Traditional Agroforestry Practices in the Indian Eastern Himalayas: Case Studies and Lessons

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Abstract This chapter examines the functioning of the various agroforestry systems, including silvopasture, agrisilviculture and agrisilviculture. Traditional agroforestry systems are considered as the classic example of sustainability due to their important role in conserving biodiversity, advancing food security and maintaining environmental health. In this chapter, these systems have been studied for their ability to sequester carbon and their contribution to food production and security. With Alder-based agroforestry in Nagaland, *Alnus* cardamom agroforestry in Sikkim, *Piper*-based agroforestry in Southern Assam, the Indian Eastern Himalayas is a region to diverse agroforestry paradigm. Globally, more than 1.2 billion people practice agroforestry on approximately 1 billion hectares of land, while in India, agroforestry is practiced on about 25.32 million hectares. Agroforestry systems offer significant environmental advantages and ecosystem functions above and beyond the farm level. These systems increase soil biodiversity and fertility, conserve water, and minimize pollution. In addition to these, the main regulatory role of agroforestry systems is to help slow down global warming. With immense potential, traditional systems can help achieve many of the sustainable development goals (SDG: 1, 2, 3, 12, 13, 15) and also help in the restoration of degraded lands.

Keywords Traditional agroforestry · Indian eastern Himalayas · Sustainable development goals

1 Introduction

Agroforestry is a technique of sustainable land management that combines the raising of livestock and/or agricultural commodities with the growth of trees and shrubs (Nair, 2005). It involves intentionally integrating woody perennial plants, such as fruit trees, timber trees, or nitrogen-fixing trees, into agricultural or pastoral systems. Agroforestry practices are designed to optimize the ecological, economic,

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and social benefits of the combined plantations (Castle et al., 2022). Traditional agroforestry systems are categorised as a group of indigenous agroforestry practises that have been used around the world with a variety of structural, functional, socioeconomic, and ecological implications (Viswanath et al., 2018). They do not involve the intensive production of agricultural or fodder crops. This system of farming is sustainable and has been passed down through generations with the knowledge and skill of agroforestry. These conventional agroforestry systems have emerged as of greater significance throughout the current the UN's decade-long ecological restoration programme,, which can significantly aid in addressing the decline in biodiversity caused by imminent climate change (Critchley et al., 2021).

The primary goal of agroforestry is to create a productive and resilient agricultural system that enhances biodiversity, improves soil fertility, conserves water, mitigates climate change, and provides a range of products and services (Tomar et al., 2021a, 2021b). By incorporating trees into agricultural landscapes, agroforestry systems can enhance ecosystem functions and provide multiple sources of income for farmers (Castle et al., 2022). Agroforestry practices based on the particular objectives and regional circumstances. According to the global definition given by Nair (1985) and Nath et al. (2021a), agroforestry systems are divided into agrisilviculture, agrisilvopastoral and silvopastoral. Agrisilviculture systems includes crops and trees including shrubs. Agrisilvipastoral systems includes crops and trees along with animals/ pasture. Silvipastoral systems include pasture/animals and trees. These systems can be adapted to different agro-ecological zones and cultural contexts, offering flexible and site-specific solutions to agricultural challenges.

In India, out of the total forest area (21.71% of the total geographical area), it has been estimated that the area under agroforestry accounts for 2.91% of the total geographical area (Panwar et al., 2022). The Indian Himalayan region is known for its diverse agro climatic conditions with ecological and environmental importance (Kumar et al., 2021). This region has the capability of reversing the regional climate change effects occurring throughout the globe. Although wide range of benefits exist, this region is facing severe impacts from climate variations, isappearance of biological diversity, developmental activities and threat to the livelihoods of the population (Kanwal et al., 2017). Additionally, shifting cultivation has accelerated soil erosion, necessitating urgent conservation of this area (Nath et al., 2021b). According to estimates, 60% of this region's land need erosion management, and 30% of it suffers severe soil erosion (Nath et al., 2021b).

Agroforestry systems are extremely important for the restoration and rehabilitation of deteriorated areas (Jinger et al., 2023). This strategy improves alleviating poverty, nutritional stability, and climate change resilience. It provides with multiple benefits including soil fertility improvement, reduction in erosion, conservation of fresh water, maintenance of shade for crops and livestock, and generating income through various timbers and non-timber forest products (NTFPs). Agroforestry systems have been represented to boost agricultural productivity while reducing carbon footprint, in line with the UN Sustainable Development Goals (SDGs) and the UN Decade of Ecological Restoration (2021–2030). Agroforestry practises can also aid in the achievement of other international goals, such as Land Degradation Neutrality (LDN), which aims to conserve sustainable management and rehabilitation of degraded land through local and national targets (Jinger et al., 2023). It is important that policies and programs are put in place to support and promote these practices to ensure their long term sustainability and effectiveness. We try to analyse the function of agrisilviculture, agrisilvopastoral, and silvipastoral systems in the Indian Eastern Himalayan region in this chapter.

1.1 Multistrata Agroforestry Systems

Mutlistrata agroforestry systems incorporate multiple layers emulate the composition of natural forests, resulting in abundant carbon sequestration and productive yields of both food and vegetation (Nair, 2017). These systems feature the combination of one or more layers of crops beneath taller trees, resulting in significant carbon sequestration alongside food production (Luedeling et al., 2016). Furthermore, they offer valuable ecosystem services such as habitat provision, erosion control, and maintenance of water quality. This multistrata systems are ecologically and economically significant. Agroforestry systems, which are considered as traditional resource management adaptations, have the potential to improve livelihoods by producing food, fodder, and firewood simultaneously in addition to mitigating the impacts of climate change (Pandey, 2007). Incorporating trees with agricultural practices, along with other vegetation management techniques in cultural landscapes such as farms, watersheds, and regional landscapes, can be integrated to utilize the benefits offered by adjacent natural, semi-natural, or restored ecosystems (Wilson & Lovell, 2016). Agroforestry is having a significant impact on maintenance of the resource base and enhancing overall productivity in rainfed regions to arid regions (Dhyani, 2018). There is abundant evidence to demonstrate that agroforestry systems generally exhibit higher overall (biomass) productivity, enhanced soil fertility, improved soil conservation, increased nutrient cycling, better micro-climate conditions, and greater potential for carbon sequestration compared to annual systems (Mathukia et al., 2016). Thus, agroforestry will play a crucial role in meeting the increasing demand for food, fruits, fuel wood, timber, fodder, biofuel, and bio-energy by the growing population, as well as in providing the perceived ecological benefits.

