

Chapter 23

Agroforestry: A Key Technique for Achieving the Sustainable Development Goals



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Abstract Climate change is the most important issue of the twenty-first century, and it's being discussed in every country. The growth of heat waves, changes in rainfall patterns, the rise of sea levels, desertification, land degradation, drought and floods have all been caused by climate change. Agriculture accounts for 30% of the total greenhouse gas emissions in the world today. As a result of climate change, food shortages and water shortages will become more common. The food problem is a direct result of deforestation and the overuse of natural resources. Agroforestry has emerged as a key component in addressing both the food issue and climate change in the modern world. In the tropical regions of Brazil, Kenya and Indonesia, farmers are paid to grow trees as part of agroforestry programmes. Farming based on agroforestry can provide food security while simultaneously providing a healthy diet. Practicing agroforestry will help recharge groundwater, avoid soil erosion and degradation and lessen the impact of natural disasters. It will reduce poverty, provide food security, produce money and empower tribal communities and rural populations. There is a growing demand for Ayurvedic medicine in India as the country attempts to enhance its forest cover from 23% to 33% through the use of kitchen gardens and agroforestry. This would help the country's commerce industry. Given its location, India's agricultural potential is greatly enhanced by agroforestry. With the majority of its population concentrated in rural areas, India is predominantly an agrarian society, and modern technology plays a crucial role in ensuring food security. In contrast, agroforestry can fill in the gaps where modern technology has not yet reached the agriculture sector. Ecological balance and proper biodiversity can also be achieved through agroforestry. There are around 300 million rural Indians who are completely reliant on forests and other natural resources for their food, clothing and shelter, and agroforestry cultivation in Jharkhand has given tribal communities the power to self-sufficiency. Rural inhabitants in the Indian subcontinent will benefit greatly from community-based farming with agroforestry, which will help reduce rural–urban migration and improve the socioeconomic and food security of the people in rural areas and sustainable use of Land.

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Keywords Agroforestry · Climate change · Sustainable use of land · Natural resources · Food security

23.1 Introduction

Agriculture is the earth's most destructive activity and has had the worst effects on the ecosystem. Deforestation for agriculture was the initial cause of environmental degradation, and as population grew and there was a greater need for food, we began to employ various chemicals to hasten the production of food. The green revolution, which concentrated on growing wheat and rice and benefited just a select states, including Punjab, Haryana and Uttar Pradesh because of their superior irrigation systems and land quality, is an example of this following the Independent. India depends on the monsoons for agriculture since it produces crops that need a lot of water. Our lack of high-quality seeds and excessive use of chemical fertilisers render the land unsuited for further development. Seventy per cent of the water is required for irrigation. We barely have any ground water left due to deforestation since trees could naturally recharge ground water, but this is no longer viable as a result of deforestation. The process of climate change and environmental deterioration has caused significant issues for the rural and tribal community. In tribal areas, depending on the location, Jhum cultivation is practised, which involves growing multiple crops simultaneously in the same field. However, climate change has made this impossible to continue with. Prolonged droughts and floods are adding to the problem as changing rainfall patterns and water logging ruin the quality of the land. Increased food security is accompanied with India's biggest water catastrophe. In order to increase food production, the government of India has implemented new laws and programmes such as soil health cards, technologies for reporting temperature and rainfall, the use of drones in the agriculture sector and new machineries and cultivation methods. However, the lack of land reforms since independence and the unequal distribution of resources, which have worsened poverty in the area and a spike in farmer suicide, are the where technology can be used, yet farmers still use traditional farming techniques because of the country's rapid development. There are small- and medium-sized farms; farmers have extremely small holdings. In fact, agriculture is responsible for 30% of the increase in greenhouse gases and is also to blame for increasing river pollution since its waste water, which contains significant amounts of chemical fertilisers, directly enters rivers and affects the marine life there. The globe is returning to the traditional kind of agriculture known as agroforestry, which is environmentally sustainable, may address the dual issues of a food and water shortage and can also increase biodiversity. When agroforestry was used earlier, issues like climate change and environmental damage did not exist. Rising of the food crisis across the world has been presented in Fig. 23.1.

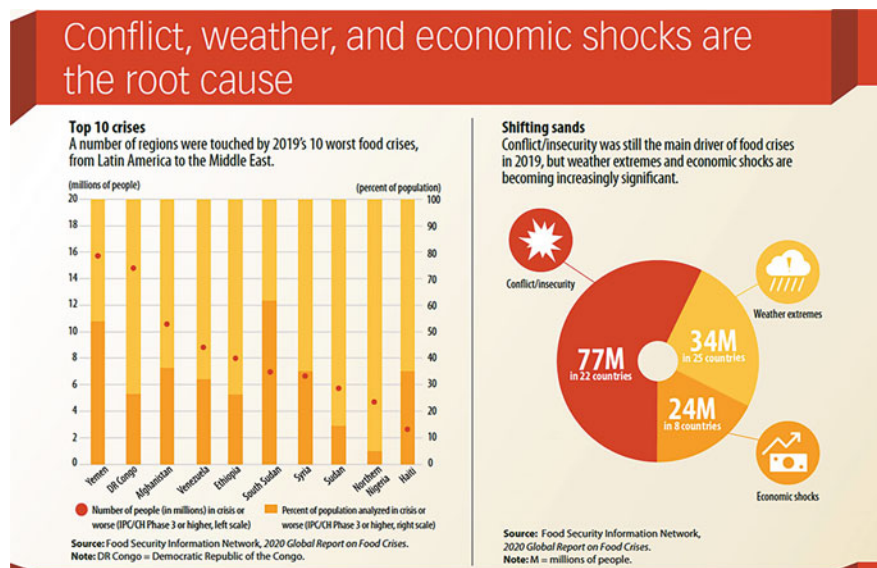


Fig. 23.1 Rising food crisis across the world (Source: Food security Information Network)

