Agroforestry Developments for Degraded Landscapes: A Synthesis

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Abstract

Due to many natural and anthropogenic factors, about two billion hectares of land is degraded globally. To meet the demands of ever-increasing population, every inch of degraded land is to be brought under cultivation. Agroforestry is an adjunct of sustainable agriculture since its evolution as science. In modern scenario of climate change, it is being considered a problem-solving science. The social, economic, and environmental costs are high for the on- and off-farm reclamation techniques, and agroforestry is now emerging as a potential tool not only for arresting land degradation but also for providing other environmental services like adaptation to climate change, sequestration of carbon, and biodiversity conservation. Recent research and developmental efforts, though experimentally in small plots or under microsite conditions in catchments, have demonstrated that trees can be successfully established through appropriate site preparation, careful species selection, and post-planting care. There is need for the collaboration between scientists, farmers, and land managers for the large-scale promotion of agroforestry on degraded lands with due consideration to the insurance, legal, and institutional arrangements by the implementing agencies. During last four decades, agroforestry as a science has gained global attention as a multi-disciplinary science playing important role in sustainable food production, meeting nutrient requirements of rural population, rehabilitation of degraded landscapes, improving biodiversity, and mitigating climate change. Recent research developments in agroforestry for degraded landscapes in tropical, subtropical, and temperate regions have been synthesized in this concluding chapter.

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17.1 Introduction

Land degradation is threatening food security as well as ecosystem goods and services and depleting ecosystems in different regions of the world. About two billion ha of land in the world is affected by various forms of natural and anthropogenic land degradation. The main causes of land degradation are inappropriate land use and management, over-exploitation of natural resources, loss of soil organic carbon, soil erosion, salinization, acidification, waterlogging, desertification, mining, soil compaction, nutrient imbalance, and loss of soil biodiversity. Besides meeting food and other needs of ever-increasing population, ecological restoration of degraded ecosystems and landscapes is a global priority. Agroforestry encompasses a wide range of approaches and technologies for restoring degraded lands for production of agricultural commodities and improving environmental services. Four decades of agroforestry research and development, as reviewed in this book, indicate that agroforestry has evolved as a problem-solving science primarily, as a means for sustaining agricultural productivity in marginal lands and alleviating many of the problems of land and environmental degradation. Agroforestry technologies have been applied to rehabilitate or restore degraded lands due to soil erosion, deforestation, rangeland degradation, salinization, waterlogging, acidification, mining sites, and over-extraction at various scales, from plot- to farm-levels to large agricultural and farming enterprises. Most of the agroforestry research has focused on biophysical parameters at the farm level. Landscape-level research undertakings are few because of the complexity of landscape, the long-time series of data needed to study economic and social impacts, and the lack of baseline studies on levels larger than the farm. These concerns are expressed by the research results presented in various chapters in this book, using different models of agroforestry under specific environmental conditions. Therefore, a quick review of chapters and critical synthesis of the results obtained in different studies from both tropical and temperate regions will be pertinent for a broader understanding of the state of existing knowledge, and the future research needs to develop agroforestry on degraded lands for environmental and livelihood security.

17.2 Synthesis

In modern times virtually all global land resources are afflicted by degradation processes to some degree. As a consequence of ever-increasing human population and thus, over-exploitation of natural resources through deforestation, over-grazing, and mismanagement of land and water resources to meet the demands of food and other commodities, particularly in developing countries (mainly in Asia and Africa), the situation has become alarming. Since 1990s, a notable development has taken place in the field of agroforestry, and its recognition among different stakeholders as sustainable agriculture has gained importance. However, the relevance of agroforestry technologies as a practicable tool for restoring degraded landscapes and as a problem-solving science has gained momentum during last four decades. In this compilation in two volumes, a detailed account of the global extent of land degradation; physical, chemical, and biological processes of land degradation; ecological restoration at the ecosystem and landscape level; and the potential of agroforestry systems to enhance biodiversity conservation, livelihood security, and mitigating climate change have been discussed.

