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Foreword

Indian agriculture is increasingly challenged by climate variability; land degradation, fragmented farm holdings, biodiversity loss and human-wildlife and livestock conflicts. In this context, field boundaries, bunds and farm margins represent an important but often underutilized resource for strengthening farm protection while generating additional ecological and economic benefits. Conventional fencing systems such as masonry walls, barbed wire and concrete barriers can be costly and ecologically inert. Biofencing offers a nature-based, low-input and multifunctional alternative by integrating living trees, shrubs and other plants along farm boundaries.

The technical bulletin entitled "**Biofencing for Sustainable Agroforestry: Integrating Farm Protection, Biodiversity Conservation and Climate Resilience**" presents biofencing as a practical approach to transform field boundaries into productive agroforestry spaces. Carefully selected multipurpose species can provide farm protection, fodder, fruits, fuelwood and other products while supporting pollinators and beneficial organisms, reducing soil erosion, conserving moisture, enhancing carbon sequestration and improving farm-level climate resilience.

The concept is closely aligned with the vision of "*Har Medh Par Ped*", implemented through the Sub-Mission on Agroforestry (SMAF) during 2016–17 to 2021–22, which promoted tree planting on agricultural boundaries and within farming systems. Biofencing provides a practical pathway for strengthening this vision by converting otherwise underutilized boundary spaces into multifunctional living infrastructure. It also contributes to several United Nations Sustainable Development Goals (SDGs), particularly SDG 1, SDG 2, SDG 6, SDG 8, SDG 12, SDG 13 and SDG 15 through livelihood diversification, sustainable food production, resource conservation, climate action and biodiversity enhancement.

This bulletin brings together scientific knowledge and field-level practices on species selection, biofencing design, multi-tier combinations, agro-ecological suitability and management of important multipurpose species such as *Carissa carandas*, *Prosopis cineraria*, *Agave* spp., *Acacia senegal* and *Ziziphus mauritiana*. The proposed Biofencing Suitability Index (BSI) and practical combination models further facilitate site-specific selection and adoption by farmers. As India scales up its national agroforestry goals to cover 53 million hectares by 2050, practical nature-based technologies like biofencing will play a pivotal role in empowering smallholder farmers, enhancing carbon sequestration, and supporting sustainable land management. The approach is closely aligned with the vision of Viksit Bharat@2047 by promoting productive, climate-resilient, resource-efficient and sustainable agricultural landscapes while strengthening farmers' livelihoods and ecological security.

I compliment the authors and research team for their efforts in synthesizing scientific evidence and practical knowledge into this valuable publication. I am confident that this technical bulletin will serve as a useful reference for researchers, extension personnel, policymakers, forestry professionals and farmers, and will contribute to wider adoption of biofencing for productive, biodiverse and climate-resilient agroforestry landscapes in India.

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Preface

Agroforestry is increasingly recognized as a nature-based solution to the interconnected challenges of climate change, land degradation, biodiversity loss, resource scarcity and declining farm profitability. In this context, biofencing offers a simple, cost-effective and ecologically sound approach for protecting agricultural fields while transforming underutilized field boundaries into productive components of agroforestry systems. Unlike conventional fencing materials, living fences established with suitable trees, shrubs and multipurpose species can provide long-term ecological, economic and social benefits.

Biofencing provides protection against stray livestock, wind, soil erosion and unwanted entry, while creating habitats for birds, pollinators and beneficial insects. Depending on species selection and design, it can additionally provide fruits, fodder, fuelwood, timber, medicinal products, nectar and other useful products. Thus, properly designed biofencing can transform field boundaries into multifunctional productive spaces supporting farm protection, biodiversity conservation, biomass production and livelihood diversification. Under changing climatic conditions, perennial trees and shrubs along farm boundaries can contribute to carbon sequestration, microclimate regulation, soil and water conservation and landscape-level biodiversity. Selection of species according to local climate, soil, water availability, farm size and farmers' needs can enhance the resilience and resource-use efficiency of farming systems. Integration of biofencing with fruit-based, silvicultural, hortisilvipastoral and other agroforestry systems can further strengthen farm productivity and ecological stability.

Biofencing also complements the vision of "*Har Medh Par Ped*" (Tree on Every Field Boundary), promoted through the Sub-Mission on Agroforestry (SMAF) during 2016–17 to 2021–22, by promoting productive utilization of agricultural boundaries for tree-based systems. It provides a practical pathway for transforming this principle into multifunctional living infrastructure that generates multiple benefits without substantially interfering with the main cropped area. The approach is also aligned with Viksit Bharat@2047, through its emphasis on productive, resource-efficient, climate-resilient and sustainable agriculture. Furthermore, multifunctional biofencing contributes to several United Nations Sustainable Development Goals (SDGs), particularly SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action) and SDG 15 (Life on Land) through livelihood diversification, resource conservation, carbon sequestration, biodiversity enhancement and sustainable land management.

This technical bulletin, entitled "**Biofencing for sustainable agroforestry: Integrating farm protection, biodiversity conservation and climate resilience**" provides scientific and practical information on biofencing principles, species selection, design, establishment, management and ecosystem services. It is intended to serve researchers, students, extension personnel, policymakers, development agencies, forestry professionals and farmers in promoting sustainable and climate-resilient agroforestry. It is hoped that this publication will encourage wider adoption of biofencing and contribute to productive, biodiverse, resilient and sustainable agricultural landscapes in India.

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Contents

Chapter 1 Introduction

Biofencing also known as living fencing is a sustainable agroforestry practice that involves establishing a dense, continuous line of living plants along farm perimeters. Unlike conventional fences made of wood, wire, or concrete, biofences are permanent, ecological assets that evolve over time. They serve a triple purpose: providing robust physical security (Farm Protection), creating essential habitats for local flora and fauna (Biodiversity Conservation), and acting as microclimate regulators (Climate Resilience). In the context of modern agroforestry, biofencing is no longer viewed merely as a barrier but as a dynamic "*Biodiversity Island*" that bridges the gap between agricultural productivity and environmental stewardship (Montagnini and Fierro, 2024).

Agroforestry systems integrate trees with agricultural crops and livestock to improve farm productivity, ecological stability, and livelihood security. These plantations require effective protection during establishment because young trees and crops are highly vulnerable to grazing by domestic animals, wildlife damage, and unauthorized entry. Reduction in common grazing lands and loss of natural vegetation have increased pressure on agricultural fields, resulting in damage to plantations by cattle, goats, and sheep etc. Therefore, protective boundary systems are essential for securing farm resources and improving plantation survival. Plant-based barriers such as live fences, shelterbelts, windbreaks, and hedgerows are key components of agroforestry that protect fields, improve soils, and buffer climate extremes. They also deliver fuel, fodder, fruits, timber and many other services that support farm income and food security. Agroforestry as climate smart infrastructure integrating trees with crops and/or livestock improves microclimate, soil health, and water regulation, and is widely recognized as a climate smart practice (Fahad et al., 2022; Dobhal et al., 2024; Rolo et al., 2023). Shelterbelts, windbreaks and live fences act as vegetative bio-shields, reducing wind speed, moderating temperature by 2-4 °C, cutting runoff by 20-50%, and thus stabilizing yields under heat, storms and drought (Dobhal et al., 2024; Awazi, 2022). Biofencing elements improve soil organic matter, structure, and moisture, thereby enhancing soil health and resilience (Fahad et al., 2022; Rolo et al., 2023; Pakaya et al., 2025). They also supply multiple provisioning services (fuelwood, timber, fodder, fruits) and regulating services (windbreaks, erosion control, pest regulation, carbon sequestration) that reduce climate vulnerability in smallholder systems (Awazi, 2022; Morantes-Toloza & Renjifo, 2018)

Traditional fencing methods such as brick walls, concrete structures, and wire fencing provide physical protection but involve high establishment costs, require external materials, and do not provide additional ecological benefits (Yadav et al., 2021). Biofencing offers a sustainable alternative by using living plants as protective boundaries around farms and agroforestry systems. However, successful establishment of agroforestry plantations often faces challenges such as grazing pressure, wildlife damage, wind erosion, boundary encroachment, and climatic stresses. Biofencing provides a sustainable alternative by using living plants as protective barriers around agricultural fields. These plant-based boundaries protect crops while simultaneously providing additional benefits such as fodder, fruits, fuelwood, medicinal products, carbon storage, biodiversity conservation, and microclimate improvement.

In order to increase farmers' income and boost climate resilience, India's Sub-Mission on Agroforestry (SMAF), also known as "*Har Medh Par Ped*" was started in 2016-17 to promote tree-based farming on agricultural land alongside crops and cropping systems. Boundary and peripheral plantations were a significant SMAF intervention, offering a solid policy basis for the creation of multipurpose biofencing systems. By converting field boundaries into productive biological zones that offer agricultural protection, biomass, feed, habitat for wildlife, soil and water conservation, and carbon sequestration, biofencing can further operationalize this strategy. Because they allow for more tree-based production while reducing direct competition with the farmed area, boundary plantations are especially important. Therefore, the "*Har Medh Par Ped*" vision can be translated into diverse, resource-efficient, climate-resilient agroforestry landscapes through the use of multifunctional biofencing. Even though SMAF was in place from 2016–17 to 2021–2022, its fundamental ideas still guide the growth of agroforestry, with RKVY presently implementing the reorganized Agroforestry Component. Practical nature-based technologies like biofencing will be crucial in empowering smallholder farmers, improving carbon sequestration, and promoting sustainable land management as India expands its national agroforestry plans to encompass 53 million hectares by 2050. By encouraging productive, resource-efficient, climate-resilient, and sustainable agricultural landscapes while bolstering farmers' livelihoods and ecological security, the strategy closely aligns with the vision of Viksit Bharat@2047.

Biofencing or live fencing is particularly important for small and marginal farmers adopting agroforestry systems because it reduces external input costs and converts farm boundaries into productive areas. The future of biofencing in agroforestry is characterized by a transition from simple boundary markers to multi-functional, technology-driven ecosystems that address global challenges such as food security, climate change, and human-wildlife conflict. India, a global leader in this field, has already launched plans to expand agroforestry, including biofencing, to 53 million hectares, signaling a massive scale-up in adoption

Need of Biofencing for Sustainable Agroforestry

Because it offers a living, multipurpose barrier that safeguards farms while enhancing ecological and economic functions, biofencing is becoming more and more significant in sustainable agroforestry. Living fences can improve microclimate, minimize wind and soil erosion, preserve soil moisture, offer habitat for wildlife, and help mitigate and adapt to climate change. Biofencing can increase farm resilience while producing extra goods like fodder, fuelwood, fruits, and biomass in India, where agroforestry is encouraged to improve productivity, profitability, diversity, and ecosystem sustainability. Additionally, using trees and shrubs as living fences can reduce reliance on chemical inputs by supporting pollinators and beneficial creatures and acting as natural insect barriers. Therefore, biofencing provides a low-input, natural way to incorporate resource efficiency, climatic resilience, biodiversity conservation, and farm protection into sustainable agroforestry systems.

Utilizing the Boundaries of Agricultural Fields

India's fragmented agricultural landscape contains extensive field-boundary and bund spaces that remain largely underutilized despite their potential to provide multiple ecosystem services. Field boundaries are often underutilized "liminal spaces" in traditional farming. Strategic integration of multipurpose trees and shrubs along these boundaries through biofencing can convert otherwise unproductive linear spaces into productive agroforestry niches, contributing to farm protection, biomass production, biodiversity conservation, carbon sequestration, soil and water conservation, and climate resilience. Utilizing these perimeters for biofencing transforms them into functional zones:

- **Strategic Buffer Zones:** Biofences act as buffers between intensive agricultural activity and neighboring ecosystems, reducing the runoff of pesticides and fertilizers into water bodies (Sivaprakash et al., 2024;Vellankanni & Saravana Ganthi, 2022).
- **Ecological Corridors:** By connecting fragmented forest patches, biofences allow wildlife, especially pollinators and beneficial insects, to move safely across the landscape (Montagnini and Fierro, 2024).