23.2 Agroforestry

We need a climate-smart agriculture system that will combat climate change, save the environment, particularly the forest, fisheries and cropland (World Bank 2021). Currently, 75% of the world's population lives in rural areas and depends on agriculture and the forest for their livelihood, which has led to widespread deforestation and resource exploitation. By 2050, our food production needs to expand by 70% in order to keep up with the population growth. In order to implement a smart agriculture system, productivity must be increased, carbon emissions must be reduced and drought, pests and disease vulnerability must be lessened (World Bank 2021). Agroforestry can be defined as growing trees along with the crops which will promote soil health, plant nutrient, crop productivity, tackle climate change, maintain ecological balance and provide animal feed and reduce the use of water for cultivation (Vi Agroforestry n.d.). Agroforestry boosts soil fertility, moisture content and biodiversity, enabling diversified food production and higher yields. With the help of the trees, which also reduce carbon dioxide, agroforestry boosts output while reducing the effects of climate change. The trees give the soil moisture as well as shade, food for the animals, compost and other benefits. A tree used in agroforestry produces more water than it uses. Recreating a natural environment is made easier by agroforestry. Larger harvests, a more favourable environment and enhanced resistance to the effects of climate change are the outcomes. Agroforestry contribution towards sustainability has been presented in Fig. 23.2.



Fig. 23.2 Agroforestry contribution towards sustainability

Especially in the East African region, small farmers are suffering due to climate change, where Vi Agroforestry is providing them with emission profit, contributing to reduce carbon emission. Trees are suffering as firewood and kept throughout the year, different kinds of crops and fruits are grown parallelly and certain trees also have medicinal leaves. Agroforestry can also resolve the problem of water crisis through natural recharge of ground water and prevent soil erosion and natural disasters as trees can control cyclones and floods. Eliminating poverty and increasing the economic activities, trees will provide timber and building materials, reduce pollution from the atmosphere and provide purify air. The whole process is based on Sustainable Land management, with land taken away for development purpose, Agroforestry does the twin work for land management and growing crops, rooftop farming and vertical farming are a product of food insecurity and land management and rise in climate change. South Africa was the first region to start with Agroforestry.

Across the world today, agroforestry has become an important component of cultivating crops, with the change in demand and supply and rapid deforestation, agroforestry is a hope to maintain ecosystem and establish sustainable agriculture practice and sustainable rural development. In India, there is a National Agroforestry



Fig. 23.3 Degraded land across the world (Source: Bonn Challenge)

policy (World Agroforestry 2014). In India, agroforestry is currently implemented on 13.5 million hectares, although there is much more potential. Already, about half of the country's fuel wood and approximately 65% of its timber originate from trees cultivated on farms (Fig. 23.3). It is providing employment to a number of people in the rural region, till now 450 new people have got jobs for the production of Timber. 300 million people depend on forest for their living in rural region.

Agroforestry and sustainable management practices.

Agroforestry can improve the conditions of the tribal community whose land has been taken away for mining and development purpose. Tribal community have been practising agroforestry since ages, there are highly depend on trees for their nutrition and food security where Jhum cultivation is also a kind of agroforestry. Kitchen garden/nutrient gardens mostly practised by rural women are a part of agroforestry. Nutrition literacy is an important part of agroforestry. Agroforestry can lead to nutrition security.

Agroforestry is an important component of sustainable management practises since it involves integrating trees, crops and livestock in a way that is advantageous to all three. This is what makes agroforestry so significant. To build environmentally friendly landscapes, one must draw inspiration from the most successful aspects of agricultural and forestry practises.

A great range of plant and animal life can be found within agroforestry systems, and it is important to preserve this diversity. The practise of planting trees in agriculturally managed ecosystems is known as agroforestry. This is done with the intention of preserving biodiversity.

Agroforestry systems use trees because they mitigate the effects of wind and water, reduce the amount of runoff and maintain the soil's moisture level, all of which contribute to the preservation and improvement of the soil. They contribute to the fertility of the soil in a variety of additional ways, including the fixation of nitrogen, the cycling of nutrients and the deposition of organic matter.

Through the process of photosynthesis, trees grown in agroforestry systems absorb carbon dioxide from the atmosphere, thereby mitigating the consequences of climate change. The capture of carbon through agroforestry has the potential to be an effective strategy for offsetting the emissions of greenhouse gases produced in other places.

Techniques used in agroforestry are beneficial for water management because they reduce the amount of water that is lost to evaporation, increase the amount of water that is replenishing the ground and control the rate at which water runoff occurs. Tree canopies act as natural shields, mitigating the effects of heavy precipitation and protecting water quality by preventing soil erosion. This is accomplished by lowering the amount of sunlight that is able to pass through.

Agroforestry provides economic benefits and resilience by allowing farmers to make money from a larger variety of sources, such as the growing of food crops, lumber, fruits, nuts and medicinal plants. This broadens the farmers' earning potential and increases their financial security. This diversification enhances resistance to the volatility of both the climate and the economy.

Improved food security, nutrition and nutritional diversity are all outcomes of agroforestry systems' commitment to growing a wide range of crops, particularly heirloom varieties, as their primary focus. They provide an alternative to monoculture that is a way of farming that is more robust and sustainable.

A higher standard of living, increased income and reduced costs of living are all possible outcomes for rural communities who use agroforestry practises. The utilisation of trees can enhance the economic stability of farmers because trees give a variety of products that can be marketed and bought and sold.

The establishment of an agroforestry system can provide a number of positive environmental effects, including the production of shade and windbreaks, as well as the regulation of local microclimates. Both crop plants and cattle stand to benefit from these services, which in turn increase the overall productivity and health of the agro-ecosystem.

A sustainable land-use practise known as agroforestry is one that, in addition to boosting agricultural production and improving local ecosystems, also helps to fortify communities. As a result, it is a beneficial instrument for ecologically conscious management as it contributes to striking a balance between agricultural production and environmental protection.