2 Traditional Agroforestry Systems of the Indian Eastern Himalayan Region

2.1 Agrisilviculture

In this approach, trees and crops are grown together on the same plot of ground. Along with trees, crops like cereals, legumes, vegetables, and aromatic plants are grown. 8.68 million hectares of India's total land area are thought to be now used for agrisilvicultural systems (Nath et al., 2021a). In the North Eastern Himalayan (NEH) region, agroforestry has a long history of integrating trees with the crop and livestock production systems in accordance with agroclimatic and other local requirements (Bhatt, 2001). In various agroclimatic zones, a wide range of grain crops, rhizomatous crops, pineapple, coffee, tea, and vegetables are grown alongside a wide range of fruits and other trees, including *Alnus nepalensis, Schima wallichii, Erythrina spp., Ficus spp., Bauhinia spp., and Terminalia spp* (Bhatt, 2001). In the Barak valley of North East India (NEI) agrisilviculture systems like *Piper* based agroforestry, pineapple agroforestry, tea agroforestry and bamboo based agroforestry systems are dominant (Brahma et al., 2018; Reang et al., 2021). The most common agroforestry systems in the Brahmaputra valley of Assam, however, include multipurpose trees on croplands, tea agroforestry, Morus and castor-based systems, and *Machillus*-based systems (Ulman et al., 2022). Successful and long-lasting agroforestry systems are based on Alder (*Alnus nepalensis*) in Nagaland and include high-value arable crops like cardamom (*Elettaria cardamomum*), large cardamom (*Amomum subulatum*), pineapple (*Ananas sativum*), many fruit trees, and tuber crops like turmeric, ginger, colocacia, and taros (Kehie et al., 2017). In farm-based agroforestry, farmers maintain multipurpose tree species for feed, fuel, and lumber, as well as other direct and indirect uses inside and around the nearby open cultivable area. Traditional farming practises in Mizoram continue to be based mostly on shifting (Jhum) cropping (Singh, 2019).

2.2 Agrisilvipastoral Systems

These systems can be identified by the integration of forestry, livestock, and agricultural activities in the same region over time and place (Nair, 1993). According to Dhyani et al. (2013) and the Forest Survey of India (2013), agrosilvopastoral systems in India covers 5.58 million ha. Home gardens are a great example in the North Eastern regions of India, specifically in Tripura and Assam (Das & Das, 2005). Examples of agrisilvipasture include beekeeping, aquaculture, and backyard gardens with animals.

Livestock and beekeeping along with the production of cardamom and other crops (like rice, maize, wheat, millet and pulses), cash crops (orange, ginger etc.) was reported by Sharma et al. (2016), from Sikkim. Assam has agroforestry systems based on the bushes Morus and Castor. Trees like *Morus alba* and Castor sp. Are grown in home gardens in the accessible areas to feed the silkworm species *Bombyx textor* and *Samia ynthia*, respectively (Ulman et al., 2022). In shady environments, silkworms are cultivated. Similar to this, certain Assam districts maintain agroforestry systems based on machilus. The *Machilus bombycina*, *Litsea polyantha*, and *Litsea salicifolia* leaves are consumed by the silkworm, *Antheraea assamensis*. To grow silkworms, most of these trees are planted in square patterns (Ulmana et al., 2022). *Schumannianthus dichtomus* also known as 'patidoi' or 'Murta' is found to be grown in Assam (Bhattacharjee & Seal, 2017). It is observed these are planted along with boundaries of fisheries and also planted in large scale. Similar to this, Assam hill regions have reported coconut and betel nut tree development along pond edges (Ulmana et al., 2022). Bun system (rice + fish along with crops) of the Jaintia hills of Meghalaya, Apatani method (paddy with fish culture) of Arunachal Pradesh and Zabo system (combination of forest, agriculture livestock and fisheries) of Nagaland (Selvan & Kumar, 2017) are examples of agrisilvipastoral systems.

2.3 Silvopastoral Systems

According to Shin et al. (2020), silvopastoral systems are those that integrate trees and cattle on grazing/range grounds. According to Nair et al. (2021), silvopastoral systems use a variety of techniques, such as planting trees on pastures or rangeland, creating protein banks, and growing plantation crops alongside grasslands and livestock. Due to their numerous conceivable component and arrangement combinations, these systems are remarkably adaptable to their environment and their user needs. In India, the total area currently covered by silvopastoral systems is projected to be 2.42 million ha (Nath et al., 2021a).

3 Case Studies from Indian Eastern Himalayan Region

3.1 Agrisilviculture and Livestock Management for Food Production in NEI

With the growing population, food security is in risk. Agroforestry systems can provide a range of food products including nuts, fruits, and vegetables. Additionally, the diversity of crops in agroforestry systems can provide more varied nutritious diet for local communities. Agrisilviculture systems like cardamom agroforestry system in Sikkim, NEI, is grown along with a number of trees which provide food (Avasthe et al., 2011). The Alder based agroforestry in Nagaland, is also an example which provides with numerous food crops such as rice, tuberous root (tapioca, potato, colocasia), large cardamom, and rhizomes (turmeric, etc.) (Kehie et al., 2017). In the west Garo hills of Meghalaya, intensified jhum cultivation has been the habitat for various food crops since decades. A total of 35 food crops are being grown and in addition four species of livestock being reared (Pandey et al., 2022). These 39 species being the structure of five food crop groups, and each group has each group has at least two predominant crop or animal species, demonstrating how traditional farming has a built-in diversity. This system hence signified as a buffer for the risks against local and national food security thereby ensuring around the year supply of food.

While mimicking the conventional agroforestry systems of NEI, in an experimental agroforestry setup at Meghalaya (Dhyani & Tripathi, 1999) represented the yield of Soybean, Linseed, Ground nut and Mustard grown with trees like *Alder, Albizia*, Cherry and Mandarin. Yield was not observed to have significant variation when intercropped with different tree species except Cherry. Soybean, Linseed, Groundnut and Mustard yield ranged between 6.4–6.8, 2.2–3.0, 4.2–5.2 and 1.6–2.3 Mg ha^{-1}. In Arunachal Pradesh, the Apatani system is eco-friendly and compared to the state average of less than 2.0 t ha^{-1}, the Apatani system in produces rice at a very high rate (4–4.5 t ha^{-1}). (Selvan & Kumar, 2017). In the Himalayan region of NEI, where erosion is a major land degradative process and the climate is humid subtropical, integrating trees with crops can aid in ecorestoration and the preservation of soil resources (Dhyani & Tripathi, 1999).

