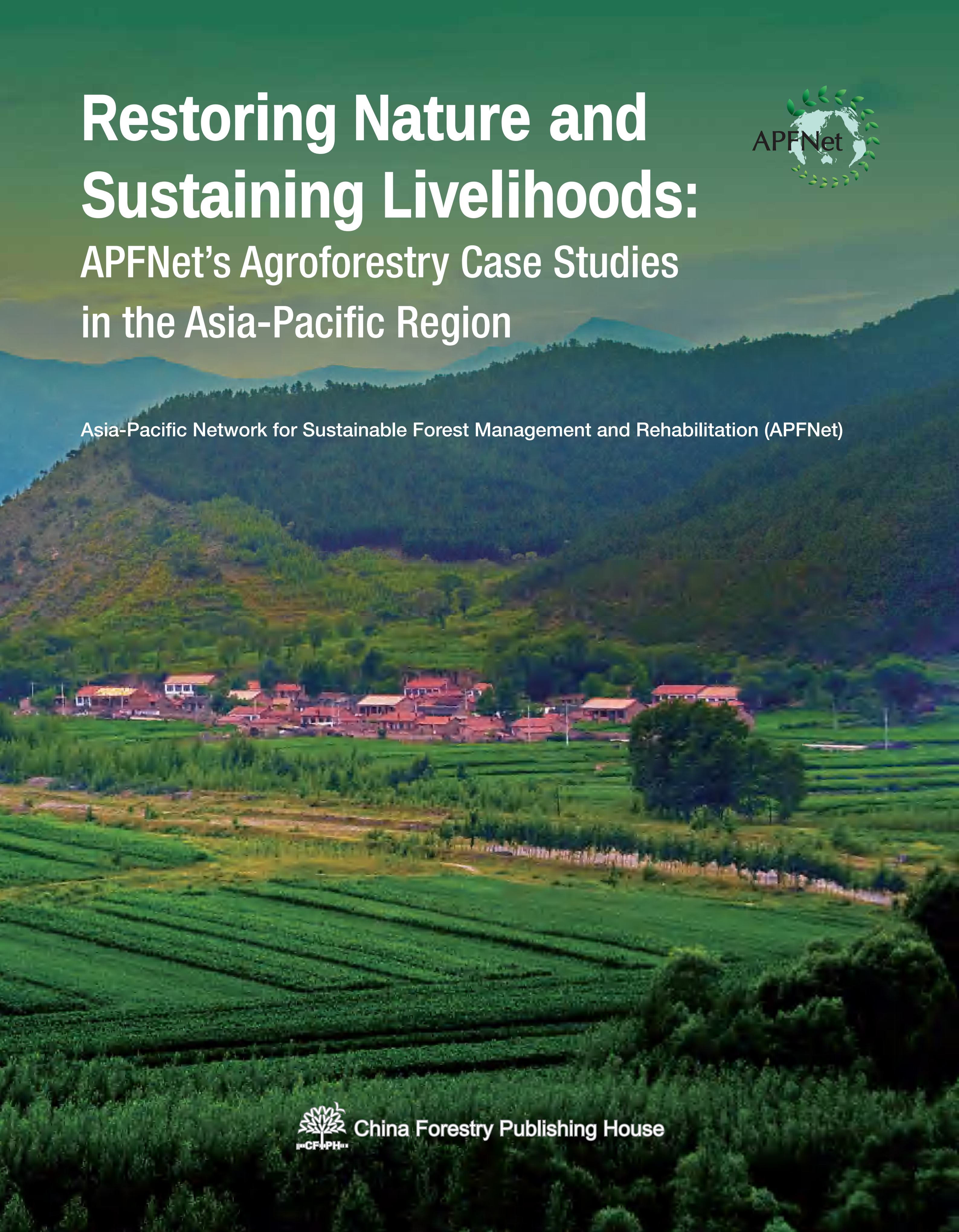

Restoring Nature and Sustaining Livelihoods:

APFNet's Agroforestry Case Studies in the Asia-Pacific Region

APFNet

Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet)

CFPH China Forestry Publishing House

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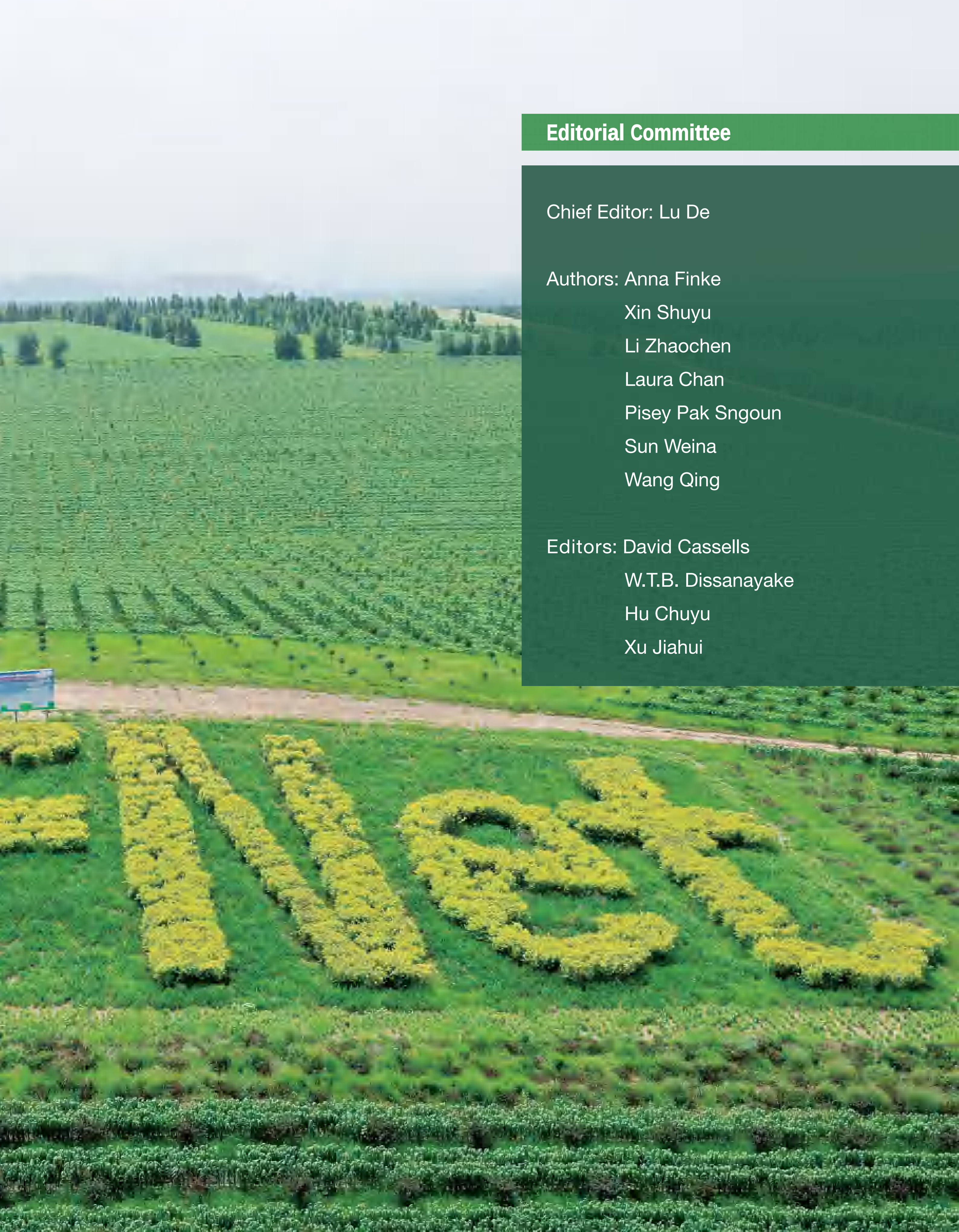

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About Us

The Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet) is a non-profit international organization dedicated to advancing sustainable forest management and rehabilitation in the Asia-Pacific region.

Despite increasing awareness of the importance of managing forests sustainably to achieve green growth, reduce poverty, and respond to climate change, large gaps remained in knowledge and capacity at global and regional levels. To address this, the establishment of APFNet was proposed by China and co-sponsored by Australia and the United States at the 15th APEC Economic Leaders' Meeting in Sydney, Australia, in September 2007. The proposal was adopted by APEC Leaders and incorporated into the *Sydney Declaration on Climate Change, Energy Security and Clean Development* as part of efforts to "enhance capacity building and strengthen information sharing on sustainable forest management in the forestry sector" in the region. In September 2008, APFNet was formally launched, with its Secretariat established in Beijing (Figure 1).

Since its establishment, APFNet, in line with the needs of member economies and forestry development trends, has made remarkable progress in advancing sustainable forestry management in the Asia-Pacific region. Its work is guided by four pillars: capacity building, information sharing, supporting regional policy dialogues, and demonstration projects. As of 2025, APFNet has 32 members, including 27 economies and 5 international organizations in the region.

