Agroforestry as a Nature-Based Solution

Agroforestry as a Nature-Based Solution:

A Holistic Approach to Food Security and Climate Change

Edited by

Amit Kumar, Gopal Shukla, Ram Gopal and Dinesha S.

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ABBREVIATIONS

IDRC	International Development Research Centre
NTFP	Non-timber forest products
ICRAF	International Centre for Research in Agroforestry
CSA	Climate-Smart Agroforestry
FAO	Food and Agriculture Organization
IPM	Integrated Pest Management
SDG	Sustainable Development Goal
UNFCCC	United Nations Framework Convention on Climate Change
SOC	Soil Organic Carbon
AFS	Agroforestry Systems
ITLS	Integrated Tree-livestock systems
INM	Integrated nutrient management
IWM	Integrated water management
BBF	Broad Bed and Furrow
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
IWMI	International Water Management Institute
WOTR	Watershed Organization Trust
BD	Bulk density

FC	Field capacity
BNF	Biological nitrogen fixation
IKS	Indian Knowledge System
IK	Indigenous knowledge
ITK	Indian Traditional Knowledge
PAFERN	Philippine Agroforestry Education and Research Network
TEK	Traditional ecological knowledge
MBDA	Meghalaya Basin Development Authority
FRA	Forest right act
AFSI	Agroforestry Systems inventory
MAP	Medicinal and aromatic plant
NMMP	National Mission on Medicinal Plants
MbAF	Millet based Agroforestry Systems
LDN	Land Degradation Neutrality
CAFRI	Central Agroforestry Research Institute
ICFRE	Indian Council of Forestry Research and Education
IIMR	Indian Institute of Millet Research
MSP	Minimum Support Price
MIIRA	Millet International Initiative for Research and Awareness
GHG	Greenhouse gas
APEDA	Agricultural and Processed Food Products Export Development Authority

PREFACE

Agroforestry, the integration of trees and shrubs into agricultural landscapes, stands as a beacon of hope in addressing some of the most pressing challenges of our time—food security and climate change. This book, "Agroforestry as a Nature-Based Solution: A Holistic Approach towards Food Security and Climate Change," delves into the multifaceted benefits and potential of agroforestry systems.

In an era where conventional agriculture often falls short of meeting the rising demands for food while concurrently degrading the environment, agroforestry offers a sustainable alternative. By mimicking natural ecosystems, agroforestry enhances biodiversity, improves soil health, and sequesters carbon, thereby mitigating climate change. This holistic approach not only bolsters food production but also strengthens the resilience of agricultural systems against climate variability and extreme weather events.

The inspiration for this book stemmed from witnessing the transformative impact of agroforestry practices in various regions across the globe. From smallholder farmers in tropical countries to large-scale agricultural enterprises in temperate zones, the integration of trees into farming systems has shown remarkable results. It is this potential to harmonize agricultural productivity with ecological integrity that we seek to highlight and promote.

Throughout this book, we explore a range of topics crucial to understanding and implementing agroforestry systems. We begin with the foundational principles of agroforestry and its historical context, setting the stage for a deeper exploration of its benefits. Subsequent chapters delve into specific agroforestry practices, such as alley cropping, silvopasture, and forest farming, providing practical insights and case studies from around the world. We also address the socioeconomic aspects, emphasizing the role of agroforestry in enhancing livelihoods and promoting social equity.

A significant portion of the book is dedicated to discussing agroforestry's role in climate change mitigation and adaptation. Through detailed analysis and empirical evidence, we illustrate how agroforestry can contribute to

reducing greenhouse gas emissions, enhancing carbon sequestration, and building resilient agricultural landscapes.

This book is intended for a diverse audience, including researchers, practitioners, policymakers, and students. By presenting a comprehensive overview of agroforestry's potential as a nature-based solution, we aim to inspire and equip readers with the knowledge and tools necessary to implement and advocate for agroforestry practices in their respective contexts.

As we face the dual challenges of ensuring food security and combating climate change, it is imperative that we embrace innovative and sustainable solutions. Agroforestry, with its myriad benefits, offers a path forward. We hope this book will serve as a valuable resource and a catalyst for action, encouraging a broader adoption of agroforestry systems worldwide.