The practise of agroforestry, often known as the 'win-win' strategy, is a type of land management that enables for several uses to be carried out on the same parcel of

land. Agriculture has the potential to profit from this land use by generating food and fuel, safeguarding the environment and biodiversity, adapting to or minimising the effects of climate change and conserving the environment. Even though it may appear that implementing this method would call for a significant adjustment to the management philosophy that is now in place, all that is actually required to make it a reality is an increase in the number of trees that are present within the field, either on their own or as part of a certain structural arrangement. The practise of agroforestry, often known as the ‘win-win’ strategy, is a type of land management that enables for several uses to be carried out on the same parcel of land. Agriculture has the potential to profit from this land use by generating food and fuel, safeguarding the environment and biodiversity, adapting to or minimising the effects of climate change and conserving the environment. It may sound like a system that would require a significant adjustment to the way management is carried out, but all that is required to put it into action is the planting of additional trees in the field. These trees can be planted on their own or as part of a structure such as a shelter belt or buffer strip. One illustration of this would be a shelter belt, often known as a buffer strip. Agroforestry is a form of agriculture that is becoming increasingly common in developing countries, particularly in drier and more arid locations. If the predictions about climate change turn out to be accurate, then British farmers will need to make modifications to their practises in order to keep up with the projected temperature shifts and, at the same time, reduce the environmental damage that their practises may cause. Agroforestry may provide an alternative management strategy for agricultural businesses, which would be beneficial in terms of satisfying their objectives of lowering their impact on the environment and increasing their potential output (Stiles 2017).

23.3 Agroforestry Role in Water Management

By enhancing local water cycles, agroforestry can give farms more control over and access to freshwater. Both the local and global water cycles depend heavily on trees. Through incorporating, it is possible to address water needs and enhance food production systems by planting trees on agricultural land without having a harmful effect on downstream or nearby water users. Climate change and irresponsible land use have consequences.

Agriculture and industry are becoming more of a worldwide problem and a lot of individuals lack access to both food and water insecurity. Around the world, agriculture makes about 70% of freshwater is a factor numerous additional environmental difficulties and consequently, one of the most crucial aspects of modern water and environmental problems (Agroforestry network 2020).

Smallholder farmers are already prevalent throughout much of the world witnessing variations in the patterns of rainfall. This decreased capacity to forecast precipitation and accessibility to both farm productivity and public health are impacted by water.

Climate change requires action to guarantee that everyone has access to sustainable water and sanitation services alteration adaption. Agroforestry provides methods that contribute to greater water security, as well as climate change adaptation and mitigation. Improved fallows, an agroforestry technique, are one instance. Trees have the capacity to increase soil moisture and enrich the soil where they are planted in rotation with cultivated crops while reducing climate change through carbon in the soils sequestration (Agroforestry network 2020).

By increasing infiltration, decreasing runoff and erosion and boosting water availability and quality, agroforestry is an essential component of effective water management.

By decreasing the effects of wind and water, agroforestry systems aid in soil erosion control. Rainfall is absorbed by the tree canopy, slowing the rate at which water runs off the land. Soil erosion is reduced and aggregate development is encouraged because tree roots bind and stabilise the soil. Sedimentation in water bodies can be avoided and aquatic ecosystems can continue to thrive with the help of erosion control measures like these.

Trees in agroforestry systems improve water infiltration into the soil and increase water retention. By breaking up the soil and forming channels, a tree's roots can increase groundwater recharge while decreasing runoff from the surface. Water penetration rates and storage capacity can be greatly improved by incorporating deep-rooted trees into agroforestry systems, such as some agroforestry alley cropping or clavipectoral systems.

Controlling the Flow of Water Agroforestry systems control the flow of water, which is especially useful during times of extreme precipitation. The canopy of trees acts as a sponge, soaking up and dispersing raindrops before they can cause rapid runoff and destructive flash floods. Agroforestry methods reduce soil erosion, shield vital infrastructure and encourage economical water usage because of their ability to control the flow of water.

Trees in agroforestry systems have a significant impact on local climate by moderating wind and water circulation. They block the sun; thus, less water is lost through the soil's surface and evaporation. The tree canopy also mitigates temperature swings, protecting crops from damage caused by high temperatures and decreasing the need for supplemental irrigation. These favourable local weather conditions improve water utilisation efficiency and help conserve water in the larger context.

Reduced runoff from agricultural land into water bodies is one way in which agroforestry systems can improve water quality. Agroforestry systems have tree buffer zones that operate as filters, preventing sediment, fertilisers and agrochemicals from entering groundwater supplies. Trees' root systems help absorb and store nutrients, lowering the likelihood that these substances would seep into nearby water sources and contaminate them.

Agroforestry can be used for river and stream bank restoration, also known as riparian zone restoration. Restoring and stabilising riparian habitats through tree planting helps reduce bank erosion, lowers nutrient runoff and keeps water

temperatures down. Improved water quality, protected aquatic habitats and a thriving watershed are all benefits of well-maintained riparian areas.

Agroforestry systems with deep-rooted trees can tap into groundwater and act as a buffer against water scarcity by soaking up extra moisture during dry spells. Certain tree species are more resistant to drought because their thick roots can reach water resources farther underground. Therefore, during times of water scarcity, agroforestry systems help keep water available for crops, livestock and other agricultural activities.

With its combination of forestry and agriculture, agroforestry provides an all-encompassing strategy for water conservation. Agroforestry systems encourage efficient and sustainable use of water resources in agricultural landscapes by decreasing soil erosion, increasing water infiltration and retention, controlling water flow, bettering water quality and adding to water availability.

23.4 Agroforestry and Food Security

Agroforestry system also contributes to increased photosynthetic efficiency of tree species. Enhanced soil fertility and structure have a growing impact on crop productivity. Less soil erosion loss and improved closed-loop nutrient- and organic-cycle management improving the microclimate for the development of agricultural crops. Forest-influenced soils have been shown to produce higher agricultural yields compared to non-forested soils. The Taungya people of Uttar Pradesh's Tarai region are known for their exceptional agricultural yields using just organic methods and no fertiliser. It has been observed that agro forestry in Haryana and western Uttar Pradesh results in grain and wood yields that are almost 20% higher than those obtained from conventional farming methods. The total output of fodder is greater when fodder grasses are cultivated with fodder trees, according to experiments done at IGFRI, Jhansi. Food, animal feed and fuel production all rise when *Leucaena leucocephala* is grown alongside conventional crops and forage grasses in an intercropping arrangement.

Agroforestry-grown nitrogen-fixing trees have a fixing capacity of 50–100 kg N/ha/year. It has been shown that a tree and farm crop production system is more productive in Punjab, Haryana, Uttar Pradesh, Gujarat and some areas of the southern states. Fuel, fodder and small timber are all claimed to be produced and worth far more on degraded fields than the coarse grains typically grown there. One of the most exciting aspects of agroforestry is the role that nitrogen-fixing trees play. As the leaf litter decomposes, humus is formed, nutrients are released and the soil's varied qualities are enhanced; in addition, less fertiliser is required (Prasad *n.d.*).