Figure 1: Launch ceremony of APFNet (Photo: APFNet)

List of Acronyms and Abbreviations

AFTA	Association for Temperate Agroforestry
APEC	Asia-Pacific Economic Cooperation
APFNet	Asia-Pacific Network for Sustainable Forest Management and Rehabilitation
CAAS	Chinese Academy of Agricultural Sciences
CAFRI	Central Agroforestry Research Institute
CBD	Convention on Biological Diversity
CF	Community Forest
CFUG	Community Forest User Group
CNY	Chinese Yuan
DBH	Diameter at Breast Height
EAs	Executive Agencies
EURAF	European Agroforestry Federation
FAO	Food and Agriculture Organization of the United Nations
GFG	Grain for Green
GMS	Greater Mekong Subregion
HIMAWANTI	Himalayan Grassroots Women's Natural Resource Management Association
ICRAF	World Agroforestry Centre
IDRC	International Development Research Centre
IPCC	Intergovernmental Panel on Climate Change
IRD	Institute of Forest and Wildlife Research and Development
LUC	Land Use Capability
MAF	Ministry of Agriculture and Forestry
MAP	Medicinal and Aromatic Plant
MMSEA	Montane Mainland of Southeast Asia
MRGM	Multipurpose Reservoir of Gajah Mungkur
NAMA	Nationally Appropriate Mitigation Action
NKRF	Nyaung Ktauk Reserve Forest
NMC	Naruan Microcatchment
NRCAF	National Research Centre for Agroforestry
NTFP	Non-Timber Forest Product
SDG	Sustainable Development Goal
SFM	Sustainable Forest Management
TCM	Traditional Chinese Medicine
TFB	Forestry Bureau, Chinese Taipei
TFI	Tropical Forestry Institute
TFRI	Taiwan Forestry Research Institute
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
UNFF	United Nations Forum on Forests
USD	United States Dollar
USDA NAC	U.S. Department of Agriculture's National Agroforestry Center

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Executive Summary

The forests of the Asia-Pacific region are among the world's most productive and ecologically significant tropical forest ecosystems, they are rich in biodiversity and vital for carbon storage. However, these landscapes face a multitude of persistent challenges—including poverty, gender inequality, illegal timber harvesting, land degradation, soil erosion, biodiversity loss, and widespread deforestation—that threaten ecological security and sustainable development.

Agroforestry has emerged as a practical and innovative solution to address many of these issues. As highlighted by the FAO (Food and Agriculture Organization of the United Nations), the restoration of degraded landscapes, including degraded forest landscapes, through agroforestry can play a vital role in reversing environmental degradation while supporting community livelihoods. In recognition of this, APFNet promotes agroforestry as a powerful tool to enhance both rural well-being and ecosystem health.

APFNet's Demonstration Projects pillar is a foundational component of its mission to promote sustainable forest management (SFM) and forest rehabilitation across the Asia-Pacific region. As practical, field-based interventions, demonstration projects serve not only as testing grounds for innovative forestry practices but also as catalysts for scaling up solutions that balance environmental, economic, and social goals. As of June 2025, APFNet has supported 54 demonstration projects, 17 of which incorporate agroforestry either as the primary focus or as an integrated component.

This book is presented in two main sections:

- The first section introduces the foundations of agroforestry, including its concepts, historical development, classifications, and core principles. It also provides an overview of the state of agroforestry in the Asia-Pacific region, highlighting prevailing challenges, evolving roles, and recent advancements. APFNet's strategies for promoting agroforestry through policy, research, and practice are also discussed.

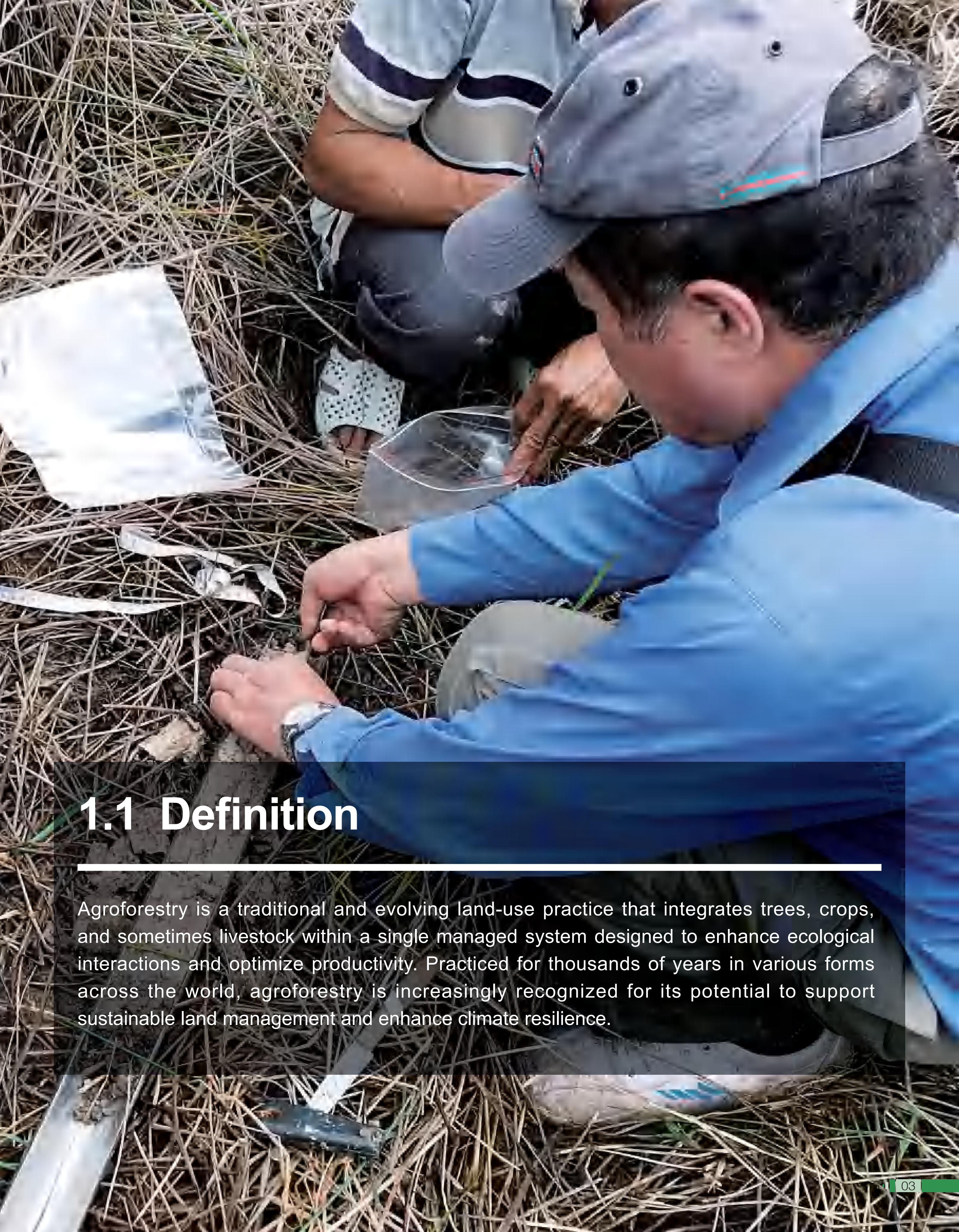
- The second section presents case studies from APFNet-supported projects. These are grouped into three thematic clusters:
    - Agroforestry for Livelihoods and Enterprise Development, featuring initiatives that empower local women, revitalize traditional homegarden systems, and diversify income through community-based agroforestry enterprises.
    - Agroforestry for Forest Restoration, presenting projects that address desertification, soil erosion, and ecological degradation using site-specific, multifunctional agroforestry models.
    - Research-Focused Projects, which explore innovative agroforestry approaches, including land classification systems and the evaluation of soil and water conservation impacts.

Agroforestry is a dynamic, evolving practice rooted in both tradition and innovation. Through its demonstration and research projects, APFNet aims to promote broader adoption of agroforestry as a nature-based solution for forest rehabilitation, livelihood improvement, and sustainable land management within the Asia-Pacific region and beyond.

1

Understanding Agroforestry

Understanding agroforestry is crucial as it represents a sustainable land-use system that integrates trees with crops or livestock, offering multifaceted benefits for both ecosystems and human livelihoods. By bridging agricultural productivity with environmental conservation, agroforestry knowledge empowers stakeholders to implement nature-based solutions addressing interconnected food security, climate change, and biodiversity challenges.



1.1 Definition

Agroforestry is a traditional and evolving land-use practice that integrates trees, crops, and sometimes livestock within a single managed system designed to enhance ecological interactions and optimize productivity. Practiced for thousands of years in various forms across the world, agroforestry is increasingly recognized for its potential to support sustainable land management and enhance climate resilience.

Since 1980s, the topic of "what is agroforestry" was discussed at a considerable number of conferences. And some of the representative definitions are as follows.