Sincerely,
Amit Kumar
Gopal Shukla
Ram Gopal
Dinesha S

INTRODUCTION

The global landscape of agriculture and forestry is undergoing profound changes driven by the escalating challenges of food insecurity, environmental degradation, and climate change. As the world population continues to grow, the pressure on our agricultural systems to produce more food is intensifying, leading to unsustainable practices that degrade soils, reduce biodiversity, and contribute to greenhouse gas emissions. In this critical juncture, the concept of agroforestry presents a beacon of hope—a nature-based solution that harmonizes agricultural productivity with environmental sustainability.

Agroforestry, the practice of integrating trees and shrubs into agricultural landscapes, offers a multifaceted approach to land management that enhances biodiversity, improves soil health, and sequesters carbon, thereby playing a pivotal role in mitigating climate change. Unlike conventional monocropping systems, agroforestry promotes a symbiotic relationship between trees and crops, creating resilient ecosystems capable of withstanding environmental stresses. This book, "Agroforestry as a Nature-Based Solution: A Holistic Approach towards Food Security and Climate Change," seeks to illuminate the diverse benefits of agroforestry systems and their potential to transform agricultural practices. By leveraging the natural synergies between forestry and agriculture, agroforestry provides a sustainable pathway to address some of the most pressing issues facing our planet today.

Agroforestry systems are uniquely positioned to offer solutions to multiple global challenges simultaneously. Trees in agricultural landscapes contribute to carbon sequestration, reducing atmospheric carbon dioxide levels and mitigating climate change. They enhance soil fertility through nutrient cycling, reduce erosion, and improve water retention, leading to more stable and productive farming systems. Furthermore, agroforestry can diversify farm incomes by providing additional products such as fruits, nuts, timber, and non-timber forest products. This book is structured to provide a comprehensive understanding of agroforestry and its applications. It begins with an exploration of the fundamental principles and historical development of agroforestry, setting the stage for a deeper dive into specific practices and their ecological, economic, and social impacts.

CHAPTER ONE

INTRODUCTION TO AGROFORESTRY: NATURE'S BLUEPRINT FOR SUSTAINABLE ENVIRONMENT

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Abstract

Agroforestry involves the growing of trees with crops and sometimes with animals in interacting combinations for a variety of objectives. Agroforestry is a sustainable land use practice and system that can be implemented worldwide in any land cover type. Agroforestry is the potential choice for increasing the tree cover outside the notified forest areas to reduce the pressure on forest land. Agroforestry practices can provide multiple ecosystem services such as carbon sequestration, biodiversity conservation, maintenance of soil fertility, prevention of soil erosion, improvement of water infiltration, reduction of wind speed, etc. This chapter aims to cover the concept of agroforestry, the origin of agroforestry, and systems of agroforestry. Agroforestry has received much more attention from researchers, policymakers, and other academicians for its perceived ability to contribute significantly to economic growth, poverty, environmental quality, and employment opportunities.

1.1 Agroforestry as an overview

A short definition of agroforestry is 'farming with trees'. Agroforestry includes the integration of trees on farmland and the use of crops and livestock in woodlands.

OR

A more detailed definition is “the practice of deliberately integrating woody vegetation (tree or shrub) with crop and animal systems to benefit from the resulting ecological and economic interaction”.

- ✓ Agroforestry is the collective name for land use systems involving trees combined with crops and animals on the same unit of land.
- ✓ Combines production of multiple outputs with the protection of resource base.
- ✓ Places emphasis on the use of multiple Indigenous trees and shrubs
- ✓ Suitable for input conditions and fragile environment
- ✓ Involves the interplay of sociocultural values more than in most other land use systems
- ✓ Structurally and functionally more complex than monoculture

Some of the definitions given by the authors are as follows:

According to Bene et al. (1977), agroforestry is a sustainable land management system for land that increases overall production, combines crops, forest plants, tree crops, and animals simultaneously, and applies management practices that are compatible with the cultural pattern of a local population.