When it comes to marginal land, it is most cost-effective to grow trees and fodder crops (including fodder trees). Evidence gathered from Rajasthan's hot, dry and semi-arid regions suggests that the state's marginal lands are not suitable for the production of healthy, abundant crops. Under Haryana, planting trees like Eucalyptus in agroforestry has been proven to be more profitable than pure agriculture. Other

types of trees including *Prosopis*, *Albizia*, *Zizyphus* and *Acacia* can also be grown in a silvopasture system. In the Tarai region of Uttar Pradesh, *Populus deltoides* doubles farm profits.

Bamboo-based agroforestry can enhance the productivity. It also produces a lot of oxygen and emits more carbon than the tropical and sub-tropical trees (Solomon et al. 2021), making the air clean and balance ecosystem. Practiced in Kerala in India, Nepal and many other developing countries, bamboo-based agriculture can contribute to economic development and employment. In the tropical regions, agroforestry is very common.

In Kenya, only 20% of the land is suitable for growing crops due to soil erosion and lack of rain; due to this, farmers are adopting dryland programme to make their land green and grow crops through agroforestry. Crops like mango, orange, neem and many more are grown in the shades (Nijagi 2021). Many crops especially plantation crops like coffee grow under the shades of trees. Agroforestry provides animal feed which also contributes to the production of better quality milk. Pineapple agroforestry systems (PAFS), which are prevalent in the Indian Eastern Himalayas and other parts of Asia and are typically grown in conjunction with multipurpose trees, can be a sustainable alternative to Jhum cultivation for the North East of India. This practise is traditionally carried out by the ethnic 'Hmar' tribe in southern Assam. In southern Assam, the ethnic 'Hmar' tribe has been growing pineapple for millennia. They currently use the native PAFS for, both for domestic use and to improve economic benefits. They have developed a distinctive agroforestry system by applying indigenous knowledge (PID Delhi 2021). An assortment of commercially significant trees, including *Albizia procera*, *Parkia timoriana* and *Aquilaria malaccensis*, as well as fruit trees, including mango, papaya, guava, lemon and litchi and with pineapple, caters to both year-round home use and year-round selling. The trees in the higher canopy control light, boost biomass inputs and broaden the range of farms, which improves soil fertility and plant nutrition. The farmers' preferred native fruit trees are preserved thanks to tree-related management techniques. Rubber plants are being introduced by farmers in the older pineapple agroforestry plantations. Today, modern technology and new approaches are used in the agricultural sector to produce crops like through vertical farming, hydroponics, artificial intelligence and machine learning, whereas developing and undeveloped countries are more into agroforestry as digitalisation has not reached it. Agroforestry can protect and preserve natural resources. It is time that the agriculture sector also reduces its carbon emission. There is a long history of agroforestry on the Indian subcontinent. Raising, caring for and loving trees are deeply ingrained in the socioreligious fabric of the people of the subcontinent, trees are heavily integrated into the region's agriculture and livestock production systems (Singh 1987).

The kherji (*Prosopis cineraria*) and agricultural-crop combination in the hot, arid region meets needs for fodder, small timber and food, while the multi-tier tree-crop combinations in the homegardens of the damp lowlands suit financial and domestic necessities. An good example of a modern but conventional agroforestry system is the combination of *Alnus nepalensis* and *Amomum subulatum* found in the humid sub-temperate regions of Nepal, Bhutan and Sikkim state in India. Other typical

instances of widespread agroforestry methods include the purposeful growth of trees on field bunds, their irregular distribution in agricultural fields and the intentional preservation of shade trees in tea and coffee plantations. Similar to this, it is customary to cultivate crops for 2–3 years in newly planted orchards and woods before interplanting shade-tolerant plants like turmeric and ginger.

The greatest number of people can benefit from agroforestry, it is good for the environment, and it does not require the application of modern technology. In order to handle the food crisis, achieve nutrition security and put an end to poverty, hunger and health crises, farmers need to acquire training, and traditional wisdom needs to be put into practise. Several Indian states, including Gujarat, Jharkhand and Maharashtra, have been implementing agroforestry practises as part of their efforts to become more sustainable. Native American groups and tribes have practised this way of life for a very long time.

A large percentage of the goals for sustainable development are significantly reliant on agroforestry. These goals include eliminating hunger and poverty as well as ensuring that everyone has access to clean drinking water and sanitary facilities. The Sustainable Development Goals 2, 3, 6, 13 and 15 all address issues related to climate change and life on land.

23.5 Agroforestry Role in Forest Restoration and Climate Resilience

Agroforestry is the outcome of agricultural practises being integrated with tree planting and management, and it has a substantial impact on the process of forest restoration as well as the climate resilience of the area.

Reforestation is possible through the application of agroforestry practises, which can be applied to reforest damaged or entirely removed areas. A form of farming known as agroforestry involves planting trees in agricultural areas in order to re-establish forest cover, boost biodiversity and help ecosystems recover from damage. The inclusion of tree species that are native to an area is beneficial to agroforestry systems since it aids in the regeneration of the local flora and fauna.

Agroforestry has the potential to be an efficient solution for projects involving reforestation as well as regeneration. Incorporating trees into agricultural holdings allows farmers to make a direct contribution to tree-planting initiatives by increasing the tree density and expanding the amount of land covered in forest. Due to the fact that it enables them to cultivate both trees and food crops at the same time, farmers and landowners can realise financial benefits from practising agroforestry. Because they are helpful in storing carbon, agroforestry systems are an important part of the fight against climate change. Agroforestry methods, in which trees are utilised to combat climate change by absorbing greenhouse gases from the air and storing their own carbon, are gaining in popularity. These methods may be found in more and more agricultural settings. The practise of agroforestry has the potential to be a more



Fig. 23.4 Agroforestry role in forest restoration and climate resilience

successful method of carbon sequestration due to the fact that it combines the benefits that are associated with farming and forestry.