During the last four decades of research on agroforestry systems in tropical drylands, substantial information has been generated and compiled recognizing the potentials of agroforestry to enhance livelihood security in Africa and Indian subcontinent. Some useful trees such as *Faidherbia albida*, *Prosopis africana*, and *Prosopis cineraria* have been identified to grow with field crops in rain-fed ecologies. These tree species do not have any negative impact on crop yields; rather they enhance the productivity of the system, increase soil organic carbon, and enrich nitrogen contents besides providing nutrient-rich fodder for animals. Many fertilizer trees and shrubs are explored for moisture-stressed conditions. Species such as *Prosopis africana*, *Vitellaria paradoxa*, *F. albida*, *Acacia senegal*, *A. laeta*, and *Parkia biglobosa* are recognized for parklands of Sudan and other dry regions in Africa, where gum is collected from these trees and *F. albida* is intercropped successfully with maize. Some of these trees and shrubs such as *Balanites aegyptiaca*, *Acacia raddiana*, *F. albida*, *Combretum aculeatum*, *Boscia angustifolia*, and *Maerua crassifolia* are rich in crude protein and grown as fodder banks. The indigenous fruit trees such as marula (*Sclerocarya birrea*) from Southern Africa, in dry West Africa, and *Emblica officinalis*, *Carissa carandas*, *Ziziphus mauritiana*, *Z. nummularia*, and *Aegle marmelos*, for the Indian subcontinent, have been advocated for domestication in different regions. There is extensive information concerning the potential uses of forest and fruit trees, but little effort has been made to improve these trees, techniques of multiplication for quality germplasm to be made available to farmers; value addition; establishment of small industries in rural areas to add values to farm produce for income generation; and to train the stakeholders and implementing the results on farmers' fields.

Kemeuze et al. (Chap. 6, Vol 1) have analyzed land-use management by smallholders' households in dry landscapes in the semiarid area of Cameroon and showed that agroforestry, urban and peri-urban forestry, and forest plantations can help to conserve biodiversity and play an important role in climate change mitigation and adaptation. This can be best achieved through landscape studies with a social-ecological systems approach. Furthermore, a more inclusive research approach can facilitate knowledge exchange and dissemination in different directions and make agroforestry adoption more relevant. Dlamini (Chap. 10, Vol 1) while discussing challenges and opportunities of agroforestry research in Africa placed emphasis for devising agroforestry systems that benefit farmers keeping in view the contextual drivers, prevailing conditions, and institutions influencing the trends in agroforestry development.

The tropical agroforestry practices in the arid and semiarid regions (Part II, Vol 1) can have a central focus on domestication of natural forest and fruit trees, sustainability, soil fertility, carbon sequestration, climate change mitigation, and adaptation and socioeconomic well-being. Recent advances in agroforestry for soil conservation and amelioration, domestication of indigenous fruit trees, their transformation and marketing, research opportunities, and policy initiatives have proved the agroforestry potentials in many of tropical and subtropical regions. The widespread adoption of agroforestry technology supported by continued participatory research and dissemination can be instrumental to achieve the goals of poverty alleviation, food security, soil conservation, and environmental sustainability in different regions of Africa, particularly in the scenario of climate change. Some researchers have argued that agroforestry systems are typically multifunctional in the landscape and support sustainable livelihoods for food production, health and nutrition, wood-based energy generation, and income generation in Sub-Saharan Africa (SSA). However, there is need for a holistic valuation of the benefits of agroforestry in terms of provisioning ecosystem services, livelihood benefits, and cultural services. Understanding the contribution of trees to various aspects of livelihoods is needed to support informed decision-making and evidence-based land-use management in SSA. In drylands, there is a need for research in agroforestry to focus more on socioeconomic aspects and address impacts at larger spatial and longer temporal scales.

The role of agroforestry in mitigating climate change is conspicuous, and the climate change impacts on the delivery of tree ecosystem services in the West African Sahel have been analyzed (Sanago et al. Chap 7, Vol 1). Based on long-term data of the past 100 years, the study revealed a decline of rainfall by 20–30%, whereas increase in the mean temperature up to 1.3 °C in the West African Sahel. A significant relationship between tree growth and annual rainfall amounts in Mali and Niger showed that climate change impacts the delivery of tree ecosystem services through the erratic rainfall. The researchers stressed the need for appropriate policies and promotion of sustainable management strategies to enhancement of food and nutrition security of the rural populations in the West African Sahel. Thus, the afforestation of degraded landscapes remains among one of the most effective strategies to mitigate climate change. There is a large potential to regrow trees in croplands and urban areas, highlighting the scope for agroforestry and urban forestry in mitigating climate change. The urban (agro)forestry, though new, proved concept to improve the environment of the surroundings. Recent studies have shown that sewage water can be efficiently utilized to develop landscapes and greenbelts in urban and peri-urban areas (Lal et al. Chap 8, Vol 2). Growing non-food crops such as aromatic and flower-yielding plants with poor-quality waters is viable option. Further, it has been found that agroforestry parklands are the predominant agro-ecosystems in West Africa.