Nair (1979) defines agroforestry as a land use system that integrates trees, crops, and animals in a way that is scientifically sound, ecologically desirable, practically feasible, and socially acceptable to that farmer.

The cycle of an agroforestry system is always more than one year. Even the simplest agroforestry system is more complex, ecologically (structurally and functionally) and economically than a mono-cropping system.

Lundgren and Raintree (1982) defined, agroforestry as a collective name for land use systems and technologies, where woody perennials (trees, shrubs, palm bamboo, etc.) are deliberately used in the same piece of land management units as crops and animals in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economic interactions between the different components.

King and Chandler (1978) – "Agroforestry is a sustainable land management system which increases the overall yield of the land, combines the production of crops (including tree and crops) and forest plants and animals sequentially, on the same unit of the land and applies management practices that are compatible with the cultural practices of the local population. Agroforestry is intentionally designed land use management combining trees and shrubs with crops and livestock.

1.1.2 Need of Agroforestry

Agroforestry offers a joined-up way of thinking about rural land use that addresses the negative environmental effects of intensive agriculture and also addresses climate change.

There are clear environmental benefits from agroforestry, relative to agriculture alone or forestry alone, including increased biodiversity, reduced run-off, increased carbon sequestration, and reduced water pollution. The most appropriate form of agroforestry will depend on the individual farm situation but there are forms of agroforestry for arable farmers, livestock farmers, horticulturalists, foresters, and householders.

1.1.3 Roots of Agroforestry

Trees have been used in cropping systems since the beginning of agriculture. Throughout the world, at one period or another, in its history, it has been the practice to cultivate tree species and crops in intimate combination. As a part of the process, human beings cut down trees, cleared the debris by burning, and sowed crops in the ash-enriched soil. Thus was born slash-and-burn agriculture, a primary forerunner of the present day agroforestry and a practice that may have originated in the Neolithic period, around 7000 BC.

In the 1960s and early 1970s, there was increasing concern for the forested lands of the tropics. It was recognized that they were under severe pressure. Some thought that commercial exploitation was the problem some believed that fuel wood needs were the culprit, while some thought that shifting cultivation was the root cause. The president of the International Development Research Centre (IDRC), located in Ottawa, Canada, to study the problem. Bene assembled a small team in Canada called the advisory committee, and recruited experts in the various

continents, to prepare studies pertinent to their area. The culmination of these various activities, including extensive travel by Bene, 1977.

1.2 Criteria of Agroforestry

Four key criteria characterize agroforestry

Intentional

The combination of trees, crops, and livestock is intentionally designed, established, and managed to work together and yield multiple products and benefits, rather than as individual elements rich may occur together but are managed separately. Agroforestry is neither monoculture farming, nor is it a mixture of monocultures.

Intensive

Agroforestry practices are created and intensively managed to maintain their productive and protective functions, and often involve cultural operations such as cultivation, fertilization, irrigation, pruning, and thinning.

Integrated

Components are structurally and functionally combined into an integrated management unit tailored to meet the objectives of the landowner. Integration may be horizontal or vertical, above or below ground, or simultaneous. Integration of multiple crops utilizes more of the productive capacity for economic production with resource conservation.

Interactive

Agroforestry actively manipulates and utilizes the interactions among components to yield multiple harvestable products, while concurrently providing numerous conservation and ecological benefits.

1.3 Attributes of Agroforestry

1.3.1 Productivity

Agroforestry systems aim to maintain or increase production commodities as well as productivity. Agroforestry can improve productivity in many

different ways. These include tree products, improved yields of associated crops, reduction of cropping system inputs, and increased labor efficiency.

1.3.2 Sustainability

By conserving the production potential of the resource base, mainly through the beneficial effects of woody perennials on soils, agroforestry can achieve and indefinitely maintain conservation and fertility goals.

1.3.3 Adoptability

The word “adopt” here means “accept” and it may be distinguished from another commonly used word adapt, which implies “modify” or change”. Agroforestry can increase adaptive capacity, and help cope with risk or uncertainty.