Agroforestry strengthens agricultural systems, making them more resistant to the effects of climate change. The presence of trees in agricultural settings protects crops from the sun and provides shelter from storms, which together make an agroforestry system more resistant to the effects of natural disasters. The tree canopy acts as a windbreak and casts shade on the ground below, both of which contribute to more moderate temperatures and humidity levels. Farmers that practise agroforestry have a more diverse range of income and food sources, which puts them in a better position to withstand the effects of shifting climates.

Because of the method in which they are integrated into landscapes, agroforestry systems can be of assistance in the management of water resources. Having trees in the area can help with water management, as well as the prevention of erosion and the infiltration of water. Their root systems contribute to the reduction of runoff and the improvement of water retention, which is a benefit to the environment. By boosting groundwater levels and retaining surface water during wetter times, agroforestry systems can help lessen the chance of flooding and drought.

Agroforestry systems are able to supply multiple ecological services, which in turn increases the resilience of the landscape (Fig. 23.4). These services include, but are not limited to, the protection of soil, the purification of water, the facilitation of pollination, the improvement of habitat for wildlife and the encouragement of beneficial insects. The capacity of ecosystems to function and recover after disturbances is improved by the practise of agroforestry, which contributes to the fortification of ecosystems. Agroforestry is essential to the process of forest regeneration as well as climate resilience since it combines the benefits of farming with those of trees and the ecosystem services they provide. It presents a holistic perspective of the ecosystem and provides long-term plans for the management of land in the context of climate change.

Agriculture is the main source of revenue and economic growth in rural areas of low-income countries. However, land pressure and climate change are detrimental to

agricultural systems in emerging countries, posing a threat to food production. While intensive agricultural methods have been successful in many parts of the world, their promotion has led to a decrease in agricultural output due to degraded soil. Negative feedbacks on climate, food security and on-farm income at local scale result from the numerous environmental implications of agricultural intensification and food production, including negative effects on soil and biodiversity (Mbow et al. 2014).

23.6 Agroforestry and Environment Governance

The two areas of study are intricately intertwined, and law plays an essential part in ensuring the effective use and regulation of agroforestry practises to maximise their potential benefits.

The practises that are known as agroforestry are governed by a set of laws and regulations. In these agreements, the rights and obligations of agroforestry stakeholders including communities, landowners and farmers are laid out in detail. Farmers are one type of agroforestry stakeholder. Legal requirements must be met for ‘sustainable land use’, ‘forest conservation’, ‘biodiversity protection’ and ‘tree incorporation into agricultural systems’, among other ‘green’ initiatives.

A stable ownership structure of land is necessary for the widespread implementation of agroforestry practises. If farmers and communities are granted the right to own land and put it to use for agroforestry purposes, then only then can agroforestry be considered a lawful practise. Clear land tenure arrangements, which also encourage sustainable land management, encourage long-term investments in agroforestry by providing stability for land ownership.

It is standard procedure to carry out what is known as an environmental impact assessment (EIA) before to beginning any kind of agroforestry endeavour on a significant scale. EIAs examine the potential environmental, social and financial ramifications of a project in order to guarantee that it will not have a negative impact on the environment, that it will be fair to the community and that it will be profitable.

The management of agroforestry systems, which are crucial for the protection of forests and biodiversity, is significantly impacted by the laws that are in place. They are responsible for the establishment of reserve zones, the establishment of rules for the responsible management of forests and the control of the extraction of timber and other forest items. Legal frameworks provide assistance for agroforestry practises that protect genetic resources and species that are in danger of extinction.

Certification Programmes and Occupational Standards By making the use of sustainable agroforestry practises mandatory, laws and regulations have the potential to increase their use and spread their benefits. By getting the appropriate certifications, such as those for organic farming or sustainable forest management, agroforestry systems can be proven to meet environmental and social requirements through the process of certification verification. Compliance with such criteria may result in gaining access to markets, conducting land management in a more responsible manner and receiving incentives to practise sustainability.

Participation from Stakeholders and Involvement of Stakeholders The participation of stakeholders and other interested parties in the decision-making processes of agroforestry and environmental governance can be enhanced through laws. It is possible for legal frameworks to require the input of the general public, the engagement of local people and the acknowledgement of indigenous and traditional knowledge.

Hearing from a diverse group of people is necessary to ensure that the laws governing agroforestry are effective, fair and in tune with the realities of the local environment.

Because laws provide methods to ensure that norms are obeyed, agroforestry regulations are considered to be enforceable. They spell out the repercussions for disobedience, explain the functions of oversight bodies and offer routes for resolving issues that develop as a result of the practises used in agroforestry. The stringent enforcement of environmental standards for agroforestry practises helps to promote both a clean and safe environment as well as responsible land management.

The legal framework that is provided by legislation in agroforestry and environmental governance is extremely helpful in promoting sustainable practises, ensuring the protection of biodiversity, ensuring the security of land tenure and providing opportunities for stakeholder participation. It is possible to strike a balance between the requirements of agricultural productivity and those of environmental protection through the lawful implementation of agroforestry systems, which requires the establishment of explicit standards and laws.

In order to slow the rate at which biodiversity is being lost and to make sustainable landscape management possible, it is crucial to incorporate protection of natural resources within agricultural practises. Convention for Biological Diversity (CBD) advocates for sustainable agriculture supporting biodiversity and ecosystem functions like connectivity and habitat stability, but governments have instead prioritised expanding the protected area network (Zinngrebe et al. 2020). Changes in environmental governance, which includes all policies and institutions affecting the state of the environment, have profound effects on tree planting and management on farms across the developing world. Multiple facets are undergoing shifts at once. Decentralised multistakeholder committees and local user groups are gradually replacing national forestry agencies as the formal power holders in the field. The use of incentives and market forces to supplement regulatory frameworks is gaining traction in the field of environmental management. Companies are increasingly providing environmental goods and services, such as water, energy and lumber, and protecting biodiversity and watersheds. International agreements and the initiatives of powerful international organisations are increasingly prioritising integrated approaches to ecosystem and landscape management that incorporate local inhabitants as vital partners (Swallow et al. n.d.).