3.2 Agroforestry for Fodder Production in Sikkim

Agroforestry systems can provide feed for livestock through the use of forage leaves and shrubs. The use of fodder trees and shrubs can improve the productivity by providing a more balanced diet. Bhatt et al. (2001) showed 15 plants and their potentials to be incorporated in the agroforestry systems as fodder yielding species. Among them *Grewia oppositifolia* and *Ficus hispida* are dominant fibre yielding species having the green fodder potentials of 95.5 and 92.5 kg $tree^{-1}$ respectively. According to reports, agroforestry-grown trees meet 9–11% of the need for green fodder (CAFRI, 2015; Sharma et al., 2017; Singh & Pandey, 2011). Singh and Teron (2019) reported *Colocasia esculenta* and *Zea mays* as a fodder for pigs from an oak based agroforestry system in Sikkim.

3.3 Traditional Homegardens as Source for Fuel

Agroforestry systems can provide a sustainable source of fuel wood for cooking and heating. Transforming agricultural leftovers into biofuel addresses both the challenges of waste disposal and energy generation simultaneously (Ambaye et al., 2021). When compared to alternative renewable energy sources like solar and wind, biomass stands out as an affordable, energy-efficient and easily storable option. NEI is no different for the options of energy fulfilment from the rest of the country, where the local population heavily relies on plant resources to fulfil their energy requirements along with other diverse needs. The extensive use of fuel wood as the main energy source for household purposes in NEI has contributed significantly to deforestation. As a result, it has become imperative to establish energy plantations in fallow lands and wastelands of the region to address this issue (Kakati & Konwer, 2001). Diverse homegardens of Barak Valley, NEI represented fuel wood being one of the dominant use class for meeting the energy demands (Das & Das, 2005; Nath et al., 2020). Among them 61% of the managed trees are the most commonly used fuel wood species. *Albizzia lebbek*, *Alnus nepalensis*, *Melia azedarach*, *Phyllanthus emblica*, *Quercus serrate*, *Schima wallichii* reported from an oak based agroforestry system in Sikkim by Singh and Teron (2019) meet the requirements of fuel wood. Therefore, agroforestry plays a vital role in alleviating pressure on forests by cultivating trees on farms. These farm-grown trees serve as a source of fuel wood, effectively meeting local energy requirements and reducing reliance on forest resources.

3.4 Biodiversity Conservation Through Cardamom Agroforestry

A crucial part of sustaining human life and the health of our planet is biological diversity, often known as biodiversity (Jose, 2012). In the present time, the transformation to agriculture systems always takes place with the expense of the natural environment. The extent to which a system is affected differs vividly between regions and in progression the area becomes barren and degraded depending on the human pressure, population density, land use change etc. Agroforestry systems have the ability to help reverse the circumstances and restore these fragmented and barren areas (Scrotch et al., 2000; Tomar et al., 2021a, 2021b). The Indian Himalayas are home to a rich biodiversity, including a variety of flora and fauna that are endemic to the region. Agroforestry systems can significantly contribute to biodiversity preservation in this region by providing habitat for wildlife and promoting ecosystem services (Udawatta et al., 2019).

Sikkim's extensive cardamom agroforestry practise promotes the region's efforts to preserve its tree biodiversity (Sharma et al., 2007). Another study (Vineeta et al., 2022) from the Darjeeling Himalayas in a Cardamom based agroforestry reported the existence of certain IUCN red listed species indicating the conservation of supported by these systems. For instance the species (*Brugmansia suaveolens*) which is reported to be extinct from Brazil are reported from the Darjeeling Himalayas and adjoining foothills of West Bengal (Vineeta et al., 2022). Comparing this to other agroforestry techniques used in the area, it encourages the existence of extremely diversified tree species and tree diversity index. The birds and other creatures that the trees support have an impact on the agroforestry system's ecological makeup and ability to function. Additionally, agroforestry systems with multiple tree species and crops can support a greater diversity of wildlife and plant species than monoculture systems (Udawatta et al., 2019). However, the success of agroforestry systems in promoting biodiversity conservation in the Indian Himalayas is governed by factors such as local environment, design and management of the system, and involvement of local communities in the process. Hence, it is vital to tailor agroforestry practices to the specific needs and conditions of the region in order to achieve effective and sustainable biodiversity conservation.

3.5 Hedgerows and Alder for Maintenance of Soil Health

In general, agroforestry systems are believed to sustainably improve soil qualities (Dollinger & Jose, 2018). Agroforestry systems can have positive impacts on soil health by improving field capacity (FC), organic matter (OM), available potassium, available phosphorus, soil carbon stocks, and lower bulk density (BD); which retain water by increasing the water holding capacity (WHC) and release the water to plants gradually, like a sponge. The supply of OM is crucial for soil aggregation and for lowering the soil BD. This decreased soil BD helps with air circulation, circulation of water in the rhizosphere, soil nutrient quality, and groundwater recharge in arid and semi-arid conditions. Soil organic carbon has a direct and indirect impact on how well nutrients are used in agriculture. The greater availability and absorption of nitrogen from soil with rich organic matter and a healthy deep root system will increase the effectiveness of nitrogen use. Additionally, mycorrhizae are probably provided by the increased microbial diversity brought on by the addition of OM, which releases P and makes it available to crops. In agroforestry systems, the buildup of litter from the loss of leaves and twigs serves as the main source of nutrients and organic carbon. Additionally, the deep root systems of trees and shrubs in agroforestry systems can help to strengthen soil structure and reduce erosion by binding soil particles together. In their study of a maize-chili intercropping system with leucaena (*Leucaena leucocephala*) trees hedgerows, Hussain et al. (2021) found that soil loss is greatly reduced while the productive capacity of the land increases, all with a minimal usage of tillage and fertilisers. In the abandoned Jhum land in India's north-eastern area, Bambusa nutans has been discovered to be effective at binding soil nutrients. (Arunachalam & Arunachalam, 2002). Furthermore, agroforestry systems with leguminous trees and shrubs can fix atmospheric nitrogen, which can increase soil fertility and reduce the need for synthetic fertilizers. In the Khonoma village of Nagaland, NEI the Alder based system is an example of agroforestry system which has the capability of fixing nitrogen. The alder root nodule fertilises the soil, and the spreading nature of the roots helps to reduce soil washing on slopes (Das et al., 2012; Rathore et al., 2010). It has been reported that *Alnus* can fix up to 29–117 kg ha^{-1} of nitrogen.