- **Space Efficiency:** Establishing multi-functional barriers on the boundary ensures that the interior of the field remains dedicated to primary crops while the perimeter produces secondary yields like fodder, fruit, or medicine (Vellankanni & Saravana Ganthi, 2022).

Types and Design of Biofencing as per classification of agroforestry systems:

Biofencing fits into several agroforestry system types: silvo-arable (windbreaks, shelterbelts around crops), silvopastoral (live fences and hedges around pastures), and agrosilvopastoral mosaics (Fahad et al., 2022; Awazi, 2022; VijayKumar et al., 2024). Shelterbelt performance depends on structural parameters such as porosity, height, width, orientation and species mix; multi-row, multi-species designs with moderate porosity maximize wind reduction and soil protection in arid regions (Aili et al., 2025; Wu et al., 2022).

Adoption and farmer perception

Live fences and boundary plantings are among the most widely adopted agroforestry practices where extension services and education are available, but labour, establishment costs, and knowledge gaps can limit uptake (Gashu et al., 2025; Morantes-Toloza & Renjifo, 2018). Systematic reviews show agroforestry interventions can significantly increase yields and modestly raise incomes, especially where soil fertility is low and tree-based soil improvement or protection measures are used (Castle et al., 2021 & 2022).

Biofencing must be designed to minimize tree-crop competition for water, light and nutrients, using appropriate spacing, canopy management and species choice, especially in water limited areas (Rolo et al., 2023; Zha & Zhang, 2025). Policy support, incentives (including payments for ecosystem services), and targeted training are highlighted as necessary to scale climate-smart agroforestry, including biofencing components, especially for smallholders (Ntawuruhunga et al., 2023; Zha & Zhang, 2025; & Gashu et al., 2025). Biofencing offers significant potential for sustainable agroforestry, but key unresolved questions still remain (table 1). Studies are needed to identify the most effective species combinations and planting designs across different agroecological regions. More quantitative evidence is required to assess its impact on farm income, livelihood security, and climate resilience. Understanding the economic and environmental benefits of biofencing will support wider adoption. Additionally, effective policy incentives and institutional support mechanisms are essential to promote large-scale implementation among smallholder farmers. Also what is the potential of multifunctional biofencing along field boundaries to enhance biomass production, carbon sequestration and ecosystem services across India's agricultural landscapes?

Table 1: Key unresolved questions on biofencing in agroforestry

Question	Why it matters
What species mixes and planting geometries make the most effective live fences across different agroecological zones?	Species choice and structure strongly influence protection, productivity and water use, but comparable data are limited.
How do biofencing systems quantitatively affect household income and risk under increasing climate extremes?	Existing impact evidence on income and resilience is still sparse and heterogeneous.
What incentive and policy packages most effectively scale biofencing adoption among smallholders?	Adoption is constrained by costs, labour, and tenure; better-designed support could accelerate uptake.
How much additional productive area, biomass, carbon and ecosystem-service potential can be generated by converting field boundaries into multifunctional biofencing systems across Indian agricultural landscapes?	These underutilized field boundaries across India offer a largely untapped opportunity to generate additional biomass, carbon and ecosystem services without substantially reducing the productive crop area

Chapter 2 Concept of biofencing

Biofencing (living fencing) refers to establishing boundaries by planting trees and shrubs at close spacing to create a living barrier. These plants act as protective walls while providing multiple ecosystem services. According to the World Agroforestry approach, live fencing involves planting rows of trees or shrubs at relatively close spacing, sometimes combined with supporting wires or dead sticks to improve protection against animal movement. Unlike conventional boundary plantations, biofences are designed primarily for protection, wind reduction, environmental improvement, and economic benefits. A well-designed biofence performs multiple functions such as protection from stray animals and grazing, reduction of wind velocity, prevention of soil erosion, improvement of farm biodiversity, carbon sequestration, additional income generation and improvement of landscape aesthetics. Unlike conventional fences, biofences grow continuously and provide long-term ecosystem services.

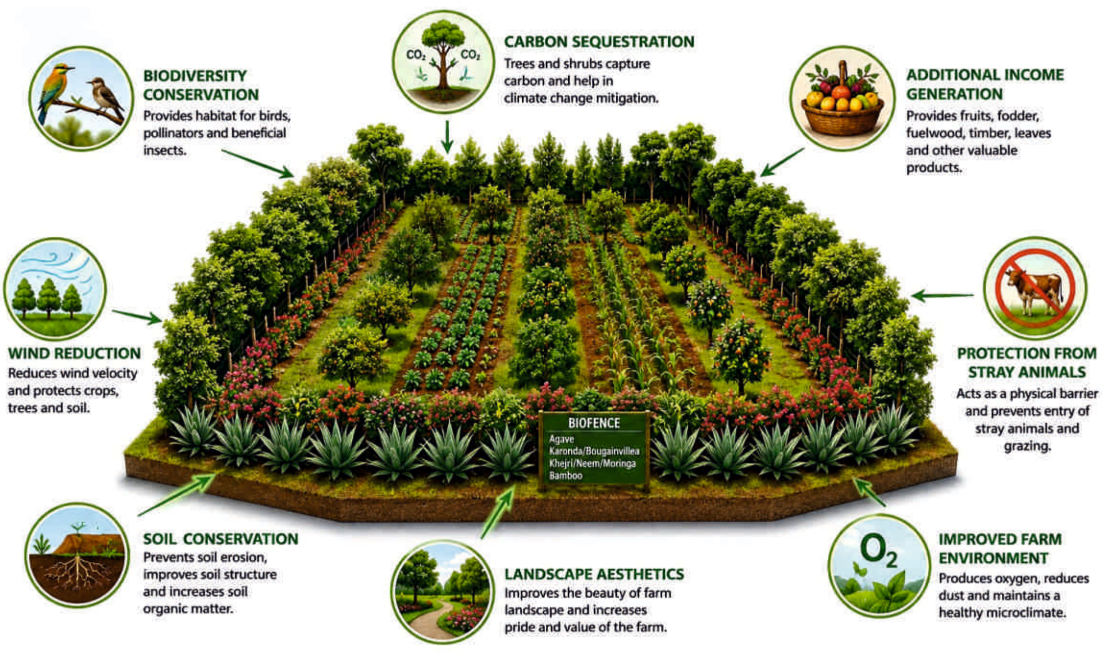


Figure 1: Bio-fencing: A multifunctional green boundary that transforming farm boundaries into multifunctional green infrastructure for farm protection, biodiversity conservation and climate resilience

Chapter 3 Multifunctional benefits of biofencing in agroforestry systems

Biofencing is not only a protective barrier but also a productive ecological component of agroforestry systems. Unlike conventional fencing materials (wire, concrete, stone), living fences continuously provide environmental, economic, and social benefits. A properly designed biofence converts unused farm boundaries into productive green infrastructure by combining protection, ecosystem services, and livelihood support. It is an important component of sustainable agroforestry systems because it provides multiple ecological, economic, and protective functions beyond simple boundary demarcation. Unlike conventional fencing materials, living fences are self-regenerating biological systems that continuously provide ecosystem services while protecting agricultural fields. A well-designed biofence transforms farm boundaries into productive green assets by integrating protection, biodiversity conservation, climate adaptation, and livelihood benefits.

3.1 Protection from grazing animals and wildlife damage:

One of the most important functions of biofencing is the protection of agricultural fields and agroforestry plantations from grazing animals and wildlife damage. Newly established tree plantations are highly vulnerable to browsing by cattle, goats, sheep, and wild herbivores, which can reduce plant survival and negatively affect plantation productivity. In many regions, grazing pressure is considered a major reason for failure of agroforestry plantations. Biofencing provides a natural protective barrier through dense growth, thorny branches, and compact plant structures that restrict animal movement and reduce crop damage. Species such as Karonda (*Carissa carandas*), Ber (*Ziziphus mauritiana*), *Acacia* species, Agave, and Bougainvillea are particularly effective because of their thorny nature and ability to form strong living barriers. Compared with artificial fencing, biofences require less external material, have lower long-term maintenance costs, and provide additional ecological and economic benefits.

3.2 Boundary demarcation and land protection:

Biofencing provides an effective and permanent method for marking farm boundaries and protecting land ownership. In agricultural landscapes where land fragmentation and boundary disputes are common, clearly established living fences help farmers identify their field limits and reduce chances of encroachment. Unlike temporary boundary markers, plants become more visible and stronger with age, providing a long-lasting natural boundary system. Biofences also improve farm organization by creating clearly defined field edges and contribute to landscape-level planning. In addition to protecting land, boundary plantations improve the appearance and ecological value of agricultural landscapes.

3.3. Windbreak effect and microclimate improvement:

Biofencing acts as a natural windbreak by reducing wind velocity and modifying the microclimate within agricultural fields. Strong winds, particularly in dryland regions, increase evaporation losses, remove soil particles, damage young plants, and cause lodging of agricultural crops. Dense rows of trees and shrubs planted along farm boundaries reduce wind speed by creating resistance to airflow and protecting crops from extreme weather conditions. Biofences help conserve soil moisture, reduce temperature fluctuations, and improve humidity conditions within the protected area. Species with dense foliage and multi-layer growth structures provide better wind protection and create a favorable microenvironment for crops and trees grown under agroforestry systems.

3.4 Prevention of soil erosion and land degradation:

Biofencing plays an important role in preventing soil erosion and maintaining land productivity. Agricultural soils are often degraded due to wind erosion, heavy rainfall, runoff, and removal of natural vegetation. The root systems of biofencing plants bind soil particles, improve soil structure, and increase soil stability. Above-ground vegetation reduces the impact of rainfall drops, decreases surface runoff, and protects soil from wind movement. Deep-rooted species such as Khejri (*Prosopis cineraria*), *Acacia* species, and *Leucaena leucocephala* improve soil conservation by enhancing soil organic matter and maintaining soil moisture. Therefore, biofencing contributes to the restoration of degraded lands and supports sustainable land management.

3.5 Carbon sequestration and climate change mitigation:

Biofencing contributes significantly to climate change mitigation by capturing and storing atmospheric carbon dioxide through plant growth. Trees and shrubs used in living fences accumulate carbon in their stems, branches, leaves, roots, and surrounding soil organic matter. As biofence plants grow, they continuously act as carbon sinks and improve the carbon storage capacity of agricultural landscapes. In addition to biomass carbon, continuous addition of leaf litter improves soil organic carbon levels and enhances soil fertility. Compared with conventional hard fencing systems, plant-based fences provide environmental benefits by sequestering carbon rather than generating carbon emissions during construction. Biofencing therefore supports climate-smart agriculture and carbon-neutral farming approaches.

3.6 Biodiversity conservation and ecological enhancement:

Living fences provide important habitats for a wide range of beneficial organisms and improve biodiversity within agricultural landscapes. Modern intensive farming systems often reduce vegetation diversity and negatively affect pollinators and natural pest-control organisms. Biofences create ecological corridors that support bees, butterflies, birds, and beneficial insects. Flowering and multipurpose species improving ecosystem stability provide food resources and shelter for pollinators and wildlife. Increased biodiversity around farms contributes to improved pollination, natural pest regulation, and enhanced ecological balance. Mixed-species biofencing systems are particularly valuable because they create different vegetation layers and provide diverse habitats.