Importers of tropical timber and timber products have been under increasing pressure from the world's largest markets in recent years to provide evidence that their goods come from legal or sustainable sources. There are a number of laws around the world that demand proof of timber's legitimacy, including the Japan Clean Wood Act, the EU Timber Regulation, Australia's Illegal Logging Prohibition

Act and the United States' Lacey Act. In order to better enforce forest laws, tropical timber-producing countries can now access resources made available by a resolution made by the International Tropical Timber Council in November 2001 (ITTO [n.d.](#)).

23.7 Role of Agroforestry to Eradicate Poverty and Food Crisis

By fostering long-term and diverse income sources for rural people, agroforestry has the potential to significantly contribute to the fight against poverty.

Farmers have the potential to increase their income through the use of agroforestry techniques. Farmers can increase their revenue diversity by growing and selling lumber, fruits, nuts, medicinal plants and other non-timber forest products by incorporating trees into their agricultural systems. When compared to conventional monoculture crops, agroforestry has the potential to yield higher-value goods, which in turn can lead to higher revenue and more financial security.

Agroforestry can improve rural populations' access to markets and their ability to participate in value chains. Farmers that use tree products in their operations can meet the demands of consumers who want to buy items made in a sustainable manner. Tree-based goods can have their market worth increased through value addition, processing and marketing thanks to agroforestry systems.

Agroforestry helps with food security and better nutrition since it increases the variety of crops grown. A variety of healthy foods can be produced in an agroforestry system because food crops are typically grown alongside trees. Increasing dietary diversity and decreasing reliance on a stable climate can both be achieved through the cultivation of a wide variety of crop and tree species.

Land Management: Agroforestry encourages sustainable land management practices that boost soil fertility, conserve water and strengthen ecosystems. Agroforestry is the practise of incorporating trees into agricultural systems to promote soil health, reduce the risk of soil erosion and increase water penetration. These methods improve farmers' incomes by increasing agricultural output while decreasing the likelihood of crop failures.

When compared to monoculture agriculture, agroforestry systems are more able to withstand the effects of climate change. Agroforestry uses trees to protect crops from the effects of extreme weather by providing shade, windbreaks and microclimate regulation. Farmers' vulnerability to climate-related hazards is mitigated by the diversification of revenue sources afforded by agroforestry, which makes them less reliant on a single crop and more able to adjust to shifting climatic conditions.

Employment and Rural Development: Agroforestry generates jobs in rural regions through on-farm and value-added processes. Communities can benefit from the creation of new jobs that result from the planting, maintenance, harvesting and sale of tree products. Infrastructure upgrades, increased awareness of sustainable

land management methods and increased community agency and capability are just few of the ways that agroforestry projects benefit rural advancement.

Agroforestry helps farmers weather market swings and price swings by spreading their revenue among multiple crops instead than relying on a single cash crop. Farmers may expand their market reach and respond to shifting customer preferences by using tree-based products. This resistance to market shocks aids in protecting rural areas from economic downturns and poverty.

In general, agroforestry is a sustainable and diverse method of farming that can boost income, increase food security, facilitate management of natural resources and make farms more resistant to climate change. Agroforestry helps improve the economic and social conditions of rural areas by tackling numerous causes of poverty.

The governments that control and manage over 77% of the world's forests do not respect the rights of indigenous peoples and local populations to the land. The locals who depend on the forests for survival do not get the benefits they should since government goals do not always line up with community needs. The natives in Africa, for instance, do not benefit from the booming forestry and ecotourism sectors. The agricultural practise of agroforestry, in which trees and bushes are grown in and around crop and pastureland, can help solve this issue. In order to avoid the ownership issue and ensure that earnings stay in the community, agroforestry builds on agricultural land currently owned by communities to establish new woods that are not controlled by the government. Although agroforestry systems are on a smaller scale than traditional forests, they still provide many of the same benefits, including increased biodiversity, diversified production and restored soil fertility.

Agroforestry is useful for more than only the environment. Increased food resources and security, enhanced nutrition and higher earnings for farmers are just a few of the ways in which agroforestry can help alleviate worldwide poverty (Quallen 2021).

It is not a coincidence that in some regions of the world natural woods and poverty can be found in close proximity to one another. This is the case for a number of reasons. The natural woods are where humans developed, and even after millennia of settlement, the people who live there have maintained a mainly primitive lifestyle. Many of the people moving from rural areas into wooded areas in quest of extra farmland are economically disadvantaged, as are the areas that they are moving into. For people who are on the socioeconomic periphery of society, for example, work opportunities in forests are often available because of the unequal distribution of land in lowlands. Throughout history, persons on the run from oppression, conflict and war have historically been able to find safety in forests. Agroforestry contribution to reducing poverty has been presented in Fig. 23.5.

There are two ways in which forests can help reduce global poverty. First, they play a crucial role as a safety net, allowing rural residents to either avoid or lessen their exposure to poverty. Second, there is unrealised potential for woods to help some rural residents escape poverty.



Fig. 23.5 Agroforestry contribution to reducing poverty

Many politicians and planners are unaware of these features because the scientific community has not done a good job of explaining the safety net functions of forests.

One explanation for this is that the poorest households' use of woods, whether for sustenance or commerce in local markets, is rarely reflected in national statistics. Some elements of timber resources actually hinder their capacity to aid marginalised people, while the lion's share of timber riches flows to better-off sectors of society. Despite these challenges, if decision-makers realise and act on the promise of forests, they can expand their contribution to poverty alleviation (Sunderlin et al. 2004).

23.8 Agroforestry and the Tribal Community

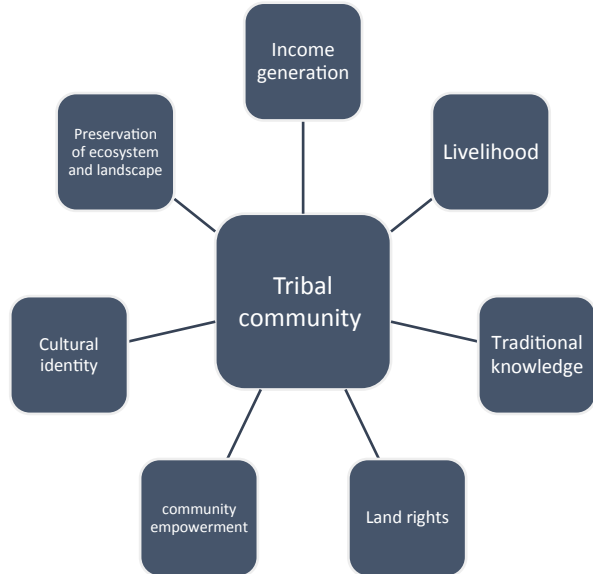
In addition to improving food security and fostering cultural and ecological resilience, agroforestry can also provide stable income for tribal people by preserving indigenous knowledge and practises.