3.6 Carbon Sequestration Through Agroforestry Transition

Agroforestry is crucial for sustaining soil organic carbon, which lowers greenhouse gas (GHG) emissions. Agroforestry systems store carbon in the woody biomass reducing the GHGs and this vary with respect to different tree species and different land management practices. The greatest potential for atmospheric CO2 absorption comes from converting underutilised agriculture and grasslands into agroforestry (IPCC 2000). In NEI, Brahma et al. (2018) assessed the ecosystem carbon sequestration capacity for the main land uses transitioned from the natural forest. According to their study, the management of degraded forests using *Piper betle* slash and mulch agroforestry and *Hevea brasiliensis* plantations resulted in carbon sequestration rates of 5 and 4 Mg ha^{-1} $year^{-1}$, respectively. The carbon sequestration reported was 0.5 and 4 Mg ha^{-1} $year^{-1}$ when *Imperata* grassland was turned into Areca catechu and *Hevea brasiliensis* plantations, respectively. Similarly, Reang et al. (2021), reported that pineapple agroforestry systems of > 15 years age has a carbon storage capacity of 175.65 Mg ha^{-1} while the ecosystem carbon storage was 247.46 Mg ha^{-1}. According to Manjaiah et al. (2017), the NEH area of India's agroforestry systems have a SOC stock that ranges from 85.3 to 121.9 Mg ha^{-1}. Agroforestry systems have the ability to store up to 0.29 to 15.2 Mg C ha^{-1} above ground and 30 to 300 Mg C ha^{-1} at a maximum soil depth of 1 m. (Nair et al., 2010).

The intensive management practices by the farm managers of agarwood (*Aquilaria malaccensis*) in the Barak Valley, NEI had induced the average soil organic carbon stock, and ranged between 11.9–28.9 g kg^{-1} at under different cultivation management systems. The economic management of different agarwood stands increased the incorporation of trees for various household needs. In addition Water Guard, Pumpkin, *Betel* leaf, Yardlong Beans, Flat Beans, Cucumber, Sponge Gourd, Spine Gourd, etc. are the crop varieties being cultivated. This inter-spatial crop-tree arrangement of agarwood agroforestry is subsequently leading to high production and accumulation of litter thereby releasing more organic materials into the system (Nath et al., 2020, 2022a, 2022b). In the same system, the suggested increase in the recalcitrant carbon pool with age indicates a higher carbon sink potential in the monoculture stands.

3.7 Alder Based Agroforestry for Microclimate Regulation

The contribution of trees and woody plant in the agroforestry system plays an important role in the microclimate regulation by providing shelterbelts. This also provides shade which are beneficial for air and water quality. Agroforestry offers a multitude of benefits, including the creation of a favourable site-specific climate, decline in erosion, enhancement of biodiversity, improved water quality, increased water infiltration resulting in effective groundwater recharge, enhanced and extended dry flow, habitat improvement, and enhancement of soil fertility (Tomar et al., 2021a, 2021b). In agroforestry systems, the performance of the crop component is typically improved when it has a greater preference for shade, especially during the initial stages of agroforestry establishment. This is because competition for light is a crucial factor that limits yields in such systems. Therefore, the presence of a tree canopy in agroforestry systems can create an optimized microclimate, benefiting the surrounding environment and crops (Burgess et al., 2022). Sharma et al. (2007), reported that, the presence of shade trees in the *Alnus*-cardamom based agroforestry system regulates the microclimate. Furthermore, it is crucial to emphasize the inclusion of local species in agroforestry systems. These species not only contribute to enhancing biodiversity but also possess adaptations to local microclimate conditions. They may have developed resilience to climate change and extreme weather events, making them valuable components of sustainable agroforestry practices (Burgess et al., 2022).

3.8 Indigenous Cultivation and Shade Management for Pest and Disease Control

The traditional farming system in the NEI stands out as intricate and distinct due to its dominance of slash and burn agriculture. In this region, the management of crops and pests is intricately linked with the integration of indigenous knowledge and traditional ecological practices passed down through generations. The land use system revolves around slash and burn agriculture, where the clearing of land and cultivation techniques are guided by the expertise and wisdom of the local communities (Chhetry & Belbahri, 2009). Agroforestry helps to create a more complex and diverse agro ecosystem, which is less vulnerable to pest and disease outbreaks. In agroforestry systems, trees can provide a natural habitat for predators, parasites, and beneficial insects that aid in the management of pest populations. By increasing the genetic diversity of the species and integrating it with other host species, it is possible to reduce the risks of pest and disease infestation by diversifying the tree component of agroforestry systems (Schrotch et al., 2000). Additionally, the presence of trees in agroforestry systems can alter the microclimate, which makes the environment less hospitable for some diseases and pests. Additionally, the presence of trees in agroforestry systems can change the microclimate, making the environment less suitable for some pests and illnesses. Shade trees frequently provide a habitat for beneficial organisms that feed on pests and pathogens, improving the level of pest and disease control (Ayalew et al., 2022). In addition, the inclusion of leguminous trees in agroforestry systems can improve the fertility and health of the soil, which will help to lower the prevalence of diseases that are transmitted through the soil. Studies have demonstrated that agroforestry practises can greatly reduce the usage of synthetic pesticides and herbicides, which are detrimental to both human health and the environment (Udawatta et al., 2019; Ollinaho & Kroger, 2021). Inbuilt approaches used in the agroforestry systems of NEI were reported by Chhetry and Belbahri (2009). The cultural customs of multiple or mixed cropping, zero tillage, clean cultivation, slash-and-burn methods, green manuring, successive cropping and harvesting, fallowing, flooding, and more. These customs, which have a strong cultural foundation, are an efficient technique of controlling diseases and pests. A sustainable and environmentally friendly method of farming is agroforestry. As a result, agroforestry is an environmentally responsible and sustainable method of controlling pests and diseases that can help farmers maintain their financial stability and ensure the long-term viability of agricultural systems.

3.9 Water Logged Agroforestry of Tripura

Reduced nutrient and sediment runoff from agricultural lands is the basis for the regulation of water quality through the use of agroforestry. By reducing the effects of leaching from rainfall-induced runoff, they may also be able to enhance groundwater quality (Anderson et al., 2009). The uptake of nutrients from the soil and water by trees in agroforestry systems can help to limit nutrient runoff. Additionally, trees' root systems can prevent soil erosion. Trees can also help to slow down water movement, allowing for infiltration into the soil and reducing surface runoff. Jinger et al. (2022) reported reduction in the total soil loss and runoff by 37.7% and 19.1%, respectively under agroforestry (sapota + cowpea + casto), compared to the sole crop (cowpea + casto) cultivation. Further, agroforestry systems can enhance soil health, which improves the water absorption capacity of soils, reducing the incidence of flood and drought.

The unique water logged agroforestry system of Tripura can be identified from dominance of woody perennial crops such as areca nut, mango, coconut, and locally adapted varieties of Colocasia. These crops are typically found in swampy areas. Additionally, the system includes certain fish species like *Anabas testudineus*, *Clarias batrachus*, *Puntius chola* etc. Other water-loving plant species such as *Enhydra fluctuans*, *Ipomoea quatic*, and *Achyranthes philoxeroides* are also commonly observed growing within these agroforestry systems. The overall benefit: cost ratio in the traditional waterlogged agroforestry systems of Tripura was 6.35 signifying livelihood potential of the system. This underscores the importance of scientific communities extending this approach to other regions of the country that share alike land-use characteristics. Such expansion can bring about positive economic outcomes and improve the overall sustainability of agricultural practices in those areas (Sarkar et al., 2019).