3.7 Additional farm income generation:

One of the major advantages of biofencing is that farm boundaries become productive areas rather than unused spaces. Many biofencing species provide additional income through fruits, fodder, fuelwood, timber, medicinal products, and other marketable resources. Fruit-bearing species such as Ber and Karonda provide edible fruits and processing opportunities, while species such as Khejri and Leucaena provide fodder and biomass. Neem and Acacia species provide products with medicinal, industrial, and fuel value. This additional production improves farm income diversification and reduces economic risks associated with dependence on a single crop. For small and marginal farmers, productive biofencing can become an important component of livelihood improvement.

3.8 Improvement of landscape aesthetics and farm environment:

Biofencing improves the visual appearance and environmental quality of agricultural landscapes by creating green boundaries around farms. Vegetated boundaries provide a more attractive and organized farm environment compared with barren or artificial fencing structures. Flowering species such as Bougainvillea, Karonda, and Duranta enhance landscape beauty while supporting pollinators and beneficial insects. Green boundaries also improve the overall ecological connectivity of agricultural areas by linking fragmented habitats. Attractive agroforestry landscapes developed through biofencing can support educational activities, demonstration farms, and agro-tourism initiatives.

Importance of biofencing in agroforestry:

Biofencing represents a multifunctional nature-based solution for sustainable agriculture and agroforestry development. A properly designed living fence provides protection from grazing animals, establishes farm boundaries, reduces wind damage, conserves soil, stores carbon, enhances biodiversity, and generates additional income for farmers. Integration of suitable species according to climate, soil conditions, and farmer objectives can convert farm boundaries into productive ecological zones. Thus, biofencing is an effective strategy for developing climate-resilient, economically viable, and environmentally sustainable farming systems.

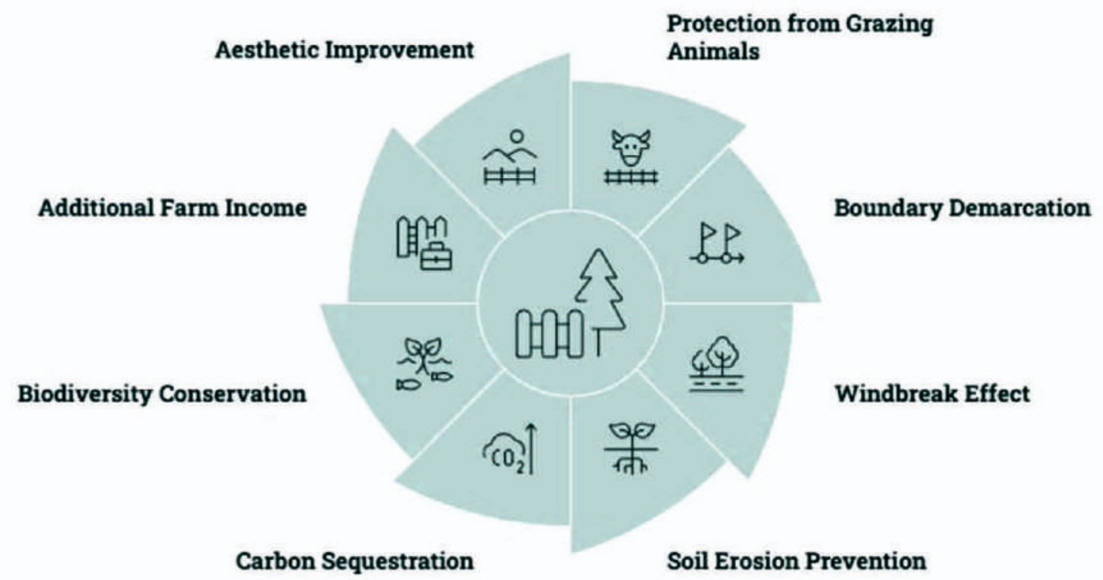
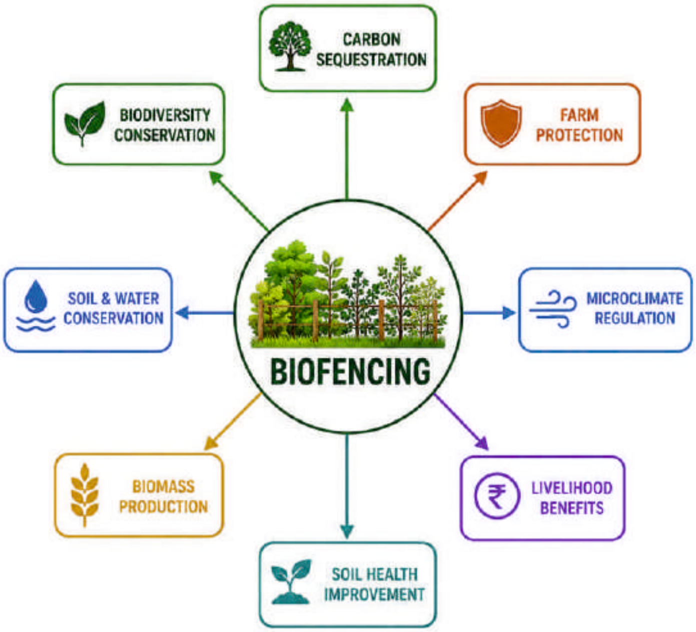


Figure 2: Multifunctional Benefits of Biofencing in Agroforestry Systems



Chapter 4

Criteria for selection of biofencing species in agroforestry systems

The success of a biofencing system depends mainly on the selection of suitable plant species that can provide effective protection, ecological benefits, and economic returns over a long period. An ideal biofencing plant should not only act as a physical barrier but should also survive under harsh environmental conditions, contribute to soil improvement, and provide additional products for farmers. The success of a biofence depends on selecting species adapted to the local climate and farm objectives, physical durability (species with thorns such as *Acacia*, *Ziziphus* or dense branching are ideal for protection; Vellankanni & Saravana Ganthi, 2022), climatic resilience (select drought-tolerant species for arid regions and flood-tolerant species for riparian zones; Montes-Londoño, 2024) and multi-purpose value (prioritize species that provide extra income or ecosystem services, such as nitrogen-fixing legumes i.e. *Gliricidia sepium* or medicinal plants such as *Azadirachta indica*; Vellankanni & Saravana Ganthi, 2022).Therefore, species selection should consider four major characteristics:

1. Protection ability
2. Environmental adaptability
3. Economic value
4. Compatibility with agroforestry systems.

4.1. Protection Characteristics of Biofencing Plants

4.1.1 Thorny Nature

- Thorniness is one of the most important characteristics for selecting plants for protective biofencing. Thorny plants create a natural physical barrier that prevents the entry of grazing animals such as cattle, goats, sheep, and wild herbivores into agricultural fields and plantations. Sharp thorns discourage animal movement and reduce damage to crops and young tree plantations without requiring expensive artificial fencing materials.
- Species such as Karonda (*Carissa carandas*), Ber (*Ziziphus mauritiana*), *Acacia nilotica*, *Acacia senegal*, and Agave are widely preferred because of their thorny structures. These plants form protective boundaries that remain effective for many years with minimum maintenance.
- Thorny biofencing species are especially valuable in dryland farming areas where livestock grazing pressure is high and farmers require low-cost protection methods. In addition to protection, many thorny species provide

fruits, fodder, fuelwood, and ecological services, making them multifunctional components of agroforestry systems.

4.1.2 Dense Branching Habit

- Dense branching is another essential feature of effective biofencing plants. Plants with closely arranged branches and thick foliage create a compact barrier that reduces gaps through which animals can enter. Dense hedges also improve the protective capacity of the fence by increasing physical resistance.
- Species such as Karonda, Bougainvillea, Duranta, Lawsonia, and Ber develop dense branching systems after regular pruning. These plants can be maintained as compact hedges of desired height and width, making them suitable for farm boundaries, orchards, and agroforestry plantations.
- Dense branching also improves environmental functions by providing shelter for birds, pollinators, and beneficial insects. Therefore, such species contribute not only to farm protection but also to biodiversity conservation.

4.1.3 Fast Growth

- Fast growth is an important requirement because biofences need to establish quickly after planting. Slow-growing species may leave farms exposed to animal damage during the initial years, increasing plantation losses.
- Fast-growing biofencing plants provide early protection and reduce the waiting period for farmers. Species such as *Leucaena leucocephala*(Subabul), Jatropha, Agave, and Karondaestablish rapidly under suitable conditions.
- Fast growth also increases biomass accumulation, which contributes to carbon sequestration, organic matter addition, fuel wood production and fodder availability. Fast-growing species are particularly useful for establishing protective boundaries in newly developed agroforestry systems.

4.1.4 Ability to Tolerate Pruning

- Regular pruning is required to maintain biofences at suitable height and density. Therefore, selected plants should have good tolerance to repeated cutting and the ability to regenerate new shoots.
- Pruning helps in maintaining fence shape, increase branch density, improve protection efficiency and control excessive growth. Species such as *Karonda, Duranta, Bougainvillea, Henna, and Leucaena* respond well to pruning and can be managed as compact living barriers. Pruning also provides additional products such as fodder, biomass, and fuelwood, increasing the economic value of biofencing systems.

4.2. Environmental adaptation characteristics

4.2.1 Drought tolerance

- Drought tolerance is a critical requirement for biofencing plants, especially in arid and semi-arid regions where water availability is limited. Farmers generally cannot provide regular irrigation to boundary plantations; therefore, plants must survive under low rainfall conditions.
- Drought-tolerant species possess characteristics such as deep root systems, efficient water use, small leaves or reduced transpiration and ability to survive moisture stress.
- Drought-resistant biofences reduce maintenance costs and provide long-term protection even under climate variability. Species such as Khejri (*Prosopis cineraria*), Ber, *Acacia* species, Agave, and Karonda perform well under drought conditions.

4.2.2 Heat tolerance

- High temperature stress is a major challenge in many agricultural regions, particularly drylands. Ideal biofencing plants should tolerate high temperatures without significant reduction in growth and survival.
- Heat-resistant biofences help farmers maintain green boundaries even under increasing climate change impacts.
- Heat-tolerant species maintainphotosynthetic activity, growth performance and water-use efficiency. Plants such as Khejri, Neem, Acacia, Ber, and Agave are suitable for hot climates because they are naturally adapted to extreme temperature conditions.

4.2.3 Survival underpoor soils

- Many agricultural boundaries are located on marginal lands withlow fertility, sandy soils, saline conditions and low organic matter.
- Therefore, biofencing plants should be able to establish under poor soil conditions without intensive management.
- Species such as *Acacia* species, Khejri, *Prosopis*, Agave and Jatropha can survive under degraded soils. Such plants also contribute to soil improvement by adding organic matter and reducing erosion.

4.3. Economic value of biofencing plants

An important advantage of biofencing is that boundary plants generate additional income while protecting farms. Productive live fences convert unused farm margins into valuable resources.

4.3.1 Fruits

- Fruit-producing biofencing species provide regular income opportunities for farmers. Instead of maintaining non-productive boundaries, farmers can grow following species that generate edible products.

  Karonda: Fruits used for pickles, jelly, candy, and processing products and also provides seasonal income.

  Ber: Produces nutritious fruits with high market demand which is also suitable for dryland regions.

  Citrus: Provides fruits along with protective thorny branches.

- Fruit-based biofencing improves livelihood security by providing additional income without reducing cultivated land area.

4.3.2 Fodder Production

- Fodder-producing biofences support integrated crop–livestock systems and reduce dependence on external fodder sources.
- Many biofencing plants provide valuable fodder resources for livestock, especially in dry regions where fodder shortages are common.Examples:

  Khejri: Leaves provide high-quality fodder which makes it important tree for livestock-based farming systems.

  Leucaena: Produces protein-rich fodder which suitable for cut-and-carry feeding systems.

  Acacia species: Provide browse material during dry seasons.