Livelihood and Income Creation: Agroforestry allows indigenous groups to make a living by growing and selling tree-based goods. Agroforestry systems combine tree planting with crop and livestock husbandry to generate revenue from a wide variety of tree-based and other products. As a result, tribal communities may become more economically secure and less dependent on any one source of revenue.

Protecting Indigenous Knowledge: Agroforestry methods are congruent with indigenous ways of knowing and using land. Tribal communities can keep their indigenous knowledge alive and well by combining traditional methods with contemporary agroforestry practises. This encompasses familiarity with native plant species, agroecological approaches, seed varieties and growing techniques. The restoration of cultural traditions and the sharing of information between generations are two important functions that agroforestry can play in this regard.

Improved nutrition and greater food security are two benefits of agroforestry for indigenous peoples. Agroforestry methods improve food availability and nutritional variety by combining crop cultivation with tree planting. Preserving local food culture and addressing food sovereignty issues are both aided by the incorporation

Fig. 23.6 Impact of agroforestry on tribal community



of indigenous food crops and traditional variations. Additionally, a more secure food supply can be maintained through the use of agroforestry systems, which increase resilience to the effects of climate change.

Restoration of degraded land and protection of biodiversity are two ways in which agroforestry increases ecological resilience in a landscape. Agroforestry protects native plant and animal species, especially those of cultural and medical value to indigenous peoples, by combining varied tree species and establishing agroecosystems. Landscape connectivity is improved with the use of agroforestry systems, which help to keep wildlife corridors in good condition.

Tribal communities' cultural identity and resilience can be bolstered by adopting agroforestry practises. The spiritual and cultural relevance of traditional agroforestry systems reflects the intrinsic bond between indigenous peoples and their environments (Fig. 23.6). Agroforestry allows indigenous groups to strengthen their cultural norms, traditional ways of life and relationships to the land. Agroforestry can aid in protecting the rights to and ownership of land for indigenous populations. For agroforestry to be practised in a sustainable manner, it is crucial that indigenous territories and community land rights be recognised and legally protected. Agroforestry can help reduce poverty and promote social justice by giving indigenous tribes more say over their property. Participation, decision-making and community empowerment are all bolstered by agroforestry in indigenous societies. Local leadership may be developed, social cohesiveness can be strengthened, and resources can be reclaimed when tribal communities engage in the planning, implementation and management of agroforestry systems. Through such participation, the tribal people' unique requirements, values and goals can be taken into account while developing agroforestry practices.

When applied with respect for tribal people's cultural and ecological values, agroforestry has the potential to safeguard indigenous knowledge, provide food security, foster social cohesion and fortify ecosystems. It promotes the health and prosperity of indigenous communities by taking an open and collaborative approach that values their unique knowledge, experience and goals.

23.9 Agroforestry and Urban Development

Agroforestry is an approach that should be given more consideration in urban planning because of its potential to assist in the development of more sustainable and resilient urban communities.

It is possible to include agroforestry as a component of green infrastructure in the design of urban landscapes. Planting trees in cities and making use of techniques from the field of agroforestry help to mitigate the heat island effect, purify the air and provide healthier environments in which people may live. Trees that provide shade not only contribute to the aesthetic appeal of a city but also assist reduce the amount of money that is spent on air conditioning. Agroforestry in urban areas can contribute to both food security and self-sufficiency in food production. Community gardens, rooftop gardens and edible landscapes are all examples of urban agroforestry systems that are capable of producing a variety of fruit, vegetables, herbs and other edible plants. This not only lessens the toll that transportation of food takes on the environment, but it also makes it easier for individuals to get their hands on fresh produce grown in their own communities.

The practises of agroforestry can be helpful for managing stormwater in an urban setting. Tree canopies serve as a natural barrier against precipitation, thereby lowering the volume of stormwater flow as well as the rate at which it moves. Tree roots have the ability to remove impurities from the water and improve its quality, in addition to increasing the amount of water that they can absorb. With the assistance of agroforestry systems, capturing and utilising the rainfall that falls in urban areas is made much simpler.

The provision of habitat and food for urban wildlife, such as birds, insects and small animals, is one of the many ways in which urban agroforestry is beneficial. This contributes to the protection of biodiversity. Agroforestry encourages urban biodiversity by re-establishing ecological balance in cities through the use of a range of tree species and the development of urban green spaces. This is accomplished by the use of agroforestry practises such as tree planting and the creation of urban green spaces.

Initiatives to promote urban agroforestry's use have the potential to strengthen community relations and encourage more people to participate in civic life. When local residents, community organisations and schools are involved in agroforestry activities from the very beginning, opportunities for education, the development of skills and the strengthening of community bonds are established. Urban reforestation

efforts can instil a sense of pride in one's town as well as a sense of success for having contributed to the betterment of that community.

Both the ability to better regulate the local microclimate and the ability to keep cities cooler in the summer are factors that contribute to the city's ability to withstand the effects of climate change. As natural air conditioners, the trees that are part of agroforestry systems help to reduce the amount of artificial cooling that is required and also contribute to the mitigation of the effects of urban heat islands. Urban agroforestry is an important weapon in the fight against climate change since it may help reduce emissions of greenhouse gases and also contribute to the sequestration of carbon dioxide.

In places that are currently underserved, urban agroforestry has the ability to both boost employment rates and encourage the growth of local businesses. Orchards, nurseries and businesses that add value to tree products can all benefit from this, as can other local businesses. One of the additional benefits of urban agroforestry programmes is the creation of jobs in ancillary businesses such as landscaping, urban forestry and environmental education.

By introducing agroforestry into urban development, improvements can be made to a city's environmental quality, food security, biodiversity and climate resilience, all of which are potential benefits of the practise. Urban agroforestry initiatives not only improve the health of the community, but also the social cohesion and economic prospects of the area. The consequence of these projects is an urban environment that is more habitable and sustainable.