Nair (1985) defines agroforestry as "an approach of integrated land-use that involves deliberate retention or admixture of trees and other woody perennials in crop/animal production fields to benefit from the resultant ecological and economic interactions".

The Association for Temperate Agroforestry (AFTA) defines agroforestry as an intensive land management system that optimizes the benefits of biological interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock (AFTA, 1997).

The World Agroforestry Centre (ICRAF) defines it on its website (www.icraf.org) proclaims a three-word-definition of agroforestry: "agriculture with trees", and further explain it as the interaction between agriculture and trees, encompassing practices such as trees on farms, tree-crop systems, and farming along forest margins, including the cultivation of cocoa, coffee, rubber, and oil palm (ICRAF, 2020).

The U.S. Department of Agriculture's National Agroforestry Center (USDA NAC) describes it as the intentional integration of trees and shrubs into crop and livestock systems to deliver environmental, economic, and social benefits (USDA NAC, 2019).

The Food and Agriculture Organization (FAO) defines agroforestry as "a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as crops and/or animals, in some form of spatial arrangement or temporal sequence" (FAO, 2019).

Although there is no single, standard definition of agroforestry, this does not diminish its role or potential in land management. While definitions differ slightly in emphasis, they consistently highlight agroforestry's contribution to promoting multifunctional landscapes that enhance biodiversity, boost productivity, and improve ecological resilience. Today, agroforestry represents the modern and science-based approach to promote sustainable development.

1.2 Evolution and Historical Context

Agroforestry is among the oldest land-use practices in human history. Historic agricultural practices have played a dominant role in shaping landscapes, creating a heritage which must be understood and conserved from the perspective of sustainable development.

Archaeological evidence suggests humans were practicing early forms of agroforestry as far back as 13,000 years ago, illustrating how communities have long understood and harnessed the multifunctionality of integrated land management. As civilizations developed, fruit trees began to be cultivated in homegardens, and later evidence indicates the integration of livestock became increasingly prevalent during protohistoric periods (Dagar et al., 2017). During the Middle Ages in Europe, agroforestry practices mainly included the clearing of forests, burning of slash, cultivation of crops, and planting of trees. During the 19th century, the establishment of forests and plantations integrated with crops became a crucial aspect of agroforestry, as exemplified by teak plantations in Burma managed using the taungya system (Box 1). From this point forward, the agroforestry practice expanded rapidly and was introduced to South Africa as early as 1887 (Ritwik et al., 2024).

Taungya System

Taungya is a forestry system that involves inter-planting trees, originally teak, with agricultural crops, particularly staple foods, thereby addressing farmers' need for arable land while supporting plantation establishment (FAO, 1984).

Box 1

Since late 1960s, new efforts were initiated in studying and promoting intercropping with tree crops, leading to efforts such as the now well-known multistory cropping (Nelliat et al., 1974). In 1975, a report written by the International Development Research Centre (IDRC) of Canada promoted agroforestry by integrating forestry, agriculture, and animal husbandry to maximize tropical land use, which established agroforestry as a solution to hunger, shelter, and environmental deterioration.

The term agroforestry was formally introduced in 1977 through the publication *Trees*, *Food and People*, marking the beginning of modern scientific engagement with the concept. In the early 1980s, the focus of agroforestry was on conceptual issues, including the inventory, classification, and definition of existing agroforestry practices (Nair, 1985). Despite ongoing research during this period, the concept of agroforestry remained unclear and often confused (Ritwik et al., 2024).

Experimental field research began in the late 1980s, and the 1990s saw increasing attention to the selection and evaluation multipurpose species. Following a growing demand for a more holistic approach in the 2000s, the concept of agroforestry evolved from plot level integration of trees, crops, and livestock, to the integration of site management with sustainable livelihood improvement (Tomich et al., 2004), and subsequently to a landscape-level approach to ecological conservation (Bhagwat et al., 2008). This broader perspective includes practices such as "trees on farms" and "farming in the forest", while also addressing cross-cutting issues such as land access rights, land-use planning and classification, and market mechanisms, including investment, product demand, and incentives (van Noordwijk et al., 2016).

Several NGOs have been established to promote the adoption of agroforestry practices and research, such as the International Council for Research in Agroforestry (ICRAF), which was established in 1977, joined forces with CIFOR, forming the CIFOR-ICRAF partnership in 2019, and renamed itself as the World Agroforestry Centre in 2002. In addition, the Association for Temperate Agroforestry (AFTA) was formed in 1991, and the European Agroforestry Federation (EURAF) was founded in 2011 (Köthke et al., 2022) to supporting a diverse and dynamic agroforestry community.

1.3 Benefits and Significance

Agroforestry systems harmonize agricultural and forestry techniques. When underpinned by the three principles of productivity, sustainability, and social acceptability, these systems can provide a wide range of environmental, economic, and social benefits, creating multifunctional and sustainable land-use systems that contribute to several Sustainable Development Goals (SDGs).

Environmental benefits

Agroforestry systems can provide a range of environmental services. When properly designed and managed, they can prevent soil erosion and improve soil health and fertility (FAO, 2017); reduce runoff, which improves water quality and water conservation (Nair, 2011); contribute to biodiversity conservation and climate-change adaptation and mitigation (Box 2) (De Giusti et al., 2019); have positive effects on land management (Craswell, 1998); help reverse forest degradation and deforestation (Dumont, 2019); and maintain ecosystem integrity while building long-term resilience (Akanwa et al., 2020).

Box 2

Contribution of Agroforestry in a Changing Climate

Agroforestry contributes to climate change mitigation through sequestering carbon in biomass and soils, reducing greenhouse gas emissions, and avoiding emissions by regulating global and local temperatures. While it is contributing to climate change adaptation by increasing the resilience of farmers and agricultural systems against climate risks, providing a range of biophysical and socioeconomic benefits.

Economic benefits

In terms of the economic benefits, agroforestry systems create opportunities to develop forest-based enterprises and support income diversification through the production and sale of a wider range of products, increase farm productivity, reducing poverty and economic risk (Hong, 2019; Dobhal et al., 2024; Mukhlis et al., 2022). Many studies have also shown that agroforestry systems can contribute to yield increases (Köthke et al., 2022), and overall resilience, for example by reducing input costs (Mukhlis et al., 2022).

Social benefits

In addition to livelihood diversification, agroforestry systems can offer a range of social benefits, including increasing community resilience in terms of food security (Kumar, 2006), enhanced nutrition, and stronger community bonds. By providing greater economic resilience and job opportunities, it can also support a reduction in migration from rural areas and address broader social issues, such as gender inequality and poverty (Mukhlis et al., 2022).

Contributing to regional and international targets

Following an increased awareness of its multiple benefits, agroforestry has become an important topic in global and national sustainable development agendas, frameworks, targets and international policy dialogues. Especially after the signing of the Kyoto Protocol, agroforestry has gained increased attention as a strategy to ensure food security and mitigate global climate change (Udawatta et al., 2012; Octavia et al., 2022).

Agroforestry is now recognized as a climate-smart agricultural system by the Intergovernmental Panel on Climate Change (IPCC), the United Nations Framework Convention on Climate Change (UNFCCC), as well as the World Bank; as a Nationally Appropriate Mitigation Action (NAMA) and National Adaptation Programme of Action (NAPA) within the agricultural sector; as an important strategy to combat desertification by the United Nations Convention to Combat Desertification (UNCCD); as beneficial to biodiversity by the Convention on Biological Diversity (CBD); and as being able to enhance ecosystem services by the United Nations Forest Forum (UNFF)(FAO, 2013).

In recent years, agroforestry has also been recognized as a key approach for achieving a wide range of SDGs, by helping to eradicate hunger, reduce poverty, support gender equality and social inclusion, provide affordable and cleaner energy, protect life on land, reverse land degradation and combat climate change (van Noordwijk et al., 2016).

1.4 Classification

In order to get clear and complete understanding of agroforestry and its different systems as well as for their further improvement, it is necessary to classify them based on some key criteria. The classification scheme would provide a practical framework for the synthesis and analysis of the existing agroforestry systems and the development of new and promising ones.

Agroforestry is an adaptable and flexible system that varies across landscapes and regions, shaped by local environmental conditions as well as human needs and capabilities. These systems can be classified into several types based on their structure, function, socio-economic factors, management level, as well as ecological context (Figure 2) (Nair, 1987). Understanding these classifications helps tailor agroforestry practices to specific local conditions by guiding the suitability of different combinations of agroforestry components, including trees, crops, pasture, and/or livestock. Careful consideration of these classifications allows practitioners to design agroforestry systems that are not only productive but also ecologically sustainable and socially relevant.