4.3.3 Medicinal Products

- Medicinal biofencing plants contribute to value addition and rural entrepreneurship. Several biofencing species have medicinal importance and provide additional economic opportunities. Examples:

  Neem: Provides neem oil, biopesticides and traditional medicinal products

  Henna: Provides leaves used for: natural dye and cosmetic products

  Aloe vera: Provides medicinal gel and commercial products

4.3.4 Timber Production

- Timber-producing biofences provide future income and improve farm asset value. Some biofencing trees provide valuable timber after maturity. These species create long-term economic benefits while performing protective functions. Examples:

  Acacia species: Timber for agricultural implements and construction.

Neem: Durable wood with multiple uses.

Leucaena: Small timber and biomass production.

4.3.5 Fuelwood Production

- Fuelwood availability from farm boundaries reduces pressure on natural forests and supports sustainable energy management.
- In rural areas, fuelwood remains an important household energy source. Biofencing plants can supply fuelwood without affecting productive agricultural land.
- Species such as: *Acacia*, *Prosopis* and *Leucaena* produce biomass suitable for fuel purposes.

4.4. Agroforestry compatibility characteristics

4.4.1 Limited competition with crops

- An ideal biofencing plant should protect farms without negatively affecting crop productivity. The selected species should have controlled canopy spread, moderate shading effect and appropriate spacing requirements.
- Plants with excessive competition may reduce crop yield by competing for light, water and nutrients. Therefore, proper species selection and pruning management are essential.

4.4.2 Deep root system

- Deep-rooted plants are preferred for biofencing because they can access water from deeper soil layers and survive drought conditions.
- The advantage of deep roots includes less competition with annual crops, better soil stabilization, improved nutrient cycling and reduced erosion. Species such as Khejri, Acacia, and Neem develop deep root systems and are suitable for agroforestry boundaries.

4.4.3 Nitrogen Fixation Ability

- Nitrogen-fixing biofencing plants improve soil fertility by converting atmospheric nitrogen into forms available for plant growth.
- Various leguminous species such as Khejri, Acacia, Leucaena etc. improve soil nutrient status through biological nitrogen fixation. The benefit includes increased soil fertility, reduced fertilizer requirement, improved crop productivity and Enhanced sustainability of agroforestry systems.

The selection of ideal biofencing plants requires consideration of multiple characteristics including protection ability, environmental adaptability, economic usefulness, and compatibility with agricultural crops. Species such as *Karonda, Ber,* *Khejri, Acacia, Leucaena, and Agave* represent excellent examples of multifunctional biofencing plants because they provide protection, income generation, biodiversity conservation, and climate resilience. Properly designed biofencing systems can transform farm boundaries into productive ecological assets and strengthen sustainable agroforestry development.

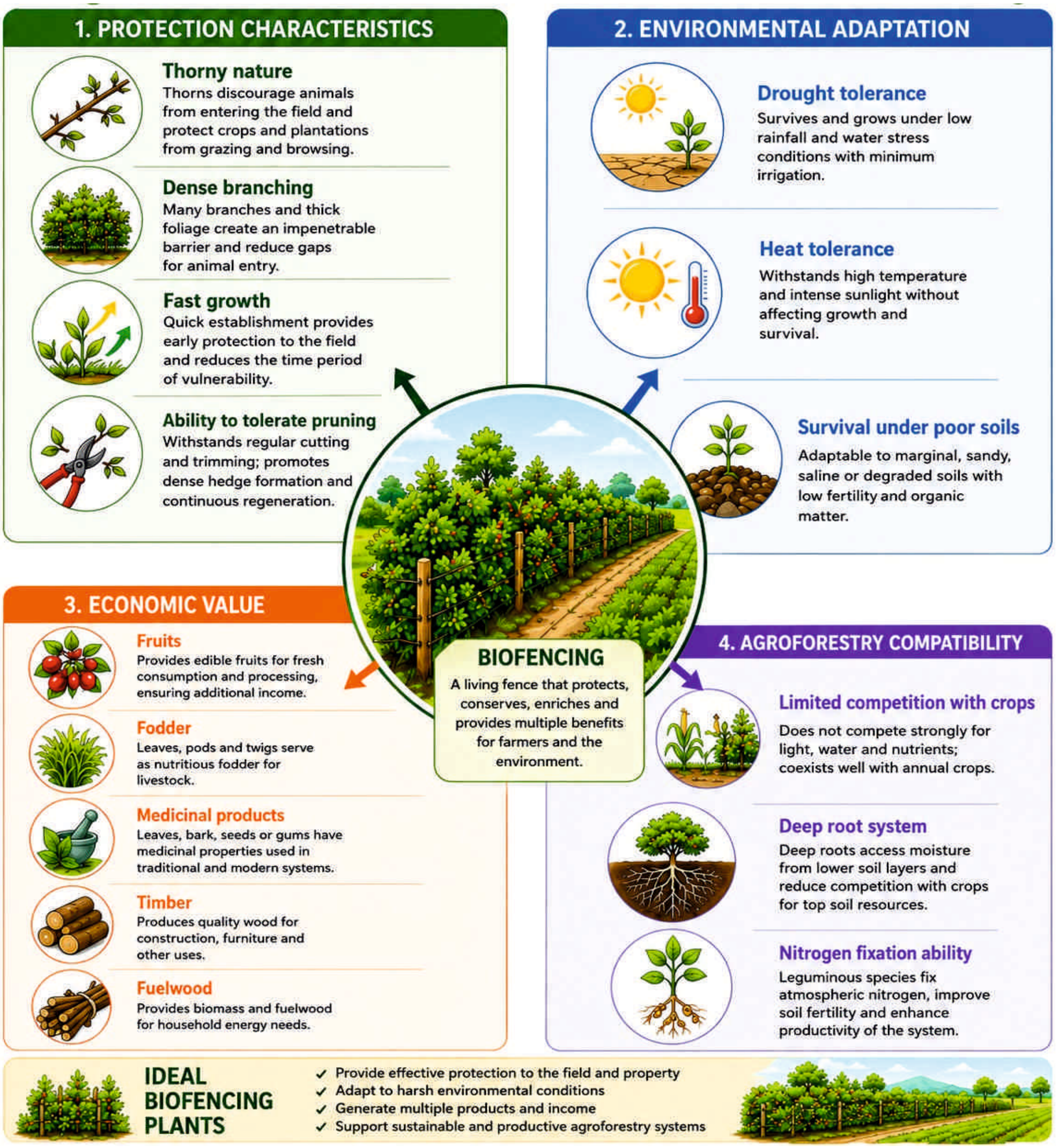


Figure 3: Key Characteristics for selection of ideal plant species for biofencing

Chapter 5

Suitable biofencing species for agroforestry systems in India

Biofencing is an eco-friendly approach that uses living plants as protective boundaries around agricultural fields, orchards, and agroforestry plantations. It provides a sustainable alternative to conventional fencing by combining farm protection with ecological and economic benefits. A well-designed biofence protects crops from grazing animals, reduces wind speed, prevents soil erosion, improves biodiversity, stores carbon, and generates additional income through fruits, fodder, fuel wood, timber, and medicinal products. Selection of suitable biofencing plants is important for long-term success. Ideal biofencing species should possess characteristics such as thorny nature, dense branching, rapid establishment, drought tolerance, adaptability to poor soils, ability to withstand pruning, and compatibility with associated agricultural crops (Figure 3). Multipurpose species that provide additional benefits beyond protection are preferred in agroforestry systems.

Table 2: List of suitable biofencing species for protection of agroforestry plantations

S.No.	Species	Main benefit as biofencing plant	Suitable region
1	Karonda (*Carissa carandas*)	Strong thorny protection, dense hedge formation, evergreen nature, fruit production, drought tolerance	All India, especially dry and semi-arid regions
2	Agave spp. (*Agave americana*)	Strong physical barrier, sharp leaves, highly drought tolerant, low maintenance, soil erosion control	Drylands, arid and semi-arid regions
3	Khejri (*Prosopis cineraria*)	Native multipurpose tree, thorny protection, fodder production, nitrogen fixation, climate resilience	Rajasthan, Haryana, Punjab, arid regions
4	Kumat (*Acacia senegal*)	Thorn protection, gum production, drought tolerance, soil conservation, carbon storage	Arid and desert regions (Rajasthan, Gujarat)
5	Bougainvillea (*Bougainvillea* spp.)	Dense thorny barrier, excellent pruning response, long-lasting hedge, landscape improvement	Tropical and subtropical regions

6	Jatropha (*Jatropha curcas*)	Living fence, unpalatable leaves, drought tolerance, oilseed production, suitable for degraded land	Semi-arid and dry regions
7	Citrus species (*Citrus* spp.)	Thorny protective boundary, fruit production, additional income, multipurpose use	Irrigated and subtropical regions
8	Moringa (*Moringa oleifera*)	Nutrition-rich leaves and pods, fast growth, biomass production, income generation	Tropical and subtropical regions
9	Malabar neem (*Melia dubia*)	Fast-growing timber tree, biomass production, carbon sequestration, long-term economic return	Tropical, subtropical and high rainfall regions
10	Neem (*Azadirachta indica*)	Drought tolerance, pest-repellent properties, medicinal products, timber and fuelwood value	Almost all regions of India
11	Aloe vera (*Aloe barbadensis*)	Drought-resistant succulent barrier, medicinal value, low water requirement, commercial gel production	Drylands, semi-arid and arid regions
12	Ber (*Ziziphus mauritiana*) *Ziziphus* spp.	Thorny protection, fruit production, drought tolerance, wildlife habitat, suitable for dryland agroforestry	Rajasthan, Gujarat, Haryana, Punjab and dry regions
13	Bamboo species (*Bambusa* spp.)	Dense green barrier, rapid growth, soil erosion control, carbon storage, multiple uses	Tropical, subtropical and humid regions
14	Henna (*Lawsonia inermis*)	Dense branching hedge, drought tolerance, pruning ability, medicinal and cosmetic value	Dry and semi-arid regions
15	Leucaena (*Leucaena leucocephala*)	Fast growth, nitrogen fixation, fodder production, biomass generation, soil fertility improvement	Tropical and subtropical regions

In India, particularly in dryland, semi-arid, and rainfed regions, species such as *Karonda, Ber, Khejri, Acacia, Agave, Jatropha, Neem, Moringa, Leucaena, Bamboo,* and *Henna* have significant potential for developing productive and climate-resilient biofencing systems. The descriptions of important biofencing species are provided below.

1. Karonda (*Carissa carandas*)

Karonda is one of the most promising biofencing species for agroforestry systems due to its dense branching habit, strong thorns, evergreen nature, and drought tolerance. It forms an effective impenetrable barrier when planted closely along field boundaries. It is highly suitable for protecting agricultural fields from livestock grazing and animal intrusion. Regular pruning promotes dense hedge formation and improves its protective efficiency. Apart from protection, it provides additional income through its edible fruits, which are used for pickles, jelly, candy, and other processed products. It performs well in dry and semi-arid regions and can survive under marginal soils with limited irrigation. Its flowers also attract pollinators, contributing to biodiversity conservation in agricultural landscapes.

Key characteristics of karonda for biofencing

- Strong thorny barrier
- Fruit-based income generation
- Drought tolerant
- Supports pollinators
- Suitable for small and marginal farms

2. Agave spp. (*Agave americana*)

Agave is an excellent biofencing plant for dryland and water-limited regions because of its extreme drought tolerance and low maintenance requirement. The thick leaves with sharp margins create a strong physical barrier that effectively prevents animal movement. It can survive under poor, rocky, and degraded soils where many other plants fail to establish. It requires very little irrigation after establishment and provides long-term protection with minimum management. It is particularly useful for dryland farmers where livestock grazing and soil erosion are major challenges.