It has been explained in this book that trees in agroforestry systems on degraded lands promote closed nutrient cycling in nutrient poor soils of drylands; however, there is a need for microbial inoculation of tree seedlings with appropriate N-fixing bacteria and mycorrhizal fungi and application of phosphorus fertilizer for their successful establishment. *Faidherbia albida*-based agroforestry practices in sub-Saharan Africa play very significant role. Some workers have presented synthesis of studies relating to the sustainability of *Gliricidia*-based agroforestry systems for improving soil fertility under resource-limited agro-ecosystems. From these studies, it has been found that data are needed on belowground ecological processes, microbial-tree-root interactions, and biodiversity of soil organisms.

Tree-based traditional cropping systems play an important role in production system, and there are opportunities for farm and tribal communities for transforming the traditional systems such as lac (*Laccifer lacca*)-based agroforestry into modern remunerative venture from degraded lands in arid and semiarid regions of India. The lac-based agroforestry can also play an important role to protect host trees in degraded lands and community lands reserved for grazing to control forest degradation. Similarly, silkworm (*Bombyx mori*)- and mopane worm (*Gonimbrasia belina*)-based agroforestry systems can be developed as commercial systems. Some workers stressed the need to recognize entomophagy as a prominent ecosystem service of agroforestry systems on degraded lands. The beneficial role of insects in agroforestry has not attracted the attention of workers because of the adverse effects of insect-pests causing crop losses or failure. For the biological control measures to be effective, it would be useful to harvest pest species such as palm weevils, grasshoppers, and caterpillars in areas of plenty to support food and nutritional security.

The researchers have explored the tropical agroforestry systems of humid and sub-humid regions in Asia, Indian subcontinent, Latin America, and other parts of the world. Van Noordwijk et al. (Chap. 11, Vol 1) have synthesized information on the restoration of degraded land in Southeast Asia by conceptualizing seven degradation syndromes including degraded hillslopes, fire-climax grasslands, over-intensified mono-cropping, forest classification conflicts, drained peatlands, and converted mangroves. For restoration of degraded landscapes, investing in trees as part of their landscapes and farming systems is important besides recognizing the relevance of adopting agroforestry at plot-level, multifunctional landscapes and the interface of agricultural and forestry policies. These workers emphasized appropriate restoration actions through agroforestry by considering local institutions and motivation; rights, knowledge, and know-how of land-use practices, markets for inputs and outputs; local ecosystem services; and global connectivity as a starting point for restoration interventions. The SE Asian experience with agroforestry offers practical lessons to gain insight across a wide range of “degradation syndromes.” There is need for a more careful and location-specific diagnosis of land degradation for successful agroforestry interventions. The recently adopted ASEAN agroforestry policy guidelines provide a conducive environment for targeted actions for inducing change at the landscape level.

Various traditional agroforestry systems have also been identified for the restoration of degraded peat swamp area in Indonesia which reflects that incorporation of human dimensions into restoration is crucial to counter the anthropogenic factors driving the degradation of the peatland ecosystem. There is need for rebuilding and documenting traditional agroforestry knowledge and practice for successful natural resources management. Further, it has been found that shifting cultivation has evolved as a part of the culture of the hill people of the region and the agricultural practices are closely linked with the socio-cultural practices and religious beliefs. However, the shortened fallow cycle as practiced in most places in Northeastern India (NEI) is not sustainable; soil erosion, nutrient loss, and other ecosystem disservices resulting with short fallows adversely affected the soil resilience and food insecurity among the shifting cultivators. Therefore, the promotion of tree-based crop production models such as alder (*Alnus nepalensis*)-based traditional agroforestry systems, promotion of traditional betel (*Piper betle*)-based agroforestry, and fertilizer tree-based potential agroforestry practices in slash-and-burn cultivation areas in NEI are important for sustaining agro-biodiversity, forest cover, and soil carbon storage. There is need to introduce an appropriate cash incentive-based mechanism for adoption and promotion of agroforestry systems in degraded fallow lands in NEI among hill farmers. In Africa, short fallows have been improved significantly through participatory mode by growing leguminous *Cajanus cajan*, *Sesbania sesban*, *Tephrosia vogelii*, *Gliricidia sepium*, and *Leucaena leucocephala*. These have been identified as the most promising N-fixing shrubs for this purpose, and *Tephrosia vogelii* is preferred the most because of its pesticidal properties.