1.4 Potential of Agroforestry

The different aspects in which agroforestry can help in enhancing the productivity of our lands to meet the demand of the ever-growing human and livestock population are as follows:

Meeting the demand for food and fodder

- Enhanced food production from crops associated with trees
- Food for man from trees such as fruits, nuts, and cereal substitutes
- Fodder for meeting rural needs

Water conservation

- Improvement of soil-moisture retention in rainfed croplands and pastures through improved soil structure and micro-climate effects of trees
- Regulation of stream flow, reducing flood hazards, and a more even supply of water through reduction of run-off and improvement of interjection and storage in infiltration galleries.
- Improvement in drainage from waterlogged or saline soil by trees with high water requirements.

Fuelwood and energy

- Fuel wood for direct combustion
- Ethanol produced from fermentation of high-carbohydrate fruits
- Oils, latex, and other combustible saps and resins.

Shelter from trees

- Shade trees for people, livestock, and shade-loving crops
- Building materials for shelter construction
- Windbreak and shelter-belts for protection of settlements, crops lands, pastures, and roadways

Raw material for industries

- Tannins, essential oils and medicinal ingredients
- Fiber for weaving
- Woods for agricultural implements and various crafts
- Raw material for the pulp and paper industry

Cash benefits

- Direct cash benefits from the sale of tree products
- Indirect cash benefits from increased productivity

Increased yield and maximized production

- Utilizing available solar radiations throughout the year and thus enhancing overall productivity.
- Many leguminous tree species fix nitrogen from the atmosphere and return much more in leaf fall than they take from the soil.

- Leaves of tree species could be used as green manure and help the farmer to increase soil productivity at optimum levels over a long period of time.

Diversified products

- Several trees, shrubs, herbs, and climbers yield a substantial quantity of food materials that are used by the rural poor and particularly by tribal.

- By adopting agroforestry one can get diversified products i.e. fuel, fodder, fruits timber, etc.

- Agroforestry aims to maximize the production of biomass of trees and agricultural crops.

Provides employment opportunity

- Agroforestry systems increase the employment opportunities.

- Agroforestry systems can enhance farmer's income.

Environmental benefits

- Reduction of pressure on forest

- More efficient recycling of nutrients by deep-rooted trees on the site

- Better protection of ecological systems

- Reduction of surface run-off, nutrient leaching, and soil erosion through the impending effect of tree roots and stems on these processes

- Improvement of microclimate, such as lowering of soil surface temperature and reduction of evaporation of soil moisture through a combination of mulching and shading

- Increment in soil nutrients through addition and decomposition of litter-fall

- Improvement of soil moisture through the constant addition of organic matter from decomposed litter.

Economic benefits

- Increase in the output of food, fuel wood, fodder, fertilizer, and timber,
- Reduction in incidence of total crop failure, which is common to single-cropping or monoculture systems.
- Increase in levels of farm income due to improved and sustained productivity.

Social benefits

- Improvement in rural living standards from sustained employment and higher income
- Improvement in nutrition and health due to increased quality and diversity of food outputs.
- Stabilization and improvement of communities through the elimination of the need to shift sites of farm activities.

1.5 Constraints in Agroforestry

- The interference of trees decreases the crop yield which is lower than the monocropping
- The felling of trees causes damage to the arable crop
- Some of the trees serve as hosts to pests that harm the main crop
- Agroforestry systems require more for its management
- Longer gestation periods for trees delay the return to the farmer
- Competition for moisture between trees and arable crops is maximum when the trees have no deep tap root system
- Farmers give more weightage to field crops compared to tree crop

- The tree canopy absorbs maximum light and causes competition for light
- Certain tree species produce chemical exudation which affects the growth of agricultural crops
- Lack of demonstration sites
- The expense of additional management
- Lack of financial assistance
- Competition between trees, crops, and animals

1.6 Agroforestry systems and practices

The system refers to a group of physical components and assemblage of objects connected or related in such a manner to form and or act as a unit e.g., an ecosystem that consists of a living organism and its non-living environment with which they are inseparably interrelated.

In land-use system refers to a type of land use specific to an area and described according to its biotechnical composition and arrangement, and level of technical management of socio-economic features, e.g., rice production system, and plantation crop system.