Key characteristics of Agave spp for biofencing:

- Highly drought resistant
- Effective livestock barrier
- Low maintenance
- Suitable for degraded lands
- Helps in soil conservation

3. Khejri (*Prosopis cineraria*)

Khejri is a native multipurpose tree of arid and semi-arid regions, especially Rajasthan. It is considered a keystone species of desert ecosystems due to its excellent drought tolerance and ecological importance. As a biofence species, it provides boundary protection through its thorny branches and dense canopy. Being a leguminous tree, it improves soil fertility through nitrogen fixation and enhances productivity of surrounding crops. It provides valuable fodder, fuel wood, and timber, making it highly beneficial for integrated crop–livestock farming systems.

Key characteristics of khejri for biofencing:

- Native climate-resilient tree
- Nitrogen fixation
- Fodder production
- Soil fertility improvement
- Carbon sequestration

4. Kumat(*Acacia senegal*)

It is a highly suitable biofencing species for arid regions because of its thorny nature, drought tolerance, and ability to survive under poor soils. It develops a strong protective barrier against grazing animals. The species is economically important due to gum production (*Gum Arabic*), which provides additional income opportunities for farmers. Its deep root system helps stabilize soil and reduces erosion.

Key characteristics of Kumat for biofencing:

- Thorny protective barrier
- Gum production
- Soil conservation
- Adapted to dry environments
- Carbon storage potential

5. Bougainvillea (*Bougainvillea spp.*)

It is a widely used ornamental biofencing plant because of its thorny stems, dense growth, and excellent pruning response. It can form attractive and effective living fences around farms, orchards, and institutional plantations. Its dense foliage restricts animal movement while its colorful flowers improve landscape aesthetics and attract pollinating insects.

Key characteristics of bougainvillea for biofencing:

- Dense thorny hedge
- Decorative value
- Easy maintenance
- Long lifespan
- Supports biodiversity

6. Jatropha (*Jatropha curcas*)

It is a hardy shrub suitable for biofencing in dry and degraded lands. Its toxic latex and unpalatable leaves discourage grazing animals, making it an effective protective barrier. The plant requires low inputs and can survive under poor soil conditions. Seeds contain oil that has industrial applications.

Key characteristics of Jatropha for biofencing:

- Animal-resistant foliage
- Drought tolerant
- Suitable for marginal lands
- Oilseed production
- Soil rehabilitation

7. *Citrus* species (*Citrus spp.*)

Citrus species such as lemon and kinnow can serve as productive biofencing plants because many citrus varieties possess thorny branches and provide economic returns. Citrus crop-based boundaries combine protection with fruit production, making them suitable for irrigated agroforestry systems.

Key characteristics of *Citrus* species for biofencing:

- Fruit income
- Thorn-based protection
- High market value
- Suitable for farm diversification

8. Moringa (*Moringa oleifera*)

It is a multipurpose tree suitable for productive biofencing systems. Although thorness compare to other some protective species, it provides high economic value through nutritious leaves and pods. Regular pruning maintains a bushy structure and increases productivity. It is suitable for farms where nutrition security and income generation are important objectives.

Key characteristics of Moringa for biofencing:

- Nutritional security
- Leaf and pod production
- Fodder value
- Fast growth
- Suitable for tropical regions

9. Malabar Neem (*Melia dubia*)

It is a fast-growing tree species with high biomass and timber value. It can be used as a boundary plantation in agroforestry systems where timber production is an important objective. Its rapid growth contributes to carbon sequestration and biomass accumulation.

Key characteristics of Malabar neem for biofencing:

- Fast-growing timber species
- Carbon storage
- Biomass production
- Long-term economic return

10. Neem (*Azadirachta indica*)

It is one of the most valuable multipurpose trees for Indian agroforestry systems. It is highly adaptable, drought tolerant, and suitable for different soil conditions. It provides ecological benefits through pest-repellent properties and supports biodiversity. Its products have medicinal and agricultural uses.

Key characteristics of neem for biofencing:

- Medicinal value
- Biopesticide production
- Shade and biodiversity
- Drought tolerance
- Timber and fuelwood

11. Aloe vera (*Aloe barbadensis*)

Aloe vera can be incorporated into low-height biofencing systems, especially in dry regions. Its succulent leaves store water, allowing survival under drought conditions. It provides medicinal and commercial value through gel production.

Key characteristics of Aloe vera for biofencing:

- Drought resistant
- Medicinal importance
- Low water requirement
- Suitable for dryland boundaries

12. Ber (*Ziziphus mauritiana*)

It is an important dryland agroforestry species with excellent potential as a biofence due to its thorny branches, drought tolerance, and multipurpose uses. It provides fruit income while protecting farms from grazing animals. It performs well in arid and semi-arid regions and is highly compatible with rainfed farming systems.

Key characteristics of ber for biofencing:

- Thorny protection
- Fruit production
- Climate resilience
- Wildlife habitat
- Suitable for dryland agroforestry

13. Bamboo Species (*Bambusa spp.*)

Bamboo can serve as a green boundary barrier due to its rapid growth, dense stems, and biomass production. It is especially suitable for humid and subtropical regions. It provides multiple products including poles, handicrafts, and construction material.

Key characteristics of bamboo for biofencing:

- Fast biomass production
- Soil erosion control
- Carbon sequestration
- Multiple economic uses

14. Henna (*Lawsonia inermis*)

It is a drought-tolerant shrub suitable for dry and semi-arid regions. It develops dense branching and responds well to pruning, making it suitable for hedge-type biofencing. Leaves provide commercial value through natural dye production.

Key characteristics of henna for biofencing:

- Dense hedge formation
- Drought tolerance

- Medicinal and cosmetic value
- Low maintenance

15. Leucaena (*Leucaena leucocephala*)

It is a fast-growing nitrogen-fixing tree suitable for productive biofencing systems. It improves soil fertility through biological nitrogen fixation and provides biomass and fodder. Regular pruning maintains manageable growth and provides fodder and fuel wood.

Key characteristics of Leucaena for biofencing:

- Nitrogen fixation
- Fodder production
- Fast biomass growth
- Soil improvement
- Carbon sequestration

Table 3: Purpose of choosing of suitable biofencing species

Purpose	**Suitable Species**
Strong animal protection (thorny barrier)	Karonda, Agave, Ber, *Acacia senegal*, Bougainvillea
Drought-resilient biofence	Khejri, Ber, Agave, *Acacia senegal*, Jatropha, Aloe vera
Remunerative biofence	Karonda, Ber, Citrus, Moringa, Henna, Neem
Fodder-based biofence	Khejri, Leucaena, Neem, Acacia
Timber and biomass production	Melia dubia, Bamboo, Leucaena, Acacia
Climate-smart and carbon-sequestering fence biofence	Khejri, Neem, Bamboo, *Melia dubia*, Leucaena
Biodiversity-supporting fence	Karonda, Bougainvillea, Neem, Citrus, Bamboo

Photographs of 15 suitable biofencing species for agroforestry systems

Karonda

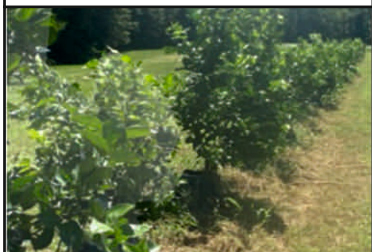
Agave

Khejri

Kumut

Bauganvillia

Jatropha



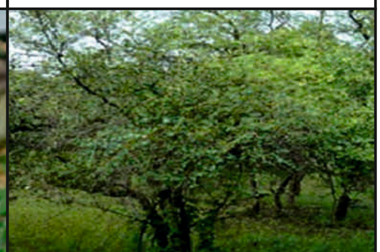
Citrus spp.

Moringa

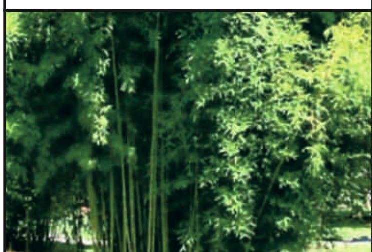
Melia dubia

Neem

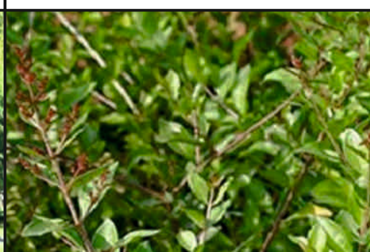
Aloe vera



Ber



Bamboo



Henna

Leuceana

Chapter 6 Recommended biofencing combination models for agroforestry farms

A scientifically designed biofencing system should not rely on a single plant species. A multi-species biofencing model provides better protection, ecological stability, and economic benefits by combining plants with different growth habits, functional characteristics, and resource uses. A combination of thorny shrubs, multipurpose trees, fodder species, fruit plants, and nitrogen-fixing trees creates a multifunctional living boundary that protects agroforestry systems while improving farm productivity.

The selection of biofencing combinations should consider:

- Agro-climatic conditions
- Soil type
- Rainfall availability
- Livestock pressure
- Farmer objectives
- Availability of planting material

Key Technical Parameters

To maximize the effectiveness of a biofence, several parameters must be considered:

- **Structural Design:** A three-tiered (multi-layered) approach is recommended for optimal protection and resilience.
    - **Tier 1 (Outer):** Low-growing, dense, and often thorny species for physical deterrents.
    - **Tier 2 (Middle):** Medium-sized trees for economic yield (e.g., fruit, medicine, or nitrogen fixation).
    - **Tier 3 (Inner):** Tall, sturdy trees to serve as primary windbreaks.
- **Density and Spacing:** Plants should be spaced closely (e.g., 0.5m to 1m for shrubs) to ensure the barrier becomes impenetrable within 2-3 years (Sivaprakash et al., 2024).
- **Maintenance:** Regular pruning and "laying" (bending stems to fill gaps) are essential to maintain the structural integrity of the fence (Diemont et al., 2021).