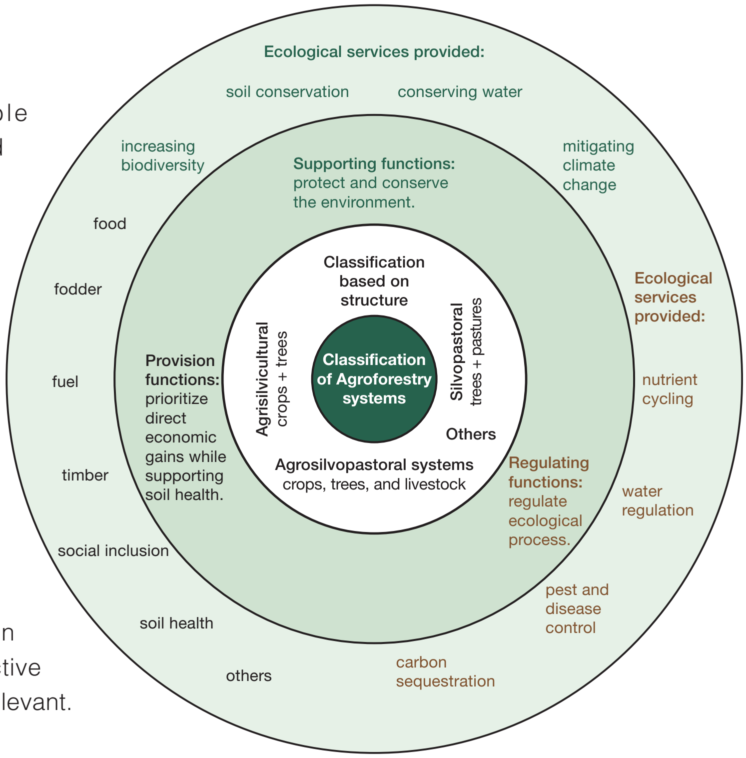


Figure 2: Classification of agroforestry system based on the structure and functions (Adapted from Shelton et al., 2021)

1.4.1 Classification Based on Structure

The FAO (2025) recognizes three main types of agroforestry based on the physical arrangement of system components—crops, trees, and sometimes livestock.

Agri-silvicultural systems

These systems integrate crops and trees, which can improve soil fertility, reduce erosion, and provide additional income from timber, fruit, or other tree products.

A notable subcategory is forest farming, which involves cultivating high-value crops such as medicinal plants (Figure 3), mushrooms, and speciality fruits under the canopy of an existing forest. These systems require careful management to minimize competition between trees and crops for resources.

Figure 3: An agri-silvicultural system at Yaoxi Forest Farm of Anhui Province, China: the newly initiated APFNet-funded project supported the interplanting of *Polygonatum cyrtonema* Hua in Chinese fir plantation in early 2025 (Photo: Xu Qing)

Silvopastoral systems

These systems combine trees and pastures, offering significant benefits to livestock farmers. Trees contribute to improved soil fertility, reduced erosion, and provide shade, shelter, and fodder. These systems are typically managed to generate both short-term income from livestock and longer-term returns from timber (Figure 4). Silvopastoral systems allow the intensification of livestock production based on natural processes and are recognized as an integrated approach to sustainable land use (Nair et al., 2009). These systems can be more productive, profitable, and sustainable than specialized forestry or animal production on their own (Jose, 2009).

Figure 4: A silvopastoral system at Wangyedian Forest Farm of Inner Mongolia, China: the APFNet-funded supported the rearing of chickens in the forest (Photo: Ma Chenggong)

Agrosilvopastoral systems

These systems integrate crops, trees, and livestock (Figure 5). They are perhaps the most complex but also the most beneficial, as they combine the advantages of both agri-silvicultural and silvopastoral systems to enhance biodiversity, improve soil health, and diversify income sources.

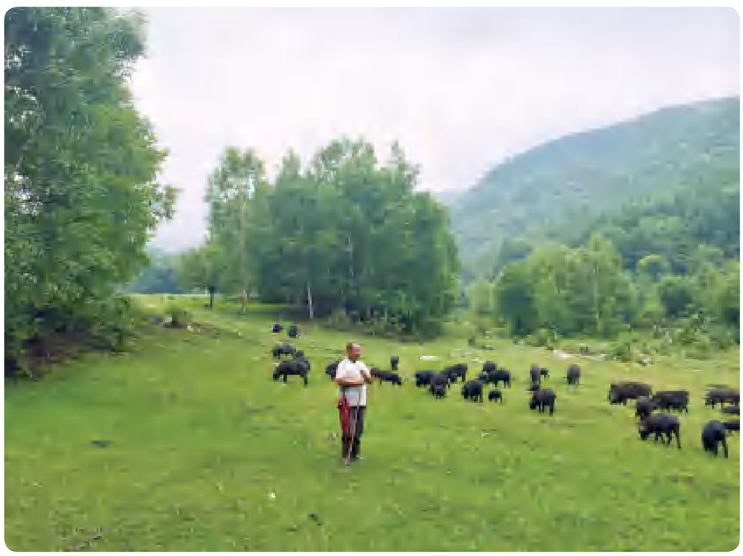


Figure 5: An agrosilvopastoral system at Wangyedian Forest Farm of Inner Mongolia, China: the APFNet-funded project supported the establishment of a community-based Lingguan Tibetan Pig Breeding Cooperative, to raise Tibetan pigs at the Forest Farm (Photo: Li Zhaochen)

1.4.2 Classification Based on Function

The FAO (2017) also defines three types of ecosystem services that agroforestry systems can enhance. All agroforestry systems are likely to incorporate all three of these functional aspects to varying degrees; however, systems can be classified based on the prioritization of one of the following primary functions:

Supporting functions

These systems aim to protect and enhance the environment by reducing soil erosion, conserving water, increasing biodiversity, and mitigating the impacts of climate change. For instance, in alley cropping, rows of trees or shrubs are planted at regular intervals, with crops grown in between. This arrangement provides shade, wind protection, and enhanced nutrient cycling.

Provisioning functions

Productive agroforestry systems prioritize direct economic gains by producing goods such as food, fodder, fuel, and timber, while also supporting soil health.

Regulating functions

These systems help regulate ecological processes such as nutrient cycling, water regulation, and pest and disease control. An example is riparian buffer strips, which are vegetative zones planted alongside water bodies that filter pollutants and prevent erosion. In hilly areas, farmers may plant willows or poplars along riverbanks to stabilize soil and improve water quality.

1.4.3 Classification Based on Ecological Context

Nair (1985) also adds that agroforestry systems can be classified based on factors such as climate, soil type, and topography. Examples include:

Tropical agroforestry systems

These systems often involve high-value crops and trees, such as coconut, banana, and spices, grown alongside timber species. These systems typically have multi-layered structures that mimic natural forests and support biodiversity.

Temperate agroforestry systems

These systems often integrate trees with pasture or crop systems, focusing on livestock production and seasonal crops.

Arid and semi-arid agroforestry systems

These systems emphasize drought-resistant species that help conserve soil and water while providing multiple income streams in water-scarce environments.

1.4.4 Classification Based on Socio-Economic Factors

These classifications depend on the scale of operation, technological inputs, and the farmers' primary goals.

Subsistence agroforestry systems

Designed primarily to meet household needs, these traditional systems support soil fertility and offer a wide variety of food and non-food products.

Commercial agroforestry systems

Oriented toward market production, these systems include practices such as planting fast-growing trees, like poplar, for timber to sell to plywood industries or other commercial markets.

Intermediate agroforestry systems

These systems aim to meet household subsistence needs while also producing surplus for sale, striking a balance between traditional and commercial practices.

2

Agroforestry in the Asia-Pacific Region

Agroforestry is deeply rooted and increasingly vital across the diverse landscapes of the Asia-Pacific region. The traditional and evolving systems, such as homegardens, provide critical benefits. Crucially, agroforestry combats environmental challenges pervasive in the region. While facing obstacles like land tenure issues, market access limitations, agroforestry holds immense potential as a sustainable and resilient land-use strategy for the future of the Asia-Pacific region, balancing productivity with essential ecological functions.

2.1 Socio-Ecological Background

The Asia-Pacific region spans a vast geographical area characterized by diverse landscapes, climates, societies, cultures, and religions. Despite this diversity, the region faces persistent challenges such as poverty, land degradation, gender inequality, illegal timber harvesting, soil erosion, biodiversity loss, and extensive deforestation—all of which threaten ecological security and sustainable development.

The Asia-Pacific region is an incredibly diverse region. It is home to over 60% of the world's population and contains the world's most populous economies—India (1.4 billion[1]) and China (1.4 billion[1])—and also some of the least populous—Pacific island economies such as Nauru (12,000[1]) and Tuvalu (10,600[1]) (United Nations, 2023). This diversity is also reflected in the socio-economic challenges faced by different economies in the region. For example, some economies are facing a rapidly aging population with low birth rates and others are experiencing a "youth bulge", highlighting the need for different approaches to development within the region (United Nations, 2023). Although estimated poverty rates vary from 0% to over 40% in different economies, the urban-rural wealth gap persists universally, with rural areas more disadvantaged than urban areas (United Nations, 2023).

Gender inequality is also a significant challenge in most Asia-Pacific economies. Female representation in government and managerial positions remains low (under 25%) in almost all economies and jobs held by women are expected to be disproportionately affected by future climate change (United Nations, 2023).

