainfall, have contributed to the spread of *Senna spectabilis*?

Part 3: Impact on Livelihoods and Women

1. Has the spread of *Senna spectabilis* affected the availability of forest resources such as tubers, mushrooms, wild fruits, and leafy vegetables? If yes, how has it affected your food security and daily life?
2. Has the spread of *Senna spectabilis* created difficulties for women in collecting forest resources such as firewood, fodder, and medicinal plants? What are the major challenges faced by women because of this?
3. Has the spread of *Senna spectabilis* affected the livelihoods of people who depend on collecting and selling forest products?
4. Is the wood obtained after removing *Senna spectabilis* used for any purpose, or is it simply destroyed?

Part 4: Health Impacts

1. Have you or anyone in your community experienced health problems such as skin irritation, breathing difficulties, or other illnesses due to *Senna spectabilis*?
2. Has the decline in traditional medicinal plants affected your healthcare practices?
3. Do people involved in removing *Senna spectabilis* experience any health problems or safety risks?

Part 5: Forest Restoration Efforts

1. Who are the main groups involved in removing *Senna spectabilis* in your area?
2. What motivates you to participate in *Senna spectabilis* removal activities?
3. What methods are used to remove *Senna spectabilis*, and are native plant species replanted after its removal?
4. Do government officials or forest authorities seek your knowledge and opinions regarding forest management and restoration?
5. What support is needed to continue *Senna spectabilis* removal and forest restoration activities?