Bamboo-based agroforestry has traditionally been managed on family farms because of their great socioeconomic values in rural lives especially in Asia and is currently being promoted as a viable option for social, economic, and environmental benefits. Well-managed bamboo in agroforestry has tremendous potential to contribute to restoration of degraded lands in tropical and subtropical regions. The Asian experiences show that bamboo-based agroforestry is a promising land-use option for enhancing productivity, rising socioeconomic benefits, and sustainable land management in tropical bamboo producing countries.

The role of agroforestry systems in restoration and conservation of biodiversity at the ecosystem and landscape levels, with greater focus on the tropical Latin America, has been assessed. Multistrata systems including home gardens and successional agroforestry systems (AFS) exhibit the highest biodiversity, while more simplified system designs such as perennial crops and silvopastoral systems are characterized by only few trees species representing the low range for biodiversity. AFS such as living fences and windbreaks can provide connectivity in the fragmented agricultural landscape. To fulfill the objectives of biodiversity restoration and conservation, AFS need to increase their structural complexity in terms of number of species and strata. Therefore, AFS should be planned within a broader strategy with due consideration to maintain areas of natural forest in the landscape. Recent studies have shown that greater plant species diversity leads to greater productivity in plant communities, higher nutrient retention in ecosystems, and greater ecosystem stability. The biodiverse agroforestry systems could be useful for recovery of degraded landscapes by implementing environmentally friendly land management practices. The socioeconomic, legal, and political actions can promote biodiversity islands in rural environments. The use of economic instruments, for example, payments for environmental services, improving environmental laws and enforcement to reduce deforestation, regulate logging, conserve on-farm tree cover, and reduce agrochemical use, could play an important role in restoration mechanism.

The functioning of terrestrial ecosystems depends on soil biodiversity as many of the plant interactions take place belowground. The role of soil microarthropods in determining the soil quality of tropical home gardens which are regulated by edaphic factors, abiotic conditions, and land management practices has been explored to some extent. Soil microarthropods being sensitive to soil temperature and soil moisture can alter in number and species composition in relation to seasonal perturbations and soil ecosystem alterations and, thus, can serve as an efficient tool in biomonitoring studies. Soil organisms, including earthworms, are a key component of terrestrial ecosystems; however, little is known about their diversity, their distribution, and the threats affecting soil organisms. Given the role of earthworms and termites as ecosystem engineers, changes in their diversity and distributions in response to management practices clearly need the attention of workers. It is important to analyze their role in nutrient cycling, organic matter decomposition, and formation of soil structure in different types of agroforestry systems. To maximize productivity in agroforestry systems, sequester more carbon in soil, or understand how degraded landscapes will further shift in response to human activities, there is urgent need for greater understanding of biodiversity of soil organisms and their role in ecosystem functioning, particularly in dryland agroforestry systems.

The drivers of change in coastal ecosystem (based on UNEP report of 2006) are land-use changes and habitat loss, fisheries, invasive species, pollution, nutrient loading, and climate change. Climate change is becoming the dominant driver of change, particularly in vulnerable habitats such as mangroves, coral reefs, and coastal wetlands, which are especially at risk from resulting sea level rises and temperature. Agroforestry land-use systems have huge potential for sustainable agricultural production and livelihood security in these regions. Important traditional and site-specific agroforestry systems/practices being followed have been tested in islands and coastal areas my many workers. Opportunities exist for agroforestry-based strategies because of the rich biodiversity and high availability of rainwater ($>$1000 mm). The site-specific farming systems can combine forest and fruit trees, plantation crops, spices, forages, vegetables, and halophytic plants. Integrated farming systems involving fish, shrimps, and different kinds of aquaculture, multi-storeyed plantation-based cropping systems, high-value medicinal, and aromatic plants and spices can be highly remunerative to local people.