3.10 Alder, *Sericulture and Fruit Tree Based Agroforestry for Economy*

In the eastern Himalaya, traditional agroforestry techniques centred on cardamom are used to cultivate perennial cash crops on marginal soils and slopes beneath the existing forest canopy.. In the majority of cardamom plantations, *Alnus nepalensis* is commonly used as shade trees. The mixture of *Alnus nepalensis* and cardamom has been found to be ecologically and economically sustainable. Cardamom cultivation is primarily carried out in altitudes ranging from 600 to 2000 m, which includes subtropical to cool temperate zones. The total output from the agroforestry was reported at US$ 1619 with a output: input ratio of 13:2. This indicates that cultivating cardamom within an agroforestry system offers substantial economic advantages and serves as a viable and lucrative alternative for farmers in the region (Sharma et al., 2007). The cardamom agroforestry system is economically viable and particularly beneficial for marginal households that heavily rely on subsistence farming practices. By engaging in cardamom cultivation within the agroforestry system, these households can improve their income and livelihoods. The system provides them with a sustainable and profitable agricultural option, enabling them to enhance their economic well-being and reduce dependence on subsistence farming alone.

Agroforestry systems has the potential to contribute significantly to the country's economy especially in the developing countries. Agroforestry systems can provide multiple products and services, including timber, fuel wood, fruits, nuts, medicinal plants and animal fodder. This diversity of products can create more sustainable and resilient livelihoods for farmers, reducing their dependence on a single crop or source of income. In a sericulture based agroforestry system of NEI, intercropping was done with spacing ranged from (90 × 60) cm to (210 × 120) cm. The net cash return from the agroforestry systems was ranged between INR 9670.00–51,300.00 in low spacing categories with the highest cocoon and fuel wood yield. This was 1.5–5.6 folds more than the net income obtained from Mulberry and groundnut monocultures respectively. Due to the low temperature and deciduous nature of mulberry, rearing activities are not feasible during winter. However, intercropping between mulberry rows can still be practiced with relative ease (Dhyani et al., 1996). The fruit tree based agroforestry system of NEI represented the highest net income generated when groundnut, soybean, turmeric and ginger were intercropped with Khasi Mandarin (Bora et al., 2019). This is attributed to the compatibility and synchronized growth between the two crops, resulting in mutually beneficial outcomes.

4 Future Opportunities of Agroforestry Management

Agroforestry has the potential role to play a in the future by improving the agricultural community's economic status, efficient resource utilisation within the farm, and environmental resistance to climate change (Raj, 2020; Raj et al., 2020). According to a World Bank (2004) estimate, there are around 1200 million rural people who currently practise agroforestry on their farms. Tree cover reaches over 10% of a billion hectares of agricultural lands, and an estimated 1.6 billion hectares of land globally are anticipated to be transformed under agroforestry management in the foreseeable future (Nair & Garrity, 2012). According to CAFRI (2015), by 2050 the need for fodder will be 1.5, 2.0 and 3.0 times that of food grain, fuel wood and timber respectively. Agroforestry has the ability to supply the demand for food, fodder, firewood, and timber. As part of the United Nations Framework Convention on Climate Change (UNFCCC), the Intergovernmental Panel on Climate Change (IPCC), Nationally Determined Contributions (NDC), and National Adaption Plans (NAP) have recognised agroforestry systems in the achievement of climate change adaptation. Furthermore, according to the IPCC's land use cover, land use change and forestry report, 2000, agroforestry systems have been identified as having the largest potential for carbon sequestration by 2040 among all other land uses. Agroforestry compensets one-third (33%) of overall GHG productions from the agriculture sector and 6% of total GHG emissions at the national level (Ajit et al., 2016). Based on this efficiency, the agroforestry systems has the potential of creating carbon trading and carbon credits opportunities. Further selling of this carbon credits can generate income while contributing to climate change mitigation.

Introducing incentive mechanisms for the agroforestry managers of NEI can be helpful to establish link between end users of the ecosystem services managed by indigenous folks at the upstream of ecosystem service loop. Studies has provided insightful information on progressive impact of payment for ecosystems services. Such a mechanism had potentially responsible for biodiversity conservation, reduction in soil erosion and sedimentation of river, increase in biomass carbon sequestration opportunities and restoration of degraded lands through different government and functional non-governmental agencies (Nath et al., 2023).

5 Conclusion and Recommendations

Agroforestry has the potential to support food production and enhance the overall efficiency and stability of agricultural systems in the NEI region. By combining tree crops with food crops, agroforestry systems can provide multiple benefits such as improved soil fertility, enhanced water retention, reduced erosion, diversified income sources, and increased resilience to climate variability. This integrated approach can contribute to sustainable food production and promote long-term agricultural sustainability in the region. It holds great promise in meeting various human needs, including food, fuel, fodder, timber, and more. Additionally, it serves as an insurance against soil erosion, floods, and other natural calamities that are commonly experienced in the NEI region. Restoration of degraded landscapes and biodiversity can be achieved through agroforestry. The agroforestry systems of the Indian Himalayan region holds profound significance of storing a significant amount of carbon. Global issues of climate change and food insecurity can be addressed with the help of agroforestry further contributing in the reduction of carbon footprint. Generation of carbon credits through agroforestry can serve as a catalyst for a positive change. Moreover, the sale of carbon credits on global markets can open up an additional source of income, assisting in the eradication of poverty and the creation of stable means of subsistence. Collaborative approach of involving scientific community, well-structured policy frameworks and community participation can also help achieve the international targets of carbon neutrality.