As the global population grows and demands increase, pressure on natural resources has reached unprecedented levels. Water stress levels are extremely high in Central and South Asia (over 70%) and high in East and Western Asia (45% to 70%). Land degradation is also a significant problem with human-induced land degradation estimated to affect a quarter of the Earth's ice-free land area (IPCC, 2019). The Asia-Pacific region contains some of the highest rates of land degradation globally. According to the FAO (2021), 41% of land in South Asia, 24% in Southeast Asia, and 20% in Western Asia is degraded–of which approximately 70%, 61%, and 75% respectively are classified as strongly degraded (FAO, 2021).

The region also faces significant challenges with regard to climate change. The region is home to mountainous economies experiencing glacial retreat—for example Nepal and Bhutan—as well as low elevation island nations highly vulnerable to the rising sea levels—such as the Maldives and Tuvalu. Extreme fluctuations in temperatures and rainfall are also expected to cause significant disruption across the whole region.

Given these pressing and diverse experiences in the Asia-Pacific region, it is critical to find and tailor solutions suitable for each economy to promote ecological security and sustainable development—such as agroforestry, which itself can be adapted to local contexts and offers both environmental and socio-economic benefits.

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[1] Population sizes are an approximation

2.2 Regional Advancement of Agroforestry

Agroforestry in the Asia-Pacific region is experiencing great advancement, with increasing recognition of its potential to address land-use challenges and promote sustainable development. National and regional policies are evolving to support agroforestry practices, and collaborative efforts are underway to enhance field practice, research, technological advancements, and policy improvement.

Agroforestry in practice

Asian societies have long developed and implemented diverse agroforestry systems to meet their needs for fuel, food, medicine, and income. These traditional farming systems reflect deep-rooted knowledge of multifunctional land use (Kumar, 2012). Across Southeast Asia, many ecosystems are home to Indigenous communities, who maintain, or adapt, traditional agroforestry practices (Elliott et al., 2019).

In recent years, agroforestry has expanded rapidly—particularly in Southeast Asia. According to Zomer et al. (2014), agroforestry now covers 77.8 percent of agricultural land in Southeast Asia, 50.5 percent in East Asia, 27 percent in South Asia, and 23.6 percent in Northern and Central Asia. Despite regional diversity, economies in Southeast Asia exhibit similar approaches to agroforestry implementation. However, since the early 20th century, growing populations and increasing food demand have led to the conversion of many agroforestry lands into intensive agriculture and monoculture tree plantations, causing environmental and social challenges (Garrity, 2012).

Agroforestry approaches suitable for Asia's degraded lands encompass several practices, such as implementing extended rotating fallows to promote soil conservation, establishing trees on grazing fields in dry regions, cultivating home gardens, implementing boundary plantings, growing perennial crops, and establishing live fences (FAO, 2021). In Southeast Asia, agroforestry is present in landscapes ranging from hill slopes in mountainous areas, fire-climax grasslands, peat lands, mangroves, and rice paddies and terraces. Major typologies include traditional homegardens, systems evolving from natural forest or shifting cultivation (such as slash-and-burn and fallow rotations) by promoting desirable tree species among agricultural mosaics, the integration of trees to open-field agricultural systems, and the addition of crops to forestry systems. Crops commonly integrated with agroforestry include rice, cassava, coffee, cacao, fruits such as pineapple, and vegetables; agroforestry tree species range from fast-growing timber (for example, *Acacia*, *Eucalyptus*, and bamboo), fruit and medicinal trees (for example, coconut, durian, and tamarind), and tree crops (for example, small-holder rubber and oil palm) (van Noordwijk, 2020).

Academic output

Over the past three decades, agroforestry research themes have evolved significantly. While various topics have emerged over time, the sustainability of agroforestry systems has remained a central focus in the Asia-Pacific region (Figure 6). It is gaining more recognition in development programs, particularly those focused on climate change (Nair et al., 2016). Indonesia leads in published agroforestry research, followed by the Philippines and Thailand. The National Research Centre for Agroforestry (NRCAF), now known as ICAR-Central Agroforestry Research Institute (CAFRI), based in India, has gained global recognition for its extensive research in the field of agroforestry.

Since 2004, a sequence of World Congresses in Agroforestry has taken place every 5 years for information sharing and cooperative initiatives.

Technological advancement

Innovative practices, rooted in research, technology integration, and novel land management approaches, are increasingly being applied in agroforestry. For example, GPS, remote sensing, and data analytics are used to optimize crop health, tree growth, and soil conditions. Ahmad et al. (2021) employed geospatial technology to map the agroforestry area of India, and Zomer et al. (2009) utilized remote sensing-derived tree cover data from ICRAF for the year 2009, and found that 40 percent of the total area, are very appropriate for agroforestry in India.

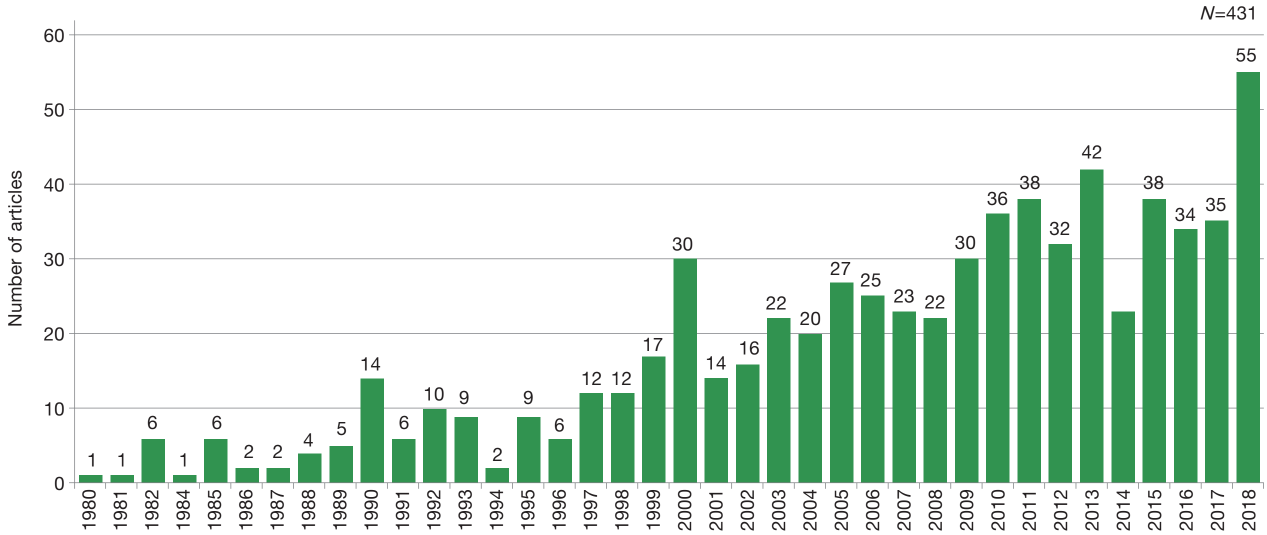


Figure 6: Number of academic publications on agroforestry and ecosystem services in Asia, based on data from Shin et al. (2020)