Sub-system: It refers to a part of the system, with more or less restricted role, content, and complexity than the system itself. A sub-system produces a defined 'basic needs' as its major output so that there can be a food sub-system, an energy production sub-system, and a cash sub-system.

Practices: agroforestry practices denote specific land management operations of any nature, carried out on a farm or other management unit. Such practices are involved in the constitution and maintenance of an agroforestry system, e.g., cropping boundary of trees and shrubs, shelterbelts and windbreaks, etc.

Technology: This refers to an innovation or improvement, usually through scientific, intervention, to either modify an existing system or practice or develop a new one.

1.6.1 Characteristics of Agroforestry

- Land-use practices are deliberately integrated into the whole farm.
- Has two or more outputs
- Contain complex interactions among components suited to particular environments and human needs.
- The “cycle” of an agroforestry practice is always more than one year.
- Competition and management are critical.
- The farmer, is often judged successful or not by the bottom line "Does it pay?”
- Even the simplest agroforestry practice is more complex, ecologically (in terms of structure and function) and economically than monocropping.

1.6.2 Classification of Agroforestry

After the conceptualization and definition of agroforestry, evolving some broad-based and widely acceptable schemes for the classification of agroforestry systems was a major issue in the process of understanding, evaluating, and improving existing agroforestry systems and designing new ones.

1.6.3 Need for Classification

provide a practical framework for the synthesis and analysis of information about existing systems and the development of new and promising ones.

- Focus and emphasis on strategies for the development of improved systems
- It indicates how the system is managed
- It offers flexibility for regrouping the information
- We usually understood and readily handled

1.6.4 Criteria of agroforestry systems classification

Agroforestry system can be categorized according to these set of criteria

Structural basis: refers to the composition of the components, including spatial arrangement of the woody component, vertical stratification of all the components, and temporal arrangement of the different components. Based on structure agroforestry systems can be divided into two categories.

A) Nature of components

B) Arrangement of components

1.6.5 A) Nature of components

Based on the nature of components agroforestry systems can be classified into the following categories.

Agrisilviculture systems

Silvopastoral system

Agrosilvopastoral system

Other system

Agrisilviculture/Silviagriculture/Agrosilviculture: This system involves the conscious and deliberate use of land or the concurrent production of agricultural crops including trees, crops, and forest crops. Based on the nature of the components this system can be grouped into various forms:

i. Improved fallow species in shifting cultivation

ii. Taungya system

iii. Multispecies tree garden

iv. Alley cropping

v. Multipurpose trees and shrubs on farmlands

vi. Crops combinations with plantation crops

vii. Agroforestry for fuelwood production

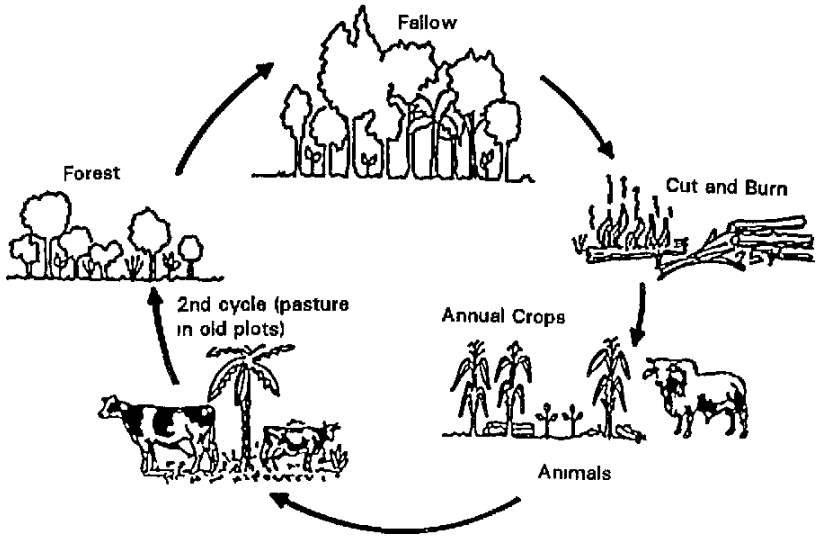
viii. Shelter belts

ix. Windbreaks

x. Soil conservation hedges etc

i. Improved fallow species in shifting cultivation

Shifting cultivation: Shifting cultivation refers to growing crops on the same plot for a few growing seasons until it is exhausted of soil nutrients, then temporarily abandons the plot of land for several years until it regenerates. Shifting cultivation is called by different names in different parts of the world.