Coastal salinity has been a major concern, and in recent years, due to frequent cyclones and phenomenon, rising of sea level due to climate change has aggravated the problem. Aquaculture, horticulture, and plantation-based agriculture has been the primary livelihoods of the people living in the coastal areas of India, but the productivity of all these sectors are much below the national average because of various constraints related to soil, water, and climate. There is much scope for utilizing the potential of halophytes for food, fodder, fuel, oils, healthcare, eco-restoration, bioremediation applications, and their role in restoring the coastal saline soils. In recent years the importance of mangroves has been highlighted, and aquaculture keeping mangroves intact, multi-enterprise agriculture involving fish, shrimp, animals, poultry, mushroom, honey and plantation-based multi-storeyed cropping systems have been advocated for remunerative agriculture. In highly saline areas, domestication of halophytic crops of high economic value is also an option. These areas may open new vistas in agroforestry research.

Among temperate agroforestry systems, riparian buffer systems have the greatest potential to produce biomass while enhancing biodiversity, environmental, and ecosystem services. The sustainability indicators and their influence on biomass production from the long-term ecological research studies on tree-based intercropping and integrated riparian buffer systems in southern Ontario, Canada, over a period of 26 years have been discussed. In tree-based intercropping systems, short rotation woody crops or herbaceous biomass crops can be grown in between the tree rows. Given the current interest on climate change mitigation strategies, the enhancement of C sequestration in terrestrial ecosystems, agroforestry-based biomass production systems can play a major role in sequestering atmospheric CO_2, particularly in roots and soils. Interestingly, soil quality indicators for the improvement of soil fertility in *Nothofagus obliqua* (deciduous) and mixed *N. dombeyi-N. obliqua* (evergreen-deciduous) forests, where a 30-ha silvopastoral trial was established, are analyzed. These studies showed that soil quality was favored by the quality of organic matter in the site dominated by deciduous species, which creates more favorable conditions for the activity of microorganisms, nitrogen dynamic, and C and N content in the light faction of soil. These novel silvopastoral systems can restore the most degraded sites through improvement of the soil quality. Thus, it is important to generate information on soil quality parameters mainly for the planning of long-term, durable silvopastoral practices. Further, the status of temperate rangelands/pastures, factors causing degradation of the grasslands, and suitable agroforestry systems to improve the existing grasslands in western Himalaya have been explored. The existing wastelands in Jammu and Kashmir in India could be potential sites for hill agroforestry systems under TOF for enhancing carbon sinks under CDM and REDD+ mechanism, carbon inventory assessment programs at national and international levels by using latest methods of remote sensing, and GIS integrated with field inventory and advanced algorithms for qualitative and quantitative assessment of TOF resources. The scope of temperate agroforestry is expanding and has attracted the attention of several research workers.

Studies in Australia and Indian subcontinent have shown that well-planned biodrainage on farmers' waterlogged fields by growing cloned *Eucalyptus* and other fast-growing species with high transpiration rates could lower down the water table for cultivation of wheat crops in Community Forestry Program after 3–4 years of growth. The speculation of salinity development in root zone due to evapo-transpiration could not be proved, and experimentation of 6–7 years showed that there was no increase in soil salinity and rather organic carbon and infiltration rate of water increased in vicinity of plantations. There was 3–4 times increase in crop yield due to plantations as compared to no plantations, and farmers could also get additional income after harvesting of trees and the system sequestered carbon in above- and belowground biomass. This is all win-win situation. Similarly, applying appropriate agroforestry techniques highly sodic as well as saline soils could be reclaimed using appropriate silvopastoral systems to the extent that after about 7 years, the land was suitable for arable crops. In large areas sand dunes have been stabilized in arid regions using appropriate agroforestry techniques.

The grazing lands in different regions of the world have become very fragile and unsustainable due to unbalanced utilization of these resources, resulting in large-scale degradation. Protection of existing trees on grazing lands and introduction of nitrogen-fixing trees constitute a sustainable and productive silvopastoral system. Multipurpose tree species can also be adopted in degraded grazing lands with poor vegetation cover or by developing location-specific silvopastoral models. Studies have also been carried out with silvopastoral systems in many Latin American countries and have generated extensive information in adopting and adapting SPS to local conditions. Intensive silvopastoral systems are a good example of a land use in Latin America that can increase the productivity of grazing lands and enhance the generation of ecosystem goods and services. In Latin America, silvopastoral arrangements have the potential to be established in most of the locations where cattle ranching is practiced. In the case of silvopastoral systems explicitly, more research is needed on the physiology of animal-tree interactions; this will allow for the evaluation of these systems with respect to the important and emerging issue of animal welfare. There is need to be mainstreaming of silvopastoral systems in rehabilitating degraded grazing lands to simultaneously address environmental sustainability and meeting the sustainable production objectives from the land. There is need to create awareness among farmers, greater research efforts, and sound implementation of government initiatives for sustainable management of grazing lands.