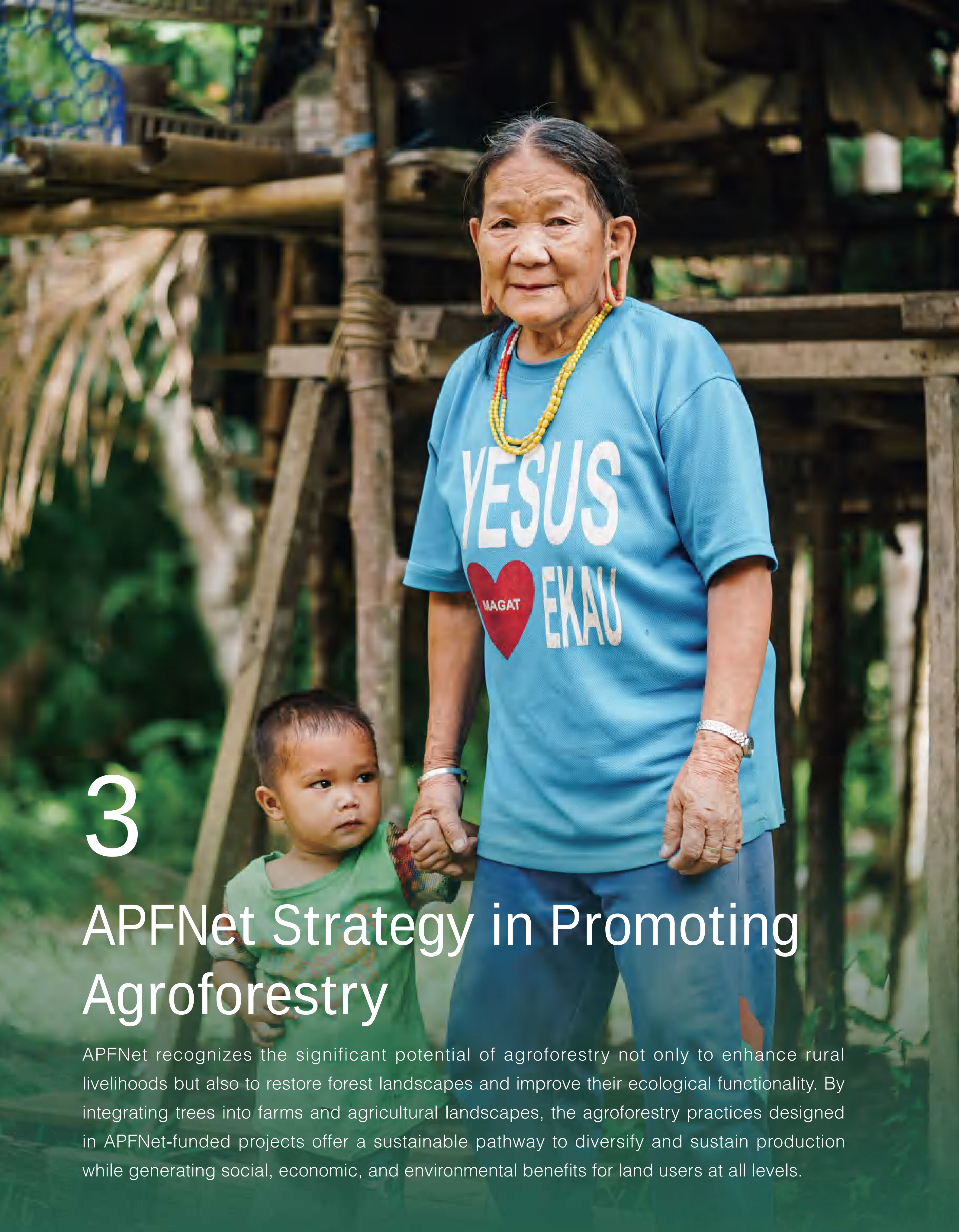
Agroforestry also plays a crucial role in carbon sequestration, and new methodologies and tools are being used to accurately measure the carbon sequestration potential of agroforestry systems (Ritwik et al.,2024).

National and regional policies

Institutionally, agroforestry has gained traction in national and regional policies across Asia. In 1999, the Grain for Green (GFG) program was introduced in China, aiming to reforest uplands to reduce erosion and downstream flooding while alleviating rural poverty by providing grain, saplings, and/or subsidies. This led to rapid development of agroforestry technologies after 2001, mainly through fruit tree intercropping. In 2002, a China-Agroforestry Program was established by World Agroforestry, the Chinese Ministry of Agriculture, and the Chinese Academy of Agricultural Sciences (CAAS), with the goal of transforming traditional practices into scientific agroforestry. In 2014, to resolve the bottlenecks that had emerged at the interface of existing policies for agriculture, forestry, water and environment, India launched the National Agroforestry Policy during the World Congress on Agroforestry held in Delhi, becoming the first economy in the world to adopt an agroforestry policy (Singh et al., 2016).

At a regional level, in 2015, the 37th ASEAN Ministers of Agriculture and Forestry Meeting endorsed the *Vision and Strategic Plan for ASEAN Cooperation in Food, Agriculture and Forestry 2016–2025*. Later, in 2016, *the ASEAN Guidelines for Agroforestry Development* were adopted at the 39th ASEAN Ministers Meeting, publishing 75 guidelines across 14 principles encompassing institutional, economic, environmental, socio-cultural, technical, communication, and scaling-up.

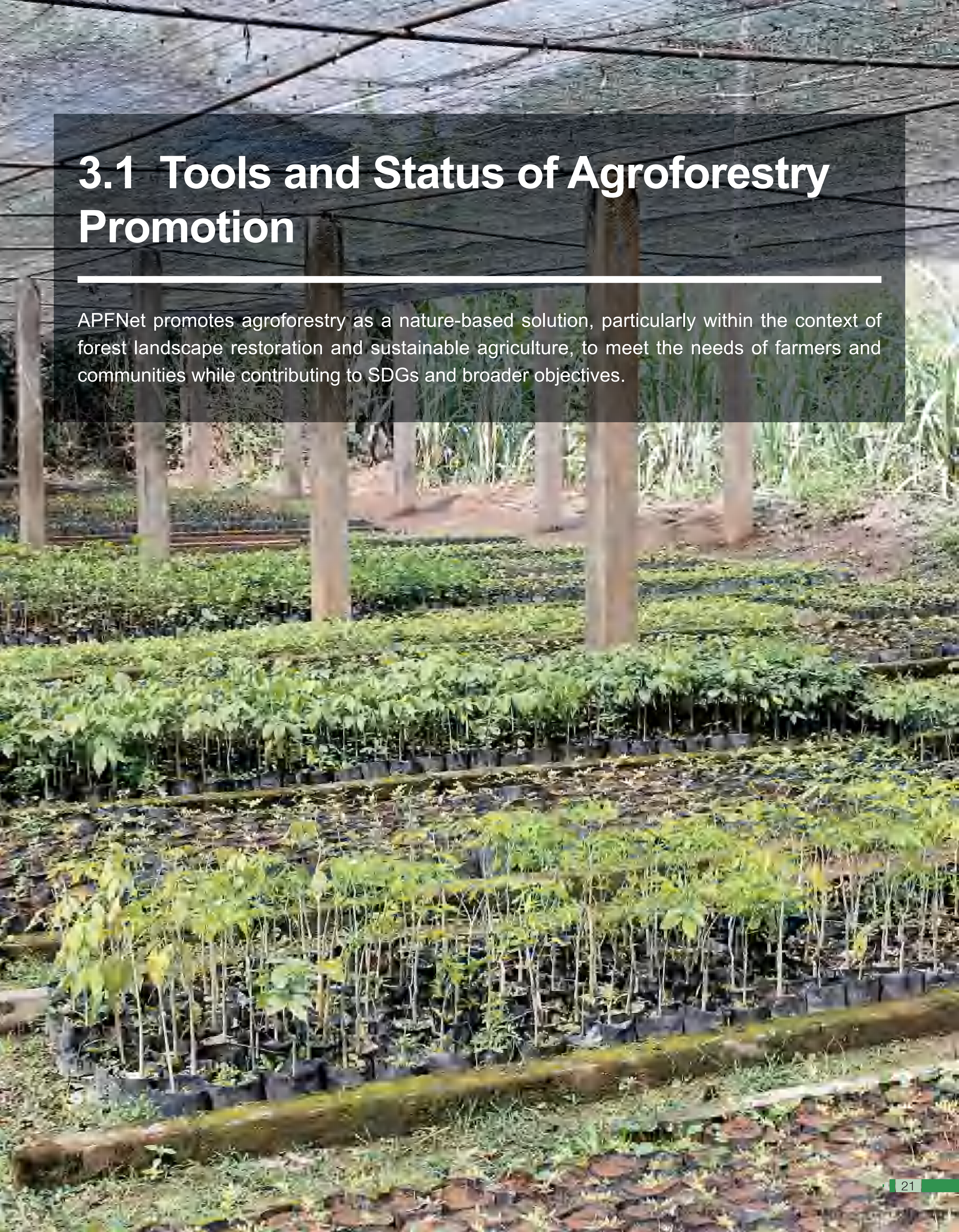
While there is consensus on the benefits of agroforestry as a whole, policies on livestock rearing in upland areas show some divergence. The Thai government discourages cattle farming in forested upland areas due to its perceived negative environmental impacts, whereas the Lao PDR government has promoted livestock production, including cattle, among upland minority groups as a strategy of poverty alleviation (Bouahom, 1997).



3

APFNet Strategy in Promoting Agroforestry

APFNet recognizes the significant potential of agroforestry not only to enhance rural livelihoods but also to restore forest landscapes and improve their ecological functionality. By integrating trees into farms and agricultural landscapes, the agroforestry practices designed in APFNet-funded projects offer a sustainable pathway to diversify and sustain production while generating social, economic, and environmental benefits for land users at all levels.



3.1 Tools and Status of Agroforestry Promotion

APFNet promotes agroforestry as a nature-based solution, particularly within the context of forest landscape restoration and sustainable agriculture, to meet the needs of farmers and communities while contributing to SDGs and broader objectives.

APFNet is committed to promoting and improving sustainable forest management and rehabilitation in the Asia-Pacific region through its four pillars, namely capacity building, demonstration projects, regional policy dialogues and information sharing.

Agroforestry is primarily promoted through field-based demonstration projects designed to restore degraded forests, expand forest cover, and promote sustainable forest management, thereby enhancing ecological health, and improving the socio-economic well-being of local communities. This is achieved by providing financial and technical support to projects that are tailored to the specific needs of individual economies and the broader region. In addition to demonstration projects, APFNet also supports capacity development and research initiatives to advance innovation in agroforestry.

APFNet's support for agroforestry includes:

- Projects that enhance the livelihoods of communities living in and around forests;
- Projects that use agroforestry as a mechanism for forest rehabilitation and restoration;
- Research-focused initiatives to foster innovation in agroforestry practices.