Shifting cultivation

It is generally known as 'slash and burn' and 'bush fallow' agriculture. It is known as Jhum or Jum in the hilly states of Northeast India, as Podu, Dabi, Koman or Bringa in Orissa, as Kumari in Western Ghats, as Watra in southeast Rajasthan, as Penda, Bear or Dahia and Deppa or Kumari in the Bastar district of Madhya Pradesh.

ii. Taungya system: The Taungya (taung = hill, ya = cultivation) is a Burmese word coined in Burma in 1850. The system was introduced to India by Brandis in 1890 and the first taungya plantations were raised in 1896 in North Bengal. It is still practiced in the states of Kerala, West Bengal, Orissa, Karnataka, and the north-eastern hill region.

The Taungya system is a modified form of shifting cultivation in which the labor is permitted to raise agri-crops in the area but only side by side with the forest species planted by it. The practice consists of land preparation, tree planting, growing agricultural crops for 1-3 years until shade becomes too dense, and then moving on to repeat the cycle in a different area.

Types of Taungya systems

Departmental Taungya: In this system, crops and tree species are raised by the forest department by employing a number of laborers on daily wages.

Leased Taungya: The plantation land is given on lease to the person who offers the highest money for raised crops for a specified number of and ensures the care of the tree plantation.

Village Taungya: In this system, crops are raised by the people who have settled down in a village inside the forest for this purpose. Usually, each family has about 0.8 to 1.7 ha of land to raise trees and cultivate crops for 3 or 4 years.

Advantages of the Taungya system

- Low-cost method of forest plantation establishment
- Problems of unemployment are solved
- Helps towards maximum utilization of the site
- Artificial regeneration of the forest is obtained cheaply
- Provision of food crops from forest land and
- Weed, climber growth, etc. is eliminated.
- In every case, highly remunerative to the departments

The disadvantage of the Taungya system

- Danger of epidemics
- Legal problems created
- Loss of soil fertility and exposure to soil
- It is a form of exploitation of human labour
- The susceptibility of land to accelerated erosion increases

iii. Multi-species tree Gardens: In this system, various kinds of tree species are grown mixed. The major function of this system is the production of food, and wood products for home consumption and sale.

iv. Alley cropping (Hedge row intercropping): In this system, trees managed as hedgerows, are grown in wide rows and the crop is planted in the interspace or alley between the tree rows. The position and spacing of hedgerows and crop plants in an alley cropping system depend on plant species, climate, slope, soil conditions, and the space required for the movement of people. The spacing used in fields is usually 4 to 8 meters between rows and 25 cm to 2 m between trees within rows. The closer spacing is generally used in humid areas and the wider spacing in sub-humid or semi-arid regions.

Species for the alley cropping: *Gliricidia sepium, Flemingia macrophylla, Leucaena, Calliandra calothyrsus, Erythrina subumbrans, Albizia saman, Pithecellobium dulce, Paraserianthes falcataria, Acacia spp., Paraserianthes falcataria, and Cajanus cajan.*

v. **Multipurpose trees and shrubs on farmlands:** In this agroforestry system, various multipurpose tree species are scattered haphazardly. Examples of multipurpose trees employed in agroforestry are *Leucaena leucocephala, Acacia albida, Cassia siamea, Casuarina equisetifolia, Azadirachta indica, Acacia senegal, Cocos nucifera, etc.*

vi. Crop combinations with plantation: perennial trees and shrubs such as coffee, tea, coconut, and cocoa are combined into intercropping systems in numerous ways including an integrated multistory mixture of plantation crops. Cacao (*Theobroma cacao*) is grown under the shade of coconut areca nut, and *Dipterocarpus macrocarpa*.