References

Ajit, D. S. K., Handa, A. K., Newaj, R., Chavan, S. B., Alam, B., Prasad, R., Ram, A., Rizvi, R. H., Jain, A. K., Uma, T. D., Shakhela, R. R., Patel, A. G., Dalvi, V. V., Saxena, A. K., Parihar, A. K. S., Backiyavathy, M. R., Sudhagar, R. J., Bandeswaran, C., & Gunasekaran, S. (2016). Estimating carbon sequestration potential of existing agroforestry systems in India. *Agroforestry Systems, 91*, 1101–1118. https://doi.org/10.1007/s10457-016-9986-z

Ambaye, T. G., Vaccari, M., Bonilla-Petriciolet, A., Prasad, S., Hullebusch, E. D., & Rtimi, S. (2021). Emerging technologies for biofuel production: A critical review on recent progress, challenges and perspectives. *Journal of Environment Management, 290*, 112627. https://doi.org/10.1016/j.jenvman.2021.112627

Anderson, S. H., Udawatta, R. P., Seobi, T., & Garrett, H. E. (2009). Soil water content and infiltration in agroforestry buffer strips. *Agroforestry Systems, 75*, 5–16. https://doi.org/10.1007/s10457-008-9128-3

Arunachalam, A., & Arunachalam, K. (2002). Evaluation of bamboos in eco-restoration of 'jhum' fallows in Arunachal Pradesh: Ground vegetation, soil and microbial biomass. *Food Policy, 159*, 231–239. https://doi.org/10.1016/S0378-1127(01)00435-2

Avasthe, R. K., Singh, K. K., & Tomar, J. M. S. (2011). Lrge cardamom (Amomum subulatum Roxb.) based agroforestry systems for production, resource conservation and livelihood security in the Sikkim Himalayas. *Indian Journal of Soil Conservation., 39*, 155–160.

Ayalew, B., Hylander, K., Zewdie, B., Shimales, T., Adugna, G., Mendesil, E., Nemomissa, S., & Tack, A. J. M. (2022). The impact of shade tree species identity on coffee pests and diseases. *Agriculture, Ecosystems & Environment, 340*, 108152. https://doi.org/10.1016/j.agee.2022.108152

Bhatt, B. P., Singh, R., Mishra, L. K., Tomar, J. M. S., Singh, M., Chauhan, D. S., Dhyani, S. K., Singh, K. A., Dhiman, K. R., & Datta, M. (2001). Agroforestry practices and research: An overview. In N. D. Verma, & B. P. Bhatt (Eds.), *Steps towards modernization of agriculture in NEH region* (pp. 365–392). ICAR Research Complex for NEH Region. https://zenodo.org/record/813234

Bhattacharjee, M., & Seal, M. (2017). Murta plant, a Non-wood forest product can be a sustainable source of rural income in the Northeastern part of India. *International Research Journal of Management Science & Technology., 8*, 137–141.

Bora, S. S., Sharma, K. K., Borah, K., Saud, R. K., Konwar, M. J., & Wasifur, S. (2019). Problems and prospects of agro-forestry systems in NE India—A review. *Bulletin of Environment, Pharmacology and Life Science, 8*, 152–161. https://bepls.com/beplsmay2019/28.pdf

Brahma, B., Pathak, K., Lal, R., Kurmi, B., Das, M., Nath, P. C., Nath, A. J., & Das, A. K. (2018). Ecosystem carbon sequestration through restoration of degraded lands in Northeast India. *Land Degradation and Development, 29*, 15–25. https://doi.org/10.1002/ldr.2816

Burgess, A. J., Cano, M. E. C., & Parkes, B. (2022). The deployment of intercropping and agroforestry as adaptation to climate change. *Crop and Environment, 1*, 145–160. https://doi.org/10.1016/j.crope.2022.05.001

CAFRI. (2015). *Vision (2050)*. Central Agroforestry Research Institute Jhansi.

Castle, S. E., Miller, D. C., Merten, N., Ordonez, 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. *Environment Evidence, 11*, 10. https://doi.org/10.1186/s13750-022-00260-4

Chhetry, G. K. N., & Belbahri, L. (2009). Indigenous pest and disease management practices in traditional farming systems in North East India: A review. *Journal of Plant Breed and Crop Science, 1*, 028–038. https://doi.org/10.5897/JPBCS.9000084

Critchley, W., Harari, N., Mekdaschi-Studer, R. (2021). *Restoring life to the land: The role of sustainable land management in ecosystem restoration*. UNCCD (United Nations Convention to Combat Desertification) and WOCAT (World Overview of Conservation Approaches and Technologies). https://www.unccd.int/sites/default/files/documents/2021-10/211018_RestoringLifetotheLand_Report%20%282%29.pdf

Das, T., & Das, A. K. (2005). Inventorying plant biodiversity in home gardens: A case study in Barak Valley, Assam, North East India. *Current Science, 89*, 155–163.

Das, A., Ramkrushna, G. I., Choudhury, B. U., Munda, G. C., Patel, D. P., Ngachan, S. V., Ghosh, P. K., Tripathi, A. K., Das, S., & Kumar, M. (2012). Natural resource conservation through indigenous farming systems: Wisdom alive in North East India. *Indian Journal of Traditional Knowledge, 11*, 505–513.

Dhyani, S. K., Chauhan, D. S., Kumar, D., Kushwaha, R. V., & Lepcha, S. T. (1996). Yield potential and economic analysis of traditional waterlogged agroforestry systems in North-East (Tripura), India. *Indian Journal of Agroforestry, 21*, 86–90. https://epubs.icar.org.in/index.php/IJA/article/view/96581

Dhyani, S. K., Tewari, R. K., Tiwari, R., Singh, R., & Srivastava, S. R. (2013). *Production and guidance*. www.nrcaf.ernet.in

Dhyani, S. K., & Tripathi, R. S. (1999). Tree growth and crop yield under agrisilvicultural practices in north-east India. *Agroforestry Systems, 44*, 1–12. https://doi.org/10.1007/bf00046925

Dhyani, S. K. (2018). Agroforestry in Indian perspective. In: G. R. Rao, M. Prabhakar, G. Venkatesh, I. Srinivas, & K. Sammi Reddy (Eds.), *Agroforestry opportunities for enhancing resilience to climate change in rainfed areas* (pp. 12–28). ICAR—Central Research Institute for Dryland Agriculture.

Dollinger, J., & Jose, S. (2018). Agroforestry for Soil Health. *Agroforestry System, 92*, 213–219. https://doi.org/10.1007/s10457-018-0223-9

Hussain, K., Ilyas, A., Bibi, I., & Hilger, T. (2021). Sustainable soil loss management in tropical uplands: Impact on Maize-Chili cropping systems. *Sustainability, 13*, 6477. https://doi.org/10.3390/su13116477

Jinger, D., Kaushal, R., Kumar, R., Paramesh, V., Verma, A., Shukla, C. S. B., Kakade, V., Dobhal, S., Utappa, A. R., Roy, T., Singhal, V., Madegowda, M., Kumar, D., Khatri, P., Dinesh, D., Singh, G., Singh, A. K., Nath, A. J., Joshi, N., … Kumawat, S. (2023). Degraded land rehabilitation through agroforestry in India: Achievements, current understanding, and future prospectives. *Frontiers in Ecology and Evolution, 11*, 1088796. https://doi.org/10.3389/fevo.2023.1088796