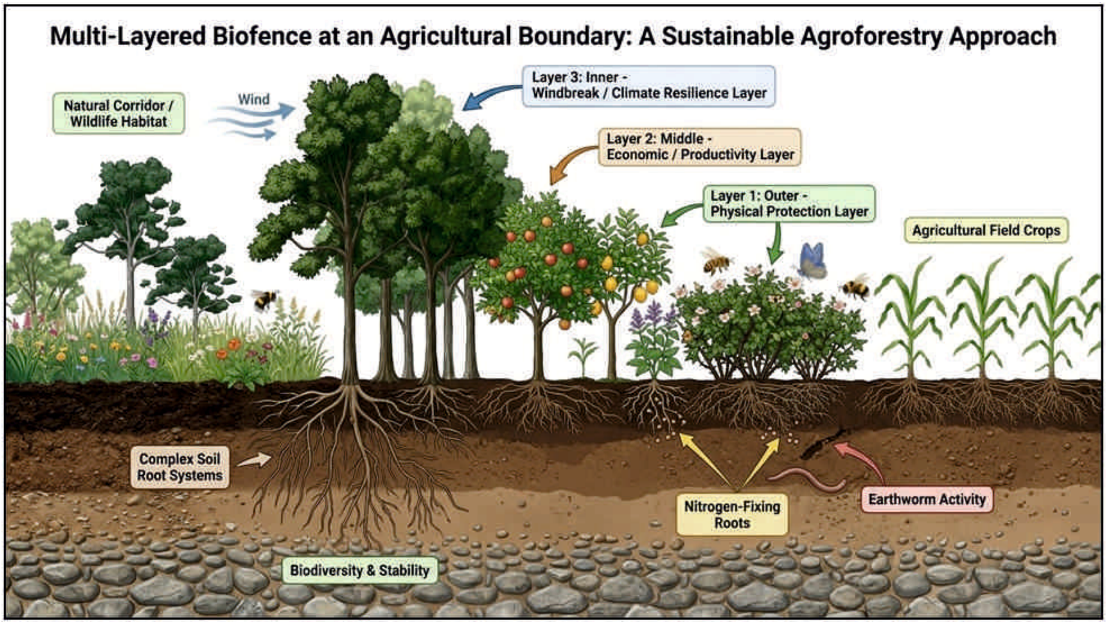


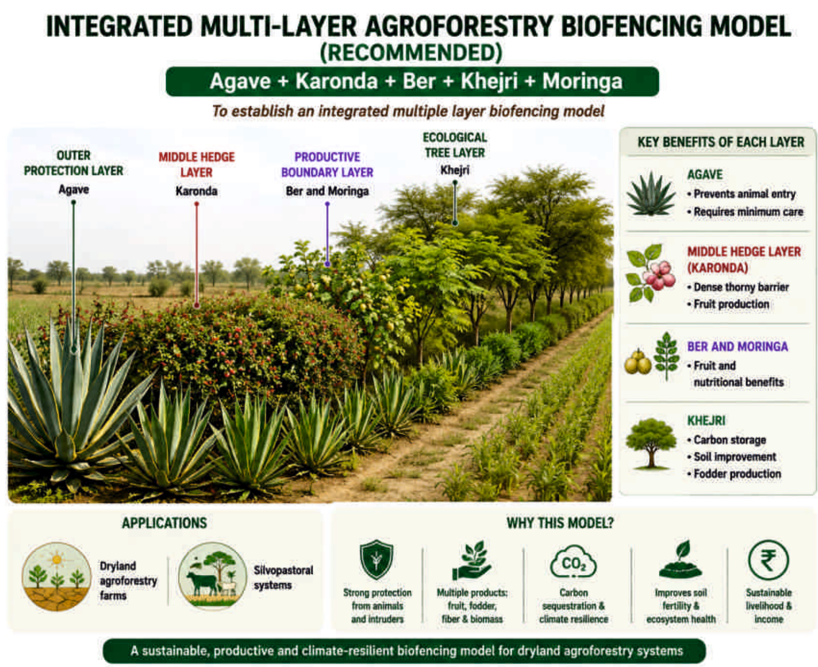
Figure 4: Cross-sectional model of an integrated biofencing system showcasing the multi-layered strategy for protection, productivity, and resilience.

Table 4: The following biofencing models are recommended for different agroforestry situations in India:

S.No.	Model	Species	Objective	Plantation Design	Major benefits	Suitable agroforestry system	Suitable Areas
1.	Dryland Protection Biofencing Model	Agave + Karonda + Ber + Khejri	To provide strong protection against grazing animals under low rainfall conditions while improving farm resilience.	**Outer layer (animal protection layer):** • Agave (*Agave americana*) • Spacing: 0.5-1.0 m **Middle layer (thorny hedge layer):** • Karonda (*Carissa carandas*) • Spacing: 0.75-1.0 m **Inner layer (multipurpose tree layer):** • Ber (*Ziziphus mauritiana*) • Khejri (*Prosopis cineraria*) • Spacing: 3-5 m	• Creates an almost impenetrable barrier against livestock • Requires very low irrigation after establishment • Protects drought-prone agroforestry plantations • Provides fruits, fodder, and biomass • Improves soil fertility through Khejri nitrogen fixation • Enhances carbon storage in dryland landscapes	• Ber-based agroforestry • Khejri-based systems • Rainfed crop production	• Rajasthan • Gujarat • Haryana • Maharashtra • Semi-arid and rainfed regions
2.	Income-Oriented Productive Biofencing Model	Karonda + Citrus + Moringa + Henna	To convert boundaries farm into productive zones generating regular income.	**Protection hedge:** • Karonda • Spacing: 0.75-1 m **Fruit-producing boundary:** • Lemon/Kinnow (Citrus spp.) • Spacing: 2-3 m **Nutrition and biomass layer:** • Moringa • Spacing: 1.5-2 m **Shrub layer:** • Henna (*Lawsonia inermis*) • Spacing: 1 m	• Provides protection from grazing • Generates fruits and vegetable products • Improves household nutrition security • Provides medicinal and cosmetic products • Creates employment opportunities through value addition	• Horticulture-based agroforestry • Vegetable-based farming • Integrated farming systems	• Irrigated farming regions • Subtropical and tropical regions
3.	Climate-Smart Carbon Sequestration Biofencing Model	Khejri + Neem + *Acacia senegal* + Leucaena	To develop climate-resilient boundaries with high carbon storage and soil improvement potential.	**Tree boundary layer:** • Khejri • Neem • *Acacia Senegal* • Spacing:3-5 m **Fast biomass layer:** • Leucaena • Spacing:1-2 m	• High biomass accumulation • Carbon sequestration • Soil fertility improvement • Nitrogen fixation • Fodder availability • Long-term farm asset creation	• Dryland agroforestry • Silvipastoral systems • Climate-smart farming systems	• Arid and semi-arid regions • Degraded agricultural lands

S.No.	Model	Species	Objective	Plantation Design	Major benefits	Suitable agroforestry system	Suitable Areas
4.	Maximum Animal Protection Biofencing Model	Agave + Karonda + Bougain-villea	To create a strong protective barrier around valuable crops and plantations.	**First barrier:** ● Agave ● Spacing: 0.5-1 m **Second barrier:** ● Karonda ● Spacing: 0.75 m **Third barrier:** ● Bougainvillea ● Spacing: 0.75-1 m	● Strong physical obstruction ● Prevents cattle and goat entry ● Low maintenance requirement ● Long lifespan ● Suitable around nurseries and orchards	● Fruit orchards ● Agroforestry demonstration plots ● Research farms	● High livestock pressure regions ● Smallholder farms ● Orchard plantations
5.	Fodder and Livestock Support Biofencing Model	Khejri + Leucaena + Neem + Acacia	To combine farm protection with livestock feed production.	**Tree spacing:** 3-5 m **Interplanting:** Leucaena at 1-2 m spacing	● Provides green fodder during dry seasons ● Supports livestock production ● Improves soil fertility ● Provides fuelwood and small timber ● Livestock Benefits: ● Reduced fodder shortage ● Lower feeding cost ● Improved farm sustainability	● Live fencing on field ● Protein bank ● Livestock-based farming systems	● Dry regions
6.	Bamboo-Based Green Biofencing Model	Bamboo + Neem + Moringa	To establish a fast-growing green boundary with biomass and economic benefits.	**Bamboo:** 3-5 m spacing **Neem/Moringa:** 2-3 m spacing	● Rapid green cover development ● Soil erosion control ● Carbon storage ● Bamboo pole production ● Improved landscape value	● Integrated farming system ● Climate smart agroforestry system	● High rainfall regions ● Eastern and southern India ● Humid areas

S.No.	Model	Species	Objective	Plantation Design	Major benefits	Suitable agroforestry system	Suitable Areas
7.	Integrated Multi-Layer Agroforestry Biofencing Model (Recommen-ded)	Agave + Karonda + Ber + Khejri + Moringa	To established a integrated multiple layer biofencing model	**Outer Protection Layer** Agave **Middle Hedge Layer** Karonda **Productive Boundary Layer** Ber and Moringa **Ecological Tree Layer** Khejri	**Agave** ● Prevents animal entry ● Requires minimum care **Middle Hedge Layer** ● Dense thorny barrier ● Fruit production **Ber and Moringa** ● Fruit and nutritional benefits **Khejri** ● Carbon storage ● Soil improvement ● Fodder production	● Dryland agroforestry ● Silvopastoral systems	● Dryland agroforestry farms



Chapter 7

Research and monitoring indicators for biofencing models

The evaluation of biofencing models requires a multidimensional monitoring framework that integrates biological, protective, environmental, and economic indicators. Biological measures include plant establishment, growth, biomass, and fence density, while protective indicators assess effectiveness in reducing animal intrusion and crop damage. Environmental parameters such as soil organic carbon, carbon sequestration, moisture, fertility, and biodiversity capture ecosystem benefits. Economic metrics-covering establishment and maintenance costs, added farm income, net returns, benefit-cost ratio, and payback period-determine financial viability. Regular monitoring enables comparison across models and helps identify suitable species and configurations for different agroecological contexts. Together, these indicators provide a scientific basis for optimizing and scaling multifunctional biofencing systems in sustainable agroforestry.

Table 5: For scientific evaluation of these models, following parameters can be measured:

Evaluation Component	Parameter	Unit/Method of Measurement	Frequency of Observation	Significance
Growth Parameters	Plant survival	Survival percentage (%)	3, 6 and 12 months after planting; annually thereafter	Indicates establishment success of biofencing species
	Plant height	m or cm	Quarterly/ Annually	Measures growth performance and adaptability
	Collar diameter	mm or cm	Quarterly/ Annually	Indicates plant vigour and biomass accumulation
	Canopy spread (N-S and E-W)	m	Annually	Assesses hedge density and protective efficiency
	Number of branches	Number $plant^{-1}$	Annually	Indicates fence compactness and pruning response
	Biomass production	Kg $plant^{-1}$ or t ha^{-1}	Annually	Determines productivity and carbon storage potential
Protection Efficiency	Animal intrusion frequency	Number of incidents $year^{-1}$	Monthly/ Seasonally	Evaluates effectiveness against stray animals and wildlife
	Crop damage reduction	Percent reduction compared with control	Seasonal/ Annually	Measures protective benefit of biofencing

	Fence density index	Number of plants m^{-1} or canopy cover (%)	Annually	Assesses physical barrier strength
	Gap formation in fence	Number of gaps per 100 m	Annually	Indicates maintenance requirement and fence continuity
Environmental Benefits	Soil organic carbon (SOC)	% or Mg C ha^{-1}	Annually/ Biennially	Measures soil health improvement and carbon storage
	Carbon sequestration	Mg CO_2 eq. ha^{-1} yr^{-1}	Annually	Quantifies climate change mitigation potential
	Soil moisture content	%	Seasonal	Assesses moisture conservation benefits
	Soil bulk density	Mg m^{-3}	Annually	Indicates improvement in soil physical condition
	Soil fertility (N, P, K)	Kg ha^{-1}	Annually	Evaluates nutrient cycling and soil improvement
	Biodiversity index (Shannon Index)	Index value	Seasonal/ Annually	Measures ecological enhancement and habitat value
	Pollinator abundance	Number m^{-2} or species richness	Seasonal	Assesses support to beneficial insects
	Bird diversity	Species richness	Seasonal	Indicates ecological health of the biofence
Economic Evaluation	Establishment cost	₹ ha^{-1} or ₹ per running metre	One-time	Determines initial investment requirement
	Maintenance cost	₹ ha^{-1} $year^{-1}$	Annually	Evaluates recurring expenditure
	Income from fruits	₹ ha^{-1} $year^{-1}$	Annually	Measures economic returns from productive species
	Income from fodder	₹ ha^{-1} $year^{-1}$	Annually	Assesses contribution to livestock production
	Income from timber/ fuelwood	₹ ha^{-1} or ₹ $year^{-1}$	At harvest	Determines long-term economic benefits
	Net returns	₹ ha^{-1} $year^{-1}$	Annually	Overall profitability of biofencing model
	Benefit-Cost Ratio (B:C)	Ratio	Annually	Determines economic feasibility
	Payback period	Years	At project completion	Indicates time required to recover investment

Chapter 8 Biofencing Suitability Index (BSI)

The Biofencing Suitability Index (BSI) provides a systematic framework for evaluating and ranking biofencing species based on protection efficiency, environmental adaptability, economic benefits, and agroforestry compatibility. It assists farmers and stakeholders in selecting species best suited to local conditions and intended functions, thereby enhancing farm security, livelihood benefits, climate resilience, and sustainable land management. It works as a decision-support tool that helps farmers, researchers, extension workers, and policymakers objectively identify the most suitable plant species for biofencing under specific agro-ecological and farming conditions. Since no single species performs equally well in all situations, it provides a standardized method to evaluate and compare species based on protection, adaptability, economic benefits, and compatibility with crops.