The potential of agroforestry to improve the economic utilization of highly degraded lands like ravine lands through simultaneous production of food, fruit, fodder, and firewood and carbon sequestration has been explored. Optimum utilization of suitable species of trees, shrubs, and grasses is important in ravine and eroded watershed rehabilitation efforts. Silvopastoral- and fruit-based agroforestry systems involving species of dry areas are the most appropriate options for rehabilitation of such lands. The developmental activities such as railway tracks, road construction, and mine exploration have caused tremendous land degradation. The use of different indigenous and exotic species for the rehabilitation of different types of mines has been identified and grown in many mine spoils. Restoration of limestone quarries in Dehradun, iron ore overburden in Kerala, and coal mining areas of Singrauli in India are successful cases of large-scale post-mining restoration practices in India. However, it is necessary that participatory planning for rehabilitation be carried out for to sustain over a long period of time, otherwise all such measures will be short lived. There is also a need to focus on indigenous species and developing seed banks and nurseries where these resilient plant species can be raised for planting in the areas selected for rehabilitation. For achieving long-term sustainability in the mining area, restoration process must aim to develop tree-based systems with native species.

Urban agroforestry systems are integration of gray and green technologies, capable of recycling and reusing of wastewater and conserving nutrients into biomass, thereby bringing multiple benefits such as fuel wood production, environmental sanitation, and eco-restoration. Still the adoption of urban and peri-urban agroforestry systems by farming community are fewer due to the lack of best suited cropping system. National standards/quality guidelines need to be prepared for the reuse of treated wastewater for agriculture and forest plantation irrigation, taking into account the legal and regulatory framework (e.g., environmental pollution, water quality, food hygiene, and occupational health). Proper intervention of policy support and awareness among the peri-urban farmers will boost the adoption of this integrated system for social, economic, and environmental benefits.

Agroforestry systems in degraded landscapes have a great scope not only of increasing agricultural production and restoration of degraded lands but also of carbon sequestration and mitigating climate change. Though enough data on carbon sequestration has been generated, most of ecological parameters have been ignored. The magnitude of carbon sequestration would vary depending on the climatic and geographical conditions of the area. Soil is a vital component in the functioning of terrestrial ecosystems, and provides a habitat for diverse and interacting populations of soil organisms; decomposition of organic matter is the principal process in soils that recycles nutrients and produces humus, and serves as a critical link with the climate system. Soils deliver provisioning, regulating, and cultural and supporting ecosystem services, which are regulated by the physical, chemical and biological properties of the soil. Soil organic matter, which in turn is governed by biological activities, plays a key role in regulating climate, soil water, and soil biodiversity. In the context of mitigating global climate change, it is important to create a well-quantified carbon sink in agricultural soils worldwide. There is large potential for managing soil carbon in agroforestry systems for climate change mitigation and enhancing the sinks of greenhouse gases. However, for effective soil organic carbon sequestration, there is need to develop agroforestry systems that reduce emission of nitrous oxide from the soil, to measure soil carbon in deep soil layers and to improve efficiency of water and fertilizer use in cropping systems. The inclusion of a diversity of crops might ensure that a diversity of carbon compounds is present in the soil, improving soil carbon.

17.3 Challenges and the Way Forward

We have gone a long way to develop several agroforestry models in different climatic regions of the world, and also site-specific conditions, such as reclaiming salty and waterlogged soils and rehabilitation of ravine lands, improved fallows, use of fertilizer trees to enhance crop productivity in rain-fed dry ecologies, alley cropping, multi-enterprise cropping systems, restoration of mine-spoil areas, restoration of degraded mangrove areas, domestication of indigenous fruit trees, and urban and peri-urban agroforestry. Some of these have been discussed in this book in separate chapters. The forest and landscape restoration is a long-term process that has a focus on the restoration of ecological functionality and enhancing human well-being using a variety of land uses and diverse plant species.

Not surprisingly, as stated earlier, agroforestry systems are playing a vital role for the rehabilitation of degraded lands, biodiversity restoration and conservation, mitigation of climate change through carbon sequestration, livelihood, and food and nutrient security to the people. For agroforestry to succeed, there is need to focus on a system's perspective that can be easily integrated into landscape approaches. The development and upscaling of traditional and improved agroforestry systems need an enabling environment, such as clear land and tree tenure, a strong legal framework, availability of agroforestry product value chains, and involvement of the various stakeholders. For a successful action plan, farmer-friendly policies are needed, both at national and regional levels. To make research more inclusive and relevant outside academia, it is important to create forums involving researchers, local leaders, companies, NGOs, extension workers, and farmers.