By 2025, APFNet had invested approximately USD 43 million in 56 projects across 22 economies, in collaboration with governments, communities, organizations, and the private sectors. Of these projects, 20 are agroforestry-related and have been implemented in nine economies, including Cambodia, China, Indonesia, Lao PDR, Myanmar, Nepal, Peru, Malaysia and Fiji. The total grant from APFNet for these projects is over USD 17.3 million, the number of projects and financial support from APFNet are shown in Figure 7.

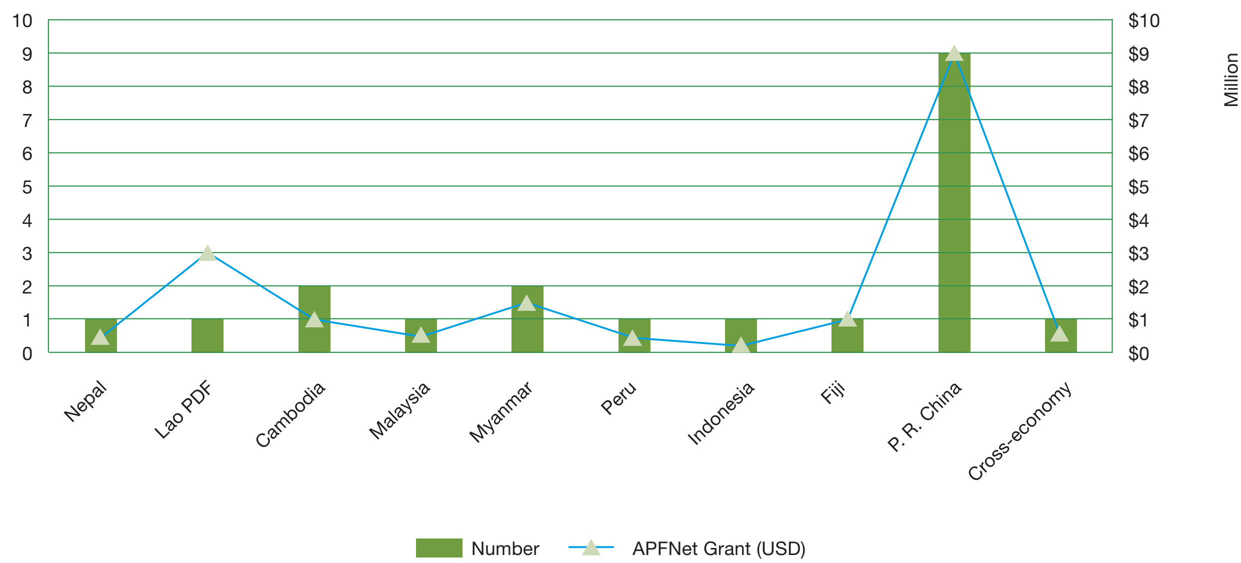
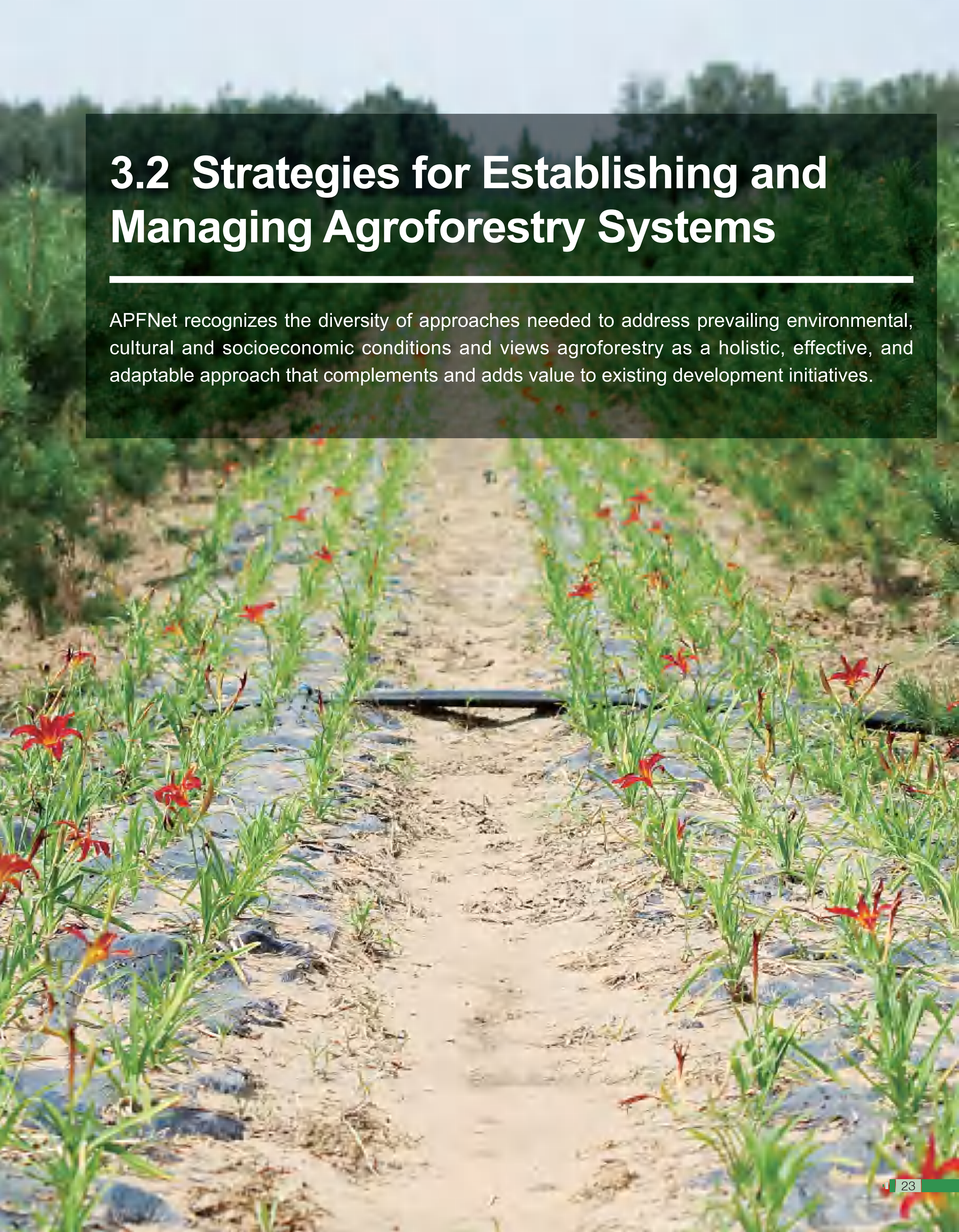


Figure 7: Number and Total Grant Value of APFNet Agroforestry Projects

3.2 Strategies for Establishing and Managing Agroforestry Systems

APFNet recognizes the diversity of approaches needed to address prevailing environmental, cultural and socioeconomic conditions and views agroforestry as a holistic, effective, and adaptable approach that complements and adds value to existing development initiatives.



The diversity inherent in agroforestry is both a challenge and an opportunity. To optimize production and broader benefits, agroforestry systems must be designed with careful consideration of individual farmer's needs, community priorities, and other economic factors such as resource availability, markets and value chains. At the same time, they also should be tailored to local environmental conditions and be designed to be ecologically sustainable.

To guide the development of appropriate agroforestry practices, APFNet emphasizes the integration of policy, science, and practice in the design and implementation of agroforestry-related projects. To achieve this, APFNet-funded typically follow a stepwise process in the development of agroforestry practices:

Step 1: Identify Opportunities and Needs

Investigations, normally using interviews, discussions, and questionnaires (Figure 8), are undertaken to identify:

- How target communities or areas currently use and manage the forest;
- Assess the suitability of land for agroforestry development;
- Understand the needs and priorities of local households or communities;
- Evaluate the potential environmental, social, and economic benefits of proposed systems.

Figure 8: Agroforestry implementation survey during an APFNet-funded project in Leinli village, Myanmar (Photo: Ei Ei Swe Hlaing)

Step 2: System Planning and Design

Agroforestry systems must be tailored to local conditions using participatory approach with a comprehensive planning process (Figure 9) that includes:

- Documentation of local knowledge and practices;
- Site assessments and environmental evaluations;
- Developing a scientific management plan with participatory approach;
- Definition of objectives and goals for the system;
- Selection of appropriate species and system components to optimize ecological and economic outcomes;
- Consideration of value chain development, investment opportunities, and support services;
- Developing technical guidelines.

It should be noted that when selecting species, attention must be paid to diversity and tree-crop interactions to ensure a wider range of products and to help build resilience.

In addition, management plans should remain flexible to accommodate changing conditions while maintaining alignment with production, restoration, and sustainability goals.