Jinger, D., Kumar, R., Kakade, V., Dinesh, D., Singh, G., Pande, V., Bhatnagar, P., Rao, B., Vishwakarma, A., Kumar, D., & Singhal, V. (2022). Agroforestry for controlling soil erosion and enhancing system productivity in Ravine lands of Western India under climate change scenario. *Environment Monitoring Assessment, 194*. https://doi.org/10.1007/s10661-022-09910-z

Jose, S. (2012). Agroforestry for conserving and enhancing biodiversity. *Agroforestry Systems, 85*, 1–8. https://doi.org/10.1007/s10457-012-9517-5

Kakati, R., & Konwer, D. (2001). Fuelwood characteristics of some indigenous woody species of north-east India. *Biomass and Bioenergy, 20*, 17–23. https://doi.org/10.1016/S0961-9534(00)00060-X

Kanwal, K. S. (2017). Climate change impact on forest and biodiversity of Indian Eastern Himalayan: An overview. *International Journal of Advance Engineering and Research Development, 12*. https://doi.org/10.21090/IJAERD.97142

Kehie, M., Khamu, S., & Kehie, P. (2017). Indigenous alder based farming practices in Nagaland, India: A sustainable agricultural model. *Journal of Traditional and Folk Practices, 5*, 82–152. https://jtfp.jntbgri.res.in/index.php/jtfp/article/view/94

Kumar, P., Sharma, P., Kumar, P., Sharma, M., & Butail, N. (2021). Agricultural sustainability in Indian Himalayan Region: Constraints and potentials. *Indian Journal of Ecology, 48*, 649–662.

Luedeling, E., Smethurst, P. J., Baudron, F., Bayala, J., Huth, N. I., van Noordwijk, M., Ong, C. K., Mulia, R., Lusiana, B., Muthuri, C., & Sinclair, F. L. (2016). Field-scale modeling of tree-crop interactions: Challenges and development needs. *Agricultural Systems, 142*, 51–69. https://doi.org/10.1016/j.agsy.2015.11.005

Manjaiah, K., Sasidharan, S., Thangavel, R., & Mayadevi, M. R. (2017). Soil organic carbon stocks under different agroforestry systems of North-Eastern regions of India. In: J. Dagar, & V. Tewari (Eds.), *Agroforestry*. Springer. https://doi.org/10.1007/978-981-10-7650-3_11

Mathukia, R. K., Sagarka, B. K., Panara, D. M. (2016). Fodder production through agroforestry—A boon for profitably dairy farming. *Innovare Journal of Agricultural Science, 4*, 13–19. https://journals.innovareacademics.in/index.php/ijags/article/view/9247

Nair, P. K. R. (1985). Classification of agroforestry systems. *Agroforestry Systems, 3*, 97–128. https://doi.org/10.1007/BF00122638

Nair, P. K. R. (1993). *An introduction to agroforestry* (pp. 21–38). Kluwer Academic Publishers.

Nair, P. K. R. (2005). Agroforestry. In: D. Hillel (Ed.), *Encyclopedia of soils in the environment* (pp 35–44). Elsevier. https://doi.org/10.1016/B0-12-348530-4/00244-7

Nair, P. K. R. (2017). Managed multi-strata tree + crop systems: An agroecological Marvel. *Frontiers in Environmental Science, 5*, 88. https://doi.org/10.3389/fenvs.201700088

Nair, P. K. R., & Garrity, D. (2012). The future of global land use. In: *Agroforestry—The future of global land use* (pp. 21–27). https://doi.org/10.1007/978-94-007-4676-3

Nair, P. K. R., Nair, V., Kumar, B. M., & Showalter, J. M. (2010). Carbon sequestration in agroforestry systems. In: D. L. Sparks (Ed.), *Advances in agronomy* (Vol. 108, pp. 237–307). https://doi.org/10.1016/S0065-2113(10)08005-3

Nair, P. K. R., Kumar, B. M., & Nair, V. D. (2021). An introduction to agroforestry: Four decades of scientific developments, (2nd edn.). Springer International Publishing. https://doi.org/10.1007/978-3-030-75358-0

Nath, P. C., Nath, A. J., Sileshi, G. W., & Das, A. K. (2020). Stand structure and functional attributes of agarwood (*Aquilaria malaccensis* Lam.) based smallholder farms in Northeast India. *Trees, Forests and People, 2*, 100027. https://doi.org/10.1016/j.tfp.2020.100027

Nath, A. J., Sileshi, G. W., Laskar, S. Y., Pathak, K., Reang, D., Nath, A., & Das, A. K. (2021a). Quantifying carbon stocks and sequestration potential in agroforestry systems under divergent management scenarios relevant to India's Nationally Determined Contribution. *Journal of Cleaner Production, 281*, 124831. https://doi.org/10.1016/j.jclepro.2020.124831

Nath, A. J., Kumar, R., Devi, N. B., Rocky, P., Giri, K., Sahoo, U. K., Bajpai, R. B., Sahu, N., & Pandey, R. (2021b). Agroforestry land suitability analysis in the Eastern Indian Himalayan region. *Environment Challenges, 4*, 100199.

Nath, P. C., Nath, A. J., Sileshi, G. W., Das, A. K. (2022a) Growth and coppicing ability of the critically endangered agarwood (*Aquilaria malaccensis* Lam.) tree in monoculture and polyculture in North East India. *Journal of Sustainable Forestry*. https://doi.org/10.1080/10549811.2022.2123823

Nath, P. C., Sileshi, G. W., Ray, P., & Das, A. K. (2022b). Variations in soil properties and stoichiometric ratios with stand age under agarwood monoculture and polyculture on smallholder farms. *CATENA, 213*, 106174. https://doi.org/10.1016/j.catena.2022.106174

Nath, A. J., Nath, P. C., & Sileshi, G. W. (2023). Payment for ecosystem services from agroforestry: Case studies and lessons. In: J. C. Dagar, S. R. Gupta, & G. W. Sileshi (Eds.), *Agroforestry for sustainable intensification of agriculture in Asia and Africa, Sustainable Agriculture and Food Security*. Springer. https://doi.org/10.1007/978-981-19-4602-8_23

Ollinaho, O. I., & Kröger, M. (2021). Agroforestry transitions: The good, the bad and the ugly. *Journal of Rural Studies, 82*, 210–221. https://doi.org/10.1016/j.jrurstud.2021.01.016

Pandey, D. N. (2007). Multifunctional agroforestry systems in India. *Current Science, 92*, 455–463.