Table 6: Importance of BSI for different biofencing purposes

Biofencing Purpose	Importance of BSI
Field Protection	Identifies species with high thorniness, dense branching, and rapid barrier formation to prevent entry of livestock and wild animals.
Climate Resilience	Selects drought, heat, and poor-soil-tolerant species suitable for arid and climate-vulnerable regions.
Livelihood Enhancement	Prioritizes species that provide fruits, fodder, fuelwood, timber, and medicinal products for additional farm income.
Agroforestry Integration	Helps choose species with deep roots and low crop competition, minimizing negative effects on crop productivity.
Land Restoration	Identifies species capable of thriving on degraded, saline, or marginal lands while improving soil quality.
Biodiversity Conservation	Encourages selection of multipurpose native species that support pollinators, birds, and beneficial organisms.
Policy and Extension Planning	Provides a scientific basis for recommending species in government programs, watershed projects, and climate-smart agriculture initiatives.

For farmers, the BSI should be simple and field-based, not complicated.

Farmers can answer

Yes (√),

Partly (△), or

No (x) for each characteristic.

Table 7: Farmer-Friendly Biofencing Suitability Score Card

Criterion	Question for Farmer	Marks
Protection (40 Marks)		
Thorny nature	Does it prevent livestock/wild animal entry?	15
Dense branching	Does it form a thick barrier with few gaps?	15
Fast growth	Can it provide protection within 2-3 years?	10
Climate Adaptation (25 Marks)		
Drought tolerance	Can it survive with low rainfall?	10
Heat tolerance	Can it withstand extreme summer temperatures?	5
Poor soil tolerance	Can it grow in degraded or marginal soils?	10
Economic Benefits (20 Marks)		
Multipurpose use	Does it provide fodder, fuelwood, fruits, timber or medicine?	10
Market value	Can its products be sold for income?	10
Crop Compatibility (15 Marks)		
Low crop competition	Does it not reduce crop yield significantly?	10
Easy management	Can it tolerate pruning and regrow well?	5
Total marks (100)		**100**

Scoring Method

- **Yes (√) = Full Marks**
- **Partly (*) = Half Marks**
- **No (x) = Zero Marks**

Suitability Classes:

Total Score	Suitability
85-100	Very Highly Suitable
70-84	Highly Suitable
50-69	Moderately Suitable
<50	Less Suitable

For Example

Species	Score	Category
Khejri (*Prosopis cineraria*)	92	Very Highly Suitable
Karonda (*Carissa carandas*)	88	Very Highly Suitable
Neem (*Azadirachta indica*)	65	Moderately Suitable
Eucalyptus spp.	42	Less Suitable

Quick Rule for Farmers

A good biofencing species should have at least 4 out of these 5 qualities:

1. Thorny or dense barrier ✓
2. Drought and heat tolerant ✓
3. Fast-growing ✓
4. Provides economic benefits ✓
5. Does not compete strongly with crops ✓

If a species satisfies **4-5 qualities**, it is suitable for biofencing; **2-3 qualities** indicate moderate suitability; **0-1 quality** indicates poor suitability. This makes the BSI easy to use during field demonstrations and farmer training programs.

Chapter 9 Conclusion

Biofencing represents a transformative approach to sustainable landscape management, seamlessly aligning ecological preservation with economic viability and social well-being. As demonstrated, these living barriers offer a low-cost, durable alternative to expensive mechanical or electric fencing, which often requires high maintenance and lacks environmental benefits. Plant-based protective barriers shelterbelts, windbreaks, hedgerows and live fences are central agroforestry components that act as "biofences," shielding crops and soils from wind, water erosion, heat, and storms while improving microclimate, soil quality, and biodiversity. They provide multiple products and ecosystem services that strengthen livelihoods and reduce climate vulnerability, especially for smallholders. Well-designed biofencing within diversified agroforestry systems therefore offers a practical, climate resilient pathway to sustain and enhance farm productivity, provided that design, competition, labour and policy constraints are carefully addressed.The selection of suitable biofencing species should be based on climate, soil conditions, livestock pressure, and farmer objectives. Multipurpose species such as *Karonda, Ber, Khejri, Acacia senegal, Neem, Leucaena, and Moringa* provide the best combination of protection, environmental benefits, and economic returns. Integration of these species into agroforestry systems can transform farm boundaries into productive ecological zones that enhance climate resilience, biodiversity conservation, and farmer livelihoods.

Biofencing is a low-cost, nature-based solution for protecting agroforestry systems. Scientific promotion of biofencing can strengthen sustainable agriculture, improve climate resilience, and support rural livelihoods. Biofencing combination models provide a practical approach for developing protected, productive, and climate-resilient agroforestry systems. Instead of using a single-purpose boundary, multi-species living fences integrate animal protection, soil conservation, biodiversity enhancement, carbon sequestration, and additional farmer income. For dryland agroforestry systems, combinations such as *Agave* + *Karonda* + *Ber* + *Khejri* and *Khejri* + *Acacia* + *Neem* + *Leucaena* are highly suitable, while productive models such as *Karonda* + *Citrus* + *Moringa* + *Henna* are recommended for income-oriented farming systems. These models can serve as scalable technologies for farmers, research farms, and climate-smart village programmes. Achieving the full potential of the biofencing will require concerted, collaborative efforts between government bodies, research institutions, and local farmers to standardize regional practices and improve market access for bio-fence products. Ultimately, the widespread adoption of biofencing is essential for bolstering agricultural resilience, mitigating the impacts of climate change, and advancing the global agenda for sustainable development.

Chapter 10 Future prospects of biofencing in agroforestry systems

Biofencing is emerging as an important component of sustainable agroforestry systems due to its ability to provide protection, ecological benefits, and economic returns simultaneously. With increasing concerns about climate change, land degradation, biodiversity loss, and rising costs of conventional fencing materials, it offers a low-cost, environmentally friendly, and multifunctional alternative for protecting agricultural and agroforestry plantations. In the future, biofencing is expected to play a significant role in developing climate-resilient and sustainable farming systems.

As agriculture moves towards climate-smart agriculture, biofencing can contribute to carbon sequestration, microclimate regulation, soil moisture conservation, and protection against extreme weather events. Tree and shrub species used in biofencing capture atmospheric carbon dioxide and store it in plant biomass and soil, thereby supporting climate change mitigation efforts. Similarly, biofencing aligns well with the principles of natural farming and organic agriculture by enhancing biodiversity, promoting natural pest regulation, and reducing dependence on synthetic inputs.

Biofencing also has immense potential in sustainable agricultural intensification, where farm boundaries can be transformed from non-productive spaces into productive zones generating fruits, fodder, fuelwood, timber, medicinal products, and other marketable commodities. Species such as *Karonda, Ber, Moringa, Neem, and Leucaena* can provide additional income while simultaneously protecting crops and trees. This multifunctional role makes biofencing particularly beneficial for small and marginal farmers.In the coming years, biofencing will become increasingly important for biodiversity conservation by creating ecological corridors and habitats for pollinators, birds, beneficial insects, and other wildlife within agricultural landscapes. Mixed-species living fences can improve ecosystem stability, pollination services, and natural pest management while enhancing the overall environmental quality of farming systems.

The integration of modern technologies such as Geographic Information Systems (GIS), remote sensing, drones, and artificial intelligence will further strengthen biofencing research and management. These tools can be used to monitor plant growth, biomass accumulation, carbon sequestration, survival rates, and overall fence performance, enabling scientific planning and large-scale implementation. Overall, the future of biofencing in agroforestry systems is highly promising. By converting farm boundaries into productive ecological assets, biofencing can contribute to climate resilience, biodiversity enhancement, soil conservation, livelihood improvement, and sustainable agricultural development. Its adoption will play a vital role in achieving environmentally sustainable and economically viable agroforestry systems for future generations.

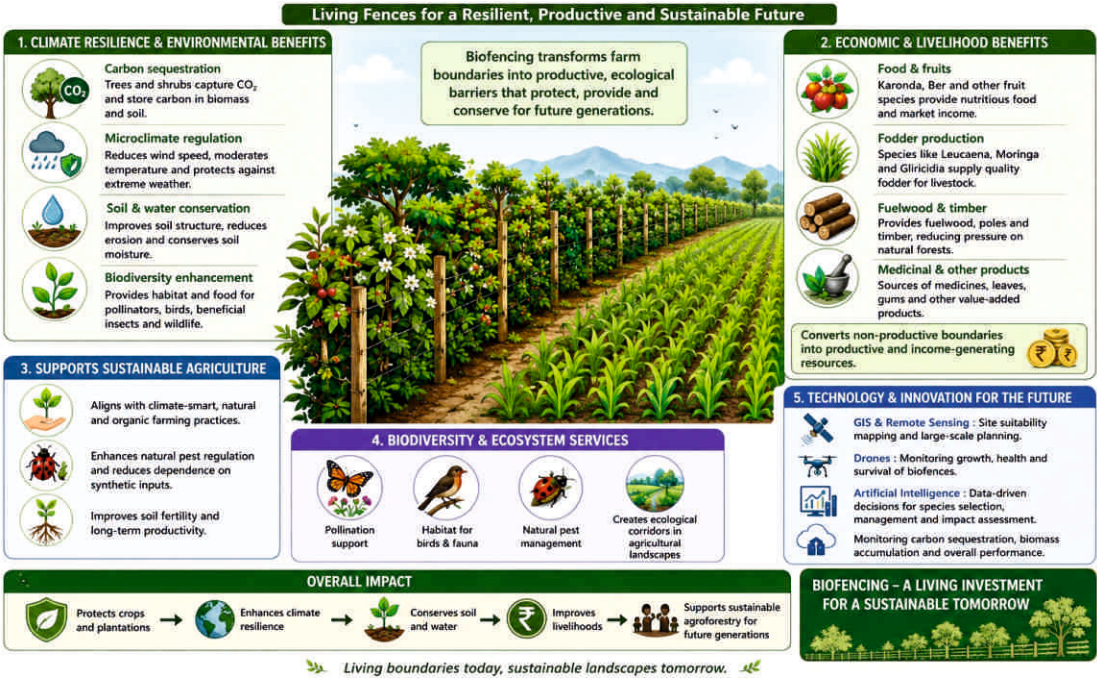


Figure 5: Future prospects of biofencing in agroforestry system

Chapter 11 Biofencing role in achieving the SDGs in India

India is concentrating on localizing the Sustainable Development Goals (SDGs) at the national and state levels. The UN Sustainable Development Goals (SDGs) offer a global framework for inclusive, resilient, and environmentally sustainable development (United Nations, 2015; NITI Aayog, 2024). By combining farm protection, resource conservation, and livelihood advantages, biofencing, a nature-based agroforestry intervention, can support seven of the seventeen Sustainable Development Goals. Through diversified farm outputs, soil and water conservation, green employment, carbon sequestration, and biodiversity enhancement, it supports SDG 1 (No Poverty),