There is growing recognition of the potential contributions of non-traditional forms of GI, such as wastelands and informal green spaces, to CUM and to urban social-ecological systems in general, and this has led to a renewed focus on the role that multifunctional green infrastructure (GI) can play in promoting circular urban metabolism (CUM), reducing the ecological footprint of cities and providing a wide range of services, including biodiversity conservation. Home and communal gardens as well as urban farms are examples of productive urban spaces that might be thought of as an alternative, multipurpose type of GI. These areas can infiltrate stormwater, reduce the effects of urban heat islands, preserve biodiversity, sequester carbon, help form soil and recycle urban wastes (Taylor and Lovell 2021). Role of agroforestry in urban development has been presented Fig. 23.7.

23.10 Agroforestry Impact on Economic Sector

By incorporating trees with crops and cattle, agroforestry systems provide numerous avenues for generating money. Timber, fruits, nuts, medicinal plants, non-timber forest products and animal products are only some of the ways in which farmers might make a living. Farmers' financial security is increased as income risks associated with mono-cropping are mitigated through diversification. Soil fertility, nitrogen cycling and water availability can all be increased through agroforestry, leading to greater agricultural output. By enhancing soil structure, nutrient retention



Fig. 23.7 Role of agroforestry in urban development

and moisture conservation, trees in agroforestry systems boost crop growth and yield. Productivity growth can boost agricultural outputs and, by extension, the economy.

Products from agroforestry can be refined to increase their market value, opening the door for home grown enterprises and regional innovators. Agroforestry goods can benefit from a boost in value and marketability through processing operations like timber milling, fruit processing and herbal medicine manufacture. This helps the economy expand in rural areas by producing jobs and money. Agroforestry systems, from planting and management to processing and selling, all generate employment opportunities along the value chain. Farmers, workers, technicians and processors are all essential members of the agroforestry community. Job creation and reduction in rural unemployment can result from the installation and upkeep of agroforestry systems. By combining tree farming with agricultural practises, agroforestry helps spread awareness of the importance of responsible forest management. With this method, lumber and other forest products will be around for generations to come. By ensuring a steady stream of forest resources and supporting companies that rely on them, sustainable forest management creates economic benefits.

Agroforestry systems can be financially rewarding thanks to carbon credits and payments for ecosystem services. Agroforestry's trees help slow global warming by

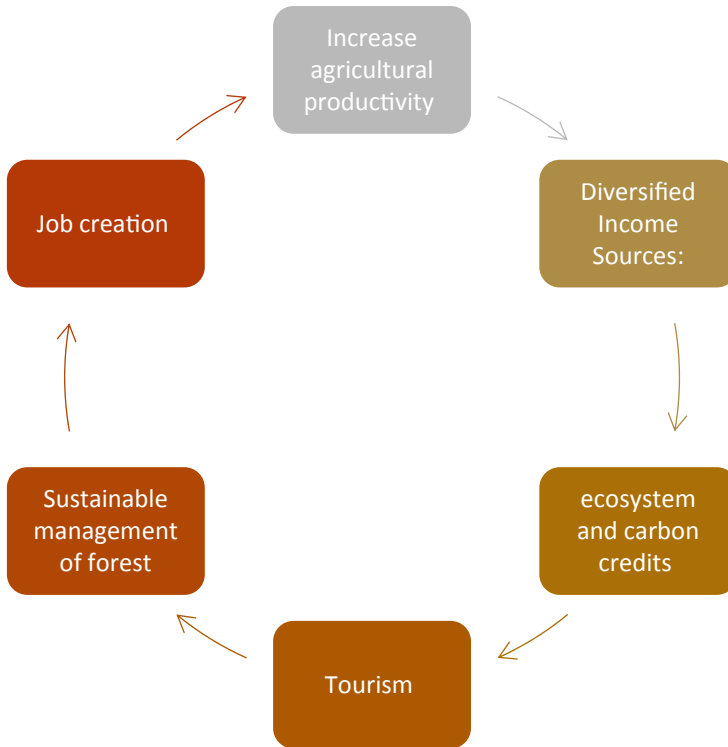


Fig. 23.8 Agroforestry contribution to the economic sector

soaking up carbon dioxide from the air. Carbon offset programmes and compensation for ecosystem services including watershed protection, biodiversity conservation and carbon sequestration are options for farmers and landowners.

The tourism and recreation industries can benefit from agroforestry landscapes due to their potential aesthetic and recreational value. Agroforestry systems, such as those that facilitate agroecotourism or farm stays, let sightseers learn about and enjoy the region's rural culture and way of life, as well as its abundant flora and fauna. Having multiple avenues of financial support helps the rural economy thrive.

Farmers benefit from increased resilience to market swings and price instability thanks to agroforestry systems. Farmers can reduce their reliance on any one commodity or market by offering a wider variety of goods and services. Income fluctuations caused by market fluctuations are reduced, and income stability is increased, thanks to this strategy of diversification. Agroforestry has the potential to considerably contribute to the economic sector due to its ability to generate several streams of income, undergo value-added processing, generate new employment opportunities and promote sustainable forest management (Fig. 23.8). In addition to helping farmers make a living, it boosts local economies, encourages entrepreneurship and improves residents' standard of living.

23.11 Conclusion

Ending the food crisis, addressing hunger and achieving a healthy nutrition level can be done through sustainable agriculture and smart agricultural systems. Agroforestry holds great promise for addressing many issues in agriculture, health and climate change. The primary cause of problems in the globe is the exploitation of natural resources. The causes of the global food crisis may range, but environmental deterioration is one of the main ones. In order to stop food waste and produce enough food to meet demand, rural areas must be electrified. Community-based farming and kitchen gardens are assisting in the fight against malnutrition. Around 60 million children worldwide suffer from undernourishment, and 850 million people are experiencing a food crisis. New agricultural techniques for growing crops, such as vertical farming, a type of urban farming, nanotechnology, biotechnology and hydroponics, are now possible thanks to modern technology. However, these techniques are more common in underdeveloped and developing nations, where agroforestry is more prevalent. Agroforestry is a natural strategy that can restore ecological balance, maintain natural resources and increase biodiversity.

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