Pandey, D. K., Momin, K. C., Dubey, S. K., & Adhiguru, P. (2022). Biodiversity in agricultural and food systems of jhum landscapes in west Garo Hills, North-eastern India. *Food Security, 14*, 791–804. https://doi.org/10.1007/s12571-021-01251-y

Panwar, P., Mahalingappa, D. G., Kaushal, R., Bhardwaj, D. R., Chakravarty, S., Shukla, G., Thakur, N. S., Chavan, S. B., Pal, S., Nayak, B. G., et al. (2022). Biomass production and carbon sequestration potential of different agroforestry systems in India: A critical review. *Forests, 13*, 1274. https://doi.org/10.3390/f13081274

Raj, A. (2020). Agroforestry and natural resources management: A linking concept. *Acta Scientific Microbiology, 3*, 94. http://actascientific.com/ASMI/pdf/ASMI-02-0462.pdf

Raj, A., Jharia, M. K., & Yadav, D. K. (2020). Impact of climate change on agroecosystems and mitigation strategies. In: A. Raj, M. K. Jharia, D. K. Yadav, & A. Banerjee (Eds.), *Climate change and agroforestry systems* (pp. 1–26). CRC Press, Taylor and Francis Group. https://doi.org/10.1201/9780429286759

Rathore, S., Karunakaran, K., & Prakash, B. (2010). Alder based farming system a traditional farming practices in Nagaland for amelioration of jhum land. *Indian Journal of Traditional Knowledge, 9*, 677–680.

Reang, D., Hazarika, A., Sileshi, G. W., Pandey, R., Das, A. K., & Nath, A. J. (2021). Assessing tree diversity and carbon storage during land use transitioning from shifting cultivation to indigenous agroforestry systems: Implications for REDD+ initiatives. *Journal of Environment Management, 298*, 113470. https://doi.org/10.1016/j.jenvman.2021.113470

Sarkar, P. K., Sarkar, P., & Pala, N. A. (2019). Yield potential and economic analysis of traditional waterlogged agroforestry systems in North-East (Tripura), India. *Indian Journal of Agroforestry, 21*, 86–90. https://epubs.icar.org.in/index.php/IJA/article/view/96581

Schroth, G., Krauss, U., Gasparotto, L., Duarte Aguilar, J. A., & Vohland, K. (2000). Pests and diseases in agroforestry systems of the humid tropics. *Agroforestry Systems, 50*, 199–241. https://doi.org/10.1023/A:1006468103914

Selvan, T., & Kumar, S. (2017) Agroforestry in the North-eastern Himalaya. In: S. K. Kumar, P. Pawar, & R. Kaushal (Eds.), *Agroforestry for increased production and livelihood security* (pp. 23–40). New India Publishing Agency.

Sharma, R., Xu, J., & Sharma, G. (2007). Traditional agroforestry in the eastern Himalayan region: Land management system supporting ecosystem services. *Tropical Ecology, 48*, 1–12.

Sharma, G., Partap, U., Dahal, D. R., Sharma, D. P., & Sharma, E. (2016). Declining large-Cardamom production systems in the Sikkim Himalayas: Climate change impacts, agroeconomic potential, and revival strategies. *Mountain Research and Development, 36*, 286–298. https://doi.org/10.1659/MRD-JOURNAL-D-14-00122.1

Sharma, P., Singh, M. K., Tiwari, P., & Verma, K. (2017). Agrofrestry systems: Opportunities and challenges in India. *Journal of Pharmacognitive Phytochemistry*, SP1, 953–957. https://www.phytojournal.com/archives/2017/vol6issue6S/PartV/SP-6-6-241.pdf

Shin, S., Soe, K. T., Lee, H., Kim, T. H., Lee, S., & Park, M. S. (2020). A systematic map of agroforestry research focusing on ecosystem services in the Asia-Pacific region. *Forests, 785*(11), 368. https://doi.org/10.3390/f11040368

Singh, V. S., & Pandey, D. N. (2011). *Multifunctional agroforestry systems in India: Science-based policy options.* Climate Change and CDM Cell, Rajasthan State Pollution Control

Board. https://krishi.icar.gov.in/jspui/bitstream/123456789/32624/1/Existing%20and%20improved%20agroforestry%20systems%20in%20low%20rainfall%20areas%20of%20India.pdf

Singh, A. B., & Teron, R. (2019). Traditional Oak agroforestry practices in Mima village of Kohima district, Nagaland state, Northeast India. *Indian Journal of Hill Farming, 32*, 203–215.

Singh, P. S. (2019). Sustainable alternatives to shifting cultivation in North east India. *International Journal of Advance Science and Research Management, 4*.

Tomar, J. M. S., Ahmed, A., Bhat, J. A., Kaushal, R., Shukla, G., & Kumar, R. (2021). Potential and opportunities of agroforestry practices in combating land degradation. In: G. Shukla, S. Chakravarty, P. Panwar, & J. A. Bhat (Eds.), *Agroforestry—Small landholder's tool for climate change resiliency and mitigation.* IntechOpen. https://doi.org/10.5772/intechopen.97843

Tomar, J. M. S., Ahmed, A., Bhat, J. A., Kaushal, R., Shukla, G., & Kumar, R. (2021). Potential and opportunities of agroforestry practices in combating land degradation. In: G. Shukla, S. Chakravarty, P. Panwar, & J. A. Bhat (Eds.), *Agroforestry—Small landholder's tool for climate change resiliency and mitigation.* Intechopen. https://doi.org/10.5772/intechopen97843

Udawatta, R. P., Rankoth, L., & Jose, S. (2019) Agroforestry and Biodiversity. *Sustainability, 11*(10), 2879. https://doi.org/10.3390/su11102879

Ulmana, Y., Kumar, A., & Sharma, M. (2022) Traditional agroforestry systems and practices of Assam. *Indian Journal of Traditional Knowledge, 21*, 414–424. http://op.niscair.res.in/index.php/IJTK/article/view/31569

Vineeta, S. B. C., Tamang, M., Shukla, G., Debnath, M. K., Nath, A. J., & Chakraborty, S. (2022). Floristic diversity, and conservation status of large cardamom based traditional agroforestry system along an altitudinal gradient in the Darjeeling Himalaya, India. *Agroforestry Systems, 96*, 1199–1210. https://doi.org/10.1007/s10457-022-00778-z

Viswanath, S., Lubina, P. A., Sruthi, S., & Sandhya, M. C. (2018). Traditional agroforestry systems and practices: A review. *Advance Agricultural Research Technology Journal, 2*, 18–29. http://isasat.org/Vol-ii,issue-i/AARJ_2_1_3_Viswanath.pdf

Wilson, M. H., & Lovell, S. T. (2016). Agroforestry—The next step in sustainable and resilient agriculture. *Sustainability, 8*, 574. https://doi.org/10.3390/su8060574

World Bank. (2004). *Sustaining forest: A development strategy*. World Bank, Appendix 2, pp. A–3. https://doi.org/10.1596/0-8213-5755-7