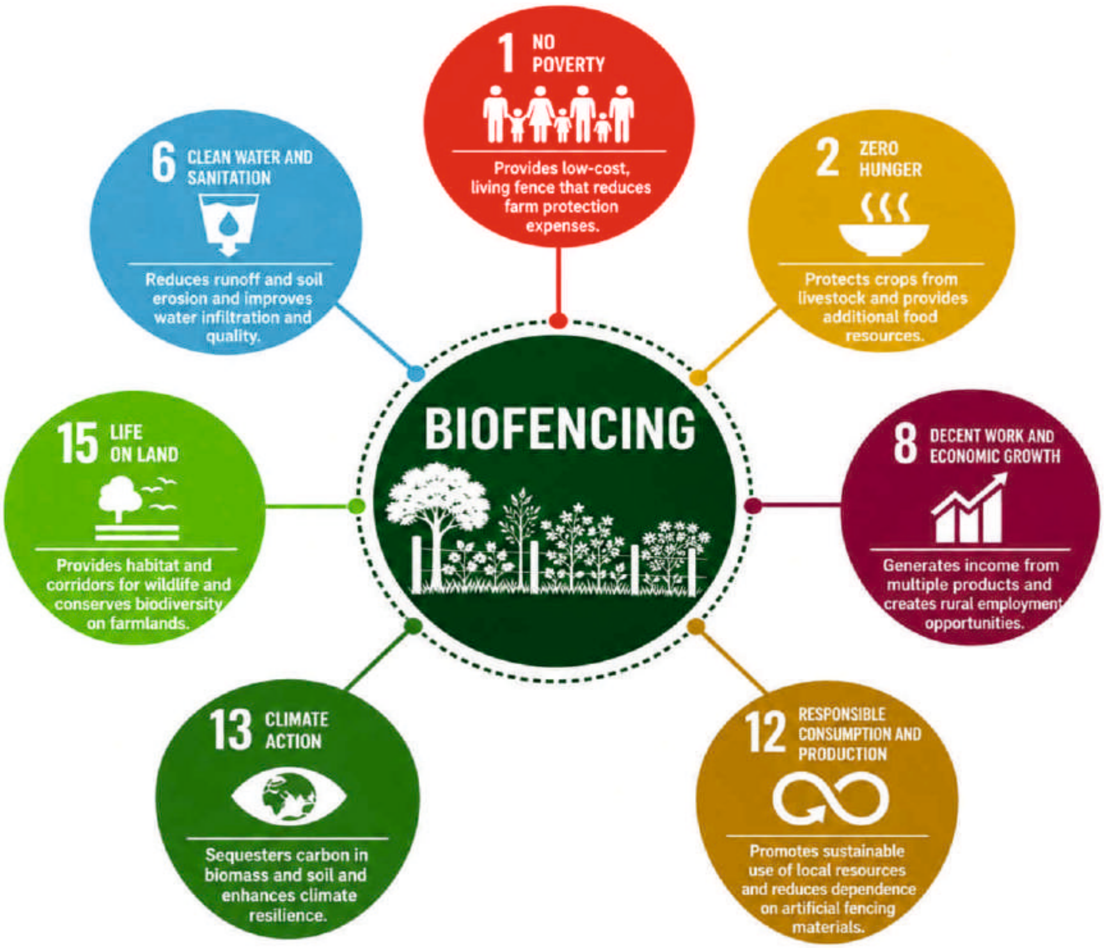


Figure 6: Biofencing role in SDGs achievements in India

SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land). Biofencing offers a workable farm-level strategy for achieving several SDG targets in India by connecting ecological functions with agricultural and livelihood advantages.

Table 8: Scientific functions of biofencing and their contribution to SDGs

SDGs	Scientific function of biofencing	Ecological pathway	Expected Outcomes
SDG 1- No Poverty	Low-cost farm protection and income diversification	Living fence, input-cost reduction, livelihood diversification	Reduced fencing cost and additional farm income
SDG 2- Zero Hunger	Crop protection and supplementary production	Crop protection, fodder, edible products, farm productivity	Reduced crop damage and improved food/fodder availability
SDG 6- Clean Water & Sanitation	Soil and water conservation	Runoff reduction, infiltration, sediment trapping, erosion control	Improved soil moisture and water quality
SDG 8- Decent Work & Economic Growth	Biomass and livelihood generation	Biomass production, NTFPs, value addition, rural employment	Income generation and rural employment
SDG 12- Responsible Consumption & Production	Renewable and resource-efficient fencing	Renewable biomass, resource efficiency, biomass recycling	Reduced dependence on synthetic fencing materials
SDG 13- Climate Action	Carbon sequestration and climate adaptation	Carbon storage, biomass carbon, soil organic carbon, microclimate regulation	Climate mitigation and increased farm resilience
SDG 15- Life on Land	Biodiversity conservation and habitat creation	Habitat provision, ecological connectivity, pollinators, agro-biodiversity	Enhanced biodiversity and ecological resilience

References

Aili, A., Bakayisire, F., Xu, H., & Waheed, A. (2025). Enhancing Agroecological Resilience in Arid Regions: A Review of Shelterbelt Structure and Function. *Agriculture*. https://doi.org/10.3390/agriculture15192004

Awazi, N.P. (2022). Agroforestry for Climate Change Adaptation, Resilience Enhancement and Vulnerability Attenuation in Smallholder Farming Systems in Cameroon. *Journal of Atmospheric Science Research*. https://doi.org/10.30564/jasr.v5i1.4303

Castle, S.E., Miller, D.C., Merten, N., Ordóñez, P.J., & Baylis, K. (2022). Evidence for the impacts of agroforestry on ecosystem services and human well-being in high-income countries: a systematic map. *Environmental Evidence, 11*. https://doi.org/10.1186/s13750-022-00260-4

Castle, S.E., Miller, D.C., Ordóñez, P. J., Baylis, K., & Hughes, K. (2021). The impacts of agroforestry interventions on agricultural productivity, ecosystem services, and human well-being in low-and middle-income countries: A systematic review.*Campbell systematic reviews, 172*, e1167. https://doi.org/10.1002/cl2.1167

Diemont, S.A.W., Soto-Pinto, L. and Jimenez-Ferrer, G. (2021). An Overview of Agroforestry and its Relevance in the Mexican Context. In North American Agroforestry (eds H.E. Garrett, S. Jose and M.A. Gold). https://doi.org/10.1002/9780891183785.ch18

Dobhal, S., Kumar, R., Bhardwaj, A.K., Chavan, S., Uthappa, A.R., Kumar, M., Singh, A., Jinger, D., Rawat, P., Handa, A., & Ramawat, N. (2024). Global assessment of production benefits and risk reduction in agroforestry during extreme weather events under climate change scenarios. *Frontiers in Forests and Global Change*. https://doi.org/10.3389/ffgc.2024.1379741

Enescu, C. M., Mihalache, M., Ilie, L., Dinca, L., Constandache, C., & Murariu, G. (2025). Agricultural Benefits of Shelterbelts and Windbreaks: A Bibliometric Analysis. *Agriculture*. https://doi.org/10.3390/agriculture15111204

Fahad, S., Chavan, S., Chichaghare, A., Uthappa, A.R., Kumar, M., Kakade, V., Pradhan, A., Jinger, D., Rawale, G., Yadav, D. K., Kumar, P.V., Farooq, T.H., Ali, B., Sawant, A., Saud, S., Chen, S., & Poczai, P. (2022). Agroforestry Systems for Soil Health Improvement and Maintenance. *Sustainability*. https://doi.org/10.3390/su142214877

FAO. *Agroforestry – Frequently Asked Questions*.

FAO. *Agroforestry – Sustainable Forest Management Toolbox*.

Gashu, M.Y., Mesfin, D., & Dessie, T.A. (2025). Farmer perceptions toward the adoption of agroforestry practices: a case study of northwestern Ethiopia. *Frontiers in Sustainable Food Systems*. https://doi.org/10.3389/fsufs.2025.1512761

Montagnini, F., del Fierro, S. (2022). Functions of Agroforestry Systems as Biodiversity Islands in Productive Landscapes. In: Montagnini, F. (eds) Biodiversity Islands: Strategies for Conservation in Human-Dominated Environments. Topics in Biodiversity and Conservation, vol 20. Springer, Cham. https://doi.org/10.1007/978-3-030-92234-4_4

Montagnini, F., del Fierro, S. (2024). Agroforestry Systems as Biodiversity Islands in Productive Landscapes. In: Montagnini, F. (eds) Integrating Landscapes: Agroforestry for Biodiversity Conservation and Food Sovereignty. Advances in Agroforestry, vol 14. Springer, Cham. https://doi.org/10.1007/978-3-031-54270-1_19

Montes-Londoño, I. (2024). Tropical Dry Forests in Multifunctional Landscapes: Agroforestry Systems for Conservation and Livelihoods. In: Montagnini, F. (eds) Integrating Landscapes: Agroforestry for Biodiversity Conservation and Food Sovereignty. Advances in Agroforestry, vol 14. Springer, Cham. https://doi.org/10.1007/978-3-031-54270-1_5

Morantes-Toloza, J.L., & Renjifo, L.M. (2018). Cercas vivas en sistemas de producción tropicales: una revisión mundial de los usos y percepciones. *Revista De Biologia Tropical, 66*, 739-753. https://doi.org/10.15517/rbt.v66i2.33405

Nair, P.K.R. (1993). *An introduction to agroforestry*. Kluwer Academic Publishers. ISBN 0-7923-2134-0

NITI Aayog. *Agroforestry and its contribution to sustainable development in India*.

Ntawuruhunga, D., Ngowi, E.E., Mangi, H.O., Salanga, R.J., & Shikuku, K. (2023). Climate-smart agroforestry systems and practices: A systematic review of what works, what doesn't work, and why. *Forest Policy and Economics*. https://doi.org/10.1016/j.forpol.2023.102937

Pakaya, P., Baderan, D.W.K., & Hamidun, M.S. (2025). Efektivitas Sistem Agroforestri dalam Meningkatkan Kesehatan Tanah dan Produktivitas Pertanian. *Hidroponik : Jurnal Ilmu Pertanian Dan Teknologi Dalam Ilmu Tanaman*. https://doi.org/10.62951/hidroponik.v2i2.329

Rolo, V., Rivest, D., Maillard, É., & Moreno, G. (2023). Agroforestry potential for adaptation to climate change: A soil-based perspective. *Soil Use and Management, 39*, 1006 - 1032. https://doi.org/10.1111/sum.12932

Sivaprakash, M., Sivakumar, B., Navaneethakrishnan, S., & Niranjan, M.A. (2024). *Trees and crops as biofence: A sustainable approach to landscape management*. Vigyan Varta, 5(12).

Szigeti, N., Frank, N., & Vityi, A. (2020). The multifunctional role of shelterbelts in intensively managed agricultural land-silvoarable agroforestry in Hungary. *Acta Silvatica et Lignaria Hungarica*. https://doi.org/10.37045/aslh-2020-0002

Vellankanni, K., & Saravana Ganthi, A. (2022). A study on flora of biofences in selected villages of Tenkasi District. *International Journal of All Research Education and Scientific Methods, 10*(4).

Vijay Kumar, R., Tiwari, P., Daniel, S., Kumar, K.R., Mishra, I., Ks, A., & Shah, D. (2024). Agroforestry Systems: A Pathway to Resilient and Productive Landscapes. *International Journal of Environment and Climate Change*. https://doi.org/10.9734/ijecc/2024/v14i124617

Wu, X., Guo, Z., Wang, R., Fan, P., Xiang, H., Zou, X., Yin, J., & Fang, H. (2022). Optimal design for wind fence based on 3D numerical simulation. *Agricultural and Forest Meteorology*. https://doi.org/10.1016/j.agrformet.2022.109072

Yadav, A., Tiwari, R.K., Kumar, S., Ram, A., Anuragi, H., Handa, A.K., & Arunachalam, A. (2021). *Horticultural trees for live fencing*. *AgriCos e-Newsletter, 2*(6): 126-130.

Zha, X., & Zhang, Z. (2025). Opinionated views on biophysical and social constraints on agroforestry system. *Frontiers in Plant Science, 16*. https://doi.org/10.3389/fpls.2025.1607207

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