Investments in effective restoration of degraded lands should form part of a broader strategy for food security and ecological sustainability. Many of the ecosystem services of agroforestry have not yet been analyzed or neglected in most of studies. The farmers and land managers are not familiar with the range of ecosystem services provided by agroforestry systems, and as a result the perceived value of agroforestry is low. The economic instruments based on ecosystem services need to be developed for greater adoptability of agroforestry for sustainable utilization of degraded landscapes and providing livelihood opportunities to the local people. Climate change-integrated tools along with ecosystem functioning and services are needed to ensure sustainable agroforestry. More rigorous discussion is needed on specificity of linkages between soils and ecosystem services. Models need to be developed with the goal of understanding and predicting key dynamics of soil carbon in relation to ecosystem processes and socioeconomic drivers under scenarios of global and regional change. There is need to facilitate the development of local technical capacities for the collection, production, and distribution of crop and tree varieties and livestock breeds that can tolerate environmental extremes (e.g., drought, heat stress, and salinity) in order to support local communities in adapting to climate change. Investments in effective restoration of degraded lands must form part of a broader strategy for food security and ecological sustainability.

It is both a challenge and an opportunity to the scientific community working in this inter-disciplinary field of agroforestry. To prepare for facing future challenges and seizing the opportunities, scientists need access to synthesized information and develop technologies to assess the environmental benefits being derived from different types of agroforestry systems. The global community is still only in formative phase to recognize the potential benefits of many underexplored systems to address the most intractable land management problems of the twenty-first century, such as food and nutrient security, climate change mitigation and adaptation, biodiversity conservation, and rehabilitation of degraded landscapes. As we move forward to vigorously explore the potential benefits of agroforestry for solving the problems of restoring degraded landscapes, there is need for successful implementation of suitable agroforestry models and outreaching the information among different stakeholders ensuring food security and environmental sustainability from regional to national and global level. Additionally, if large- scale agroforestry is to be promoted on degraded landscapes, special commitment would be required from governments on the procurement of farm produce on minimum support price, insurance, legal, institutional, and even community arrangements. At the same time, the new paradigms of agroforestry on degraded lands demand management strategies based upon the long-term research collaborations between land managers and scientists with more objective analysis and thus, understanding of their ecological functioning.

Despite the many promises and benefits that agroforestry holds under appropriate conditions, there are also limitations arising from biophysical, socioeconomic, and socio-political conditions, such as land ownership and control and usage rights. One limitation comes from the time lag until the full benefits of agroforestry practice become apparent. Soil conservation benefits and cash from tree harvesting may only become apparent several years after the establishment of the system. These problems are partly like those encountered in forestry. They may be overcome by careful planning and appropriate combination of crops and animals with trees, both in space and time. The implementation of agroforestry technologies requires support by specialized extension services that use participatory methods to teach farmers how to implement and manage agroforestry systems compatibly with the aim of restoring their lands and increasing agricultural production both in the short and long terms.

The absence of an effective agroforestry policy in developing countries has been felt since long. The policy issues need to be addressed for an all-out development of agroforestry. Institutional issues are also critical and need attention. For a national-level planning of agroforestry to succeed, it will be necessary to develop effective means of coordination between different sectors and the development of a common understanding of policy and legal issues affecting the adoption of an agroforestry policy framework. The initiative for National Policy on Agroforestry in India was taken at the same time when FAO was preparing guidelines for decision-makers for advancing agroforestry on the policy agenda. After long deliberations and discussion, the Indian Government launched a forward-looking National Agroforestry Policy in 2014. However, to implement the same, appropriate guidelines for production of quality planting material, supply system and coordination, convergence, and synergy between various sectors linked with agroforestry will be required. This will require adequate research interventions and support as well as trained manpower. The stakeholders would have to be linked with market, and they would have to be assured the appropriate cost for their produce. Along with the crop insurance, tree component also needs to be insured and all agricultural produces must be brought under minimum support price (MSP) system protected by legal rights. Farmers with small and marginal holdings may adopt cooperative farming well supported by value-addition chain and market. This will ensure the livelihood security to the farming community.