Figure 9: Discussing activity design for the APFNet project aimed at improving the livelihoods of local villagers (Photo: Ei Ei Swe Hlaing)

Step 3: Implementation, Monitoring, and Scaling Up

APFNet promotes the demonstration of agroforestry practices and capacity-building activities through its field-based projects. This includes:

- Implementing agroforestry systems aligned with planned objectives;
- Monitoring impacts and performance;
- Producing policy briefs and knowledge products;
- Upscaling successful practices and lessons learned across regions.

To address challenges such as land degradation and climate vulnerability, APFNet promotes context-specific agroforestry practices that are tailored to local conditions. Techniques such as contour hedgerows and living terraces are commonly applied on sloped lands to reduce soil erosion, while windbreaks and shelterbelts help protect central crop zones from wind damage and moisture loss (Figure 10).

Figure 10: Vegetation restoration using living biocomposite sand barriers (Photo: Sanyijing Forest Farm)

Agroforestry models supported by APFNet encompass a wide range of systems:

- Alley cropping and strip intercropping, which combine rows of trees with annual crops to enhance productivity, soil fertility, and biodiversity.
- Successional intercropping and improved fallows, which allow soils to regenerate after intensive cultivation, contributing to long-term soil health.
- Multistrata systems, such as traditional homegardens, which layer trees, shrubs, and herbaceous plants to produce diverse outputs—ranging from food and fuel to fibre and medicinal products—on small land areas with high efficiency.

These practices demonstrate the versatility of agroforestry across different ecological and cultural settings.

"After field monitoring and surveys, I find that with the implementation of the agroforestry practices through the APFNet-funded project, the pressure on natural forests was eased greatly."

—Professor San Win, external evaluator of APFNet-funded project "Integrated Forest Ecosystem Management Planning and Demonstration Project in Greater Mekong Sub-region (Myanmar site)".

In addition, the agroforestry practices in APFNet projects are normally monitored and evaluated based on productivity, including regulating, provision and supporting services they provide, sustainability, and adoptability by stakeholders.

Step 4: Integrating Socio-Economic Dimensions

In addition to biophysical components, such as site selection, species selection, and soil and water conservation, socio-economic dimensions are integral to APFNet-funded projects (Figure 11 to 13). Based on field surveys and participatory approaches, APFNet-supported agroforestry projects also address key socio-economic factors including:

- Land tenure security;
- Women's empowerment;
- Awareness raising;
- Livelihood diversification, e.g. fungi agroforestry and bee-keeping;
- Capacity building;
- Promotion of alternative energy sources.

Figure 11: Bee-keeping supported by APFNet-funded project in Vietnam (Photo: Forest Inventory and Planning Institute, Vietnam)

Figure 12: Empowerment and awareness-raising for women in target communities of the APFNet-funded project in Nepal (Photo: Community Resource Management Centre, Nepal)

Figure 13: Agroforestry training for villagers in Myanmar: explaining topography and soil conservation in taungya plantations (left) and the frame method for ladder plantations on slopes (right) (Photo: Ei Ei Swe Hlaing)

"Through APFNet-supported agroforestry planning and demonstration practices in Paung Laung watershed forests, the villagers are now skilled with hill cultivation and their livelihood is secured and deforestation in the region was reduced."

— H. E. U Khing Maung Yi, Union Minister of the Ministry of Natural Resources and Environmental Conservation (Figure 14).

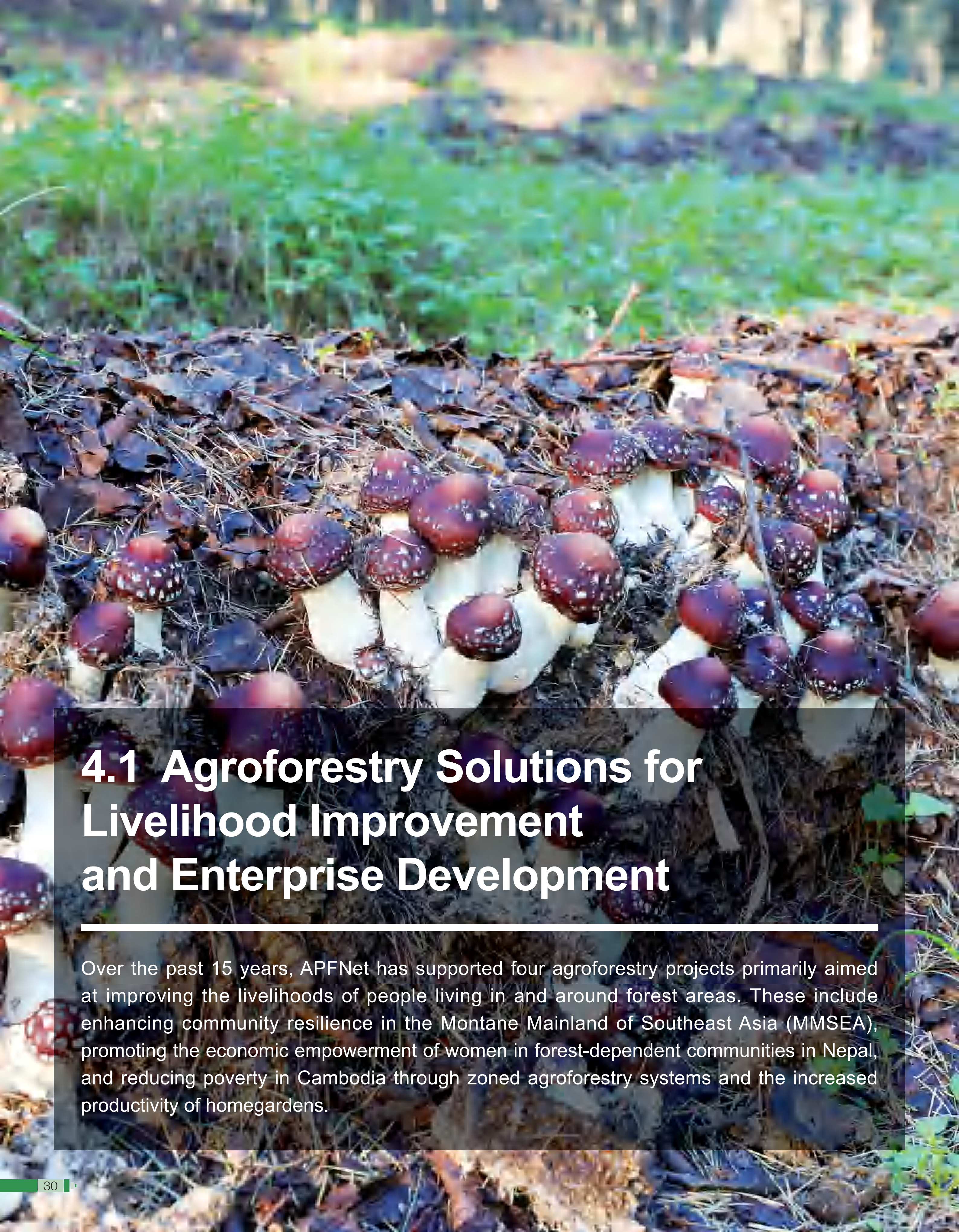
Figure 14: H. E. U Khing Maung Yi gave the opening speech at the opening ceremony of APFNet-funded Education Center (Photo: Xin Shuyu)

By supporting innovation, knowledge exchange, and policy engagement in agroforestry, APFNet aims to scale up these integrated land-use systems as viable tools for sustainable forest management and rural development across the Asia-Pacific region.

4

APFNet Project Cases

APFNet's support for agroforestry has covered projects that aim to improve the livelihoods of people living in and near forest areas, projects that use agroforestry as a tool for forest rehabilitation and restoration and projects that focus on research to stimulate innovation in agroforestry practice. Ten project cases from seven economies will be shared under three thematic clusters in this section.



4.1 Agroforestry Solutions for Livelihood Improvement and Enterprise Development

Over the past 15 years, APFNet has supported four agroforestry projects primarily aimed at improving the livelihoods of people living in and around forest areas. These include enhancing community resilience in the Montane Mainland of Southeast Asia (MMSEA), promoting the economic empowerment of women in forest-dependent communities in Nepal, and reducing poverty in Cambodia through zoned agroforestry systems and the increased productivity of homegardens.

Case 1

More than Trees! Building Resilience of Communities and Forests through Agroforestry in the Montane Mainland of Southeast Asia

Project Title

Sustainable Forest Rehabilitation and Management for the Conservation of Trans-boundary Ecological Security in MMSEA—Pilot Demonstration of Lao PDR, Myanmar and China/Yunnan
[2012P2/2-UNU]

Executing Agency

United Nations University (UNU)

Implementing Agencies

- Yunnan Academy of Forestry
- Department of Agricultural Land Management, Ministry of Agriculture and Forestry, Lao PDR (MAF)
- Forest Research Institute, Myanmar

Budget in USD (Total/APFNet Grant)

650,000/500,000

Project Duration

01/2013–12/2015, completed

Site Location

- Puwen, Yunnan, China;
- Koum Houaykot, Luang Prabang, Lao PDR;
- Nyaung-Htauk Village, Shan State, Myanmar

Introduction

The MMSEA encompasses the northern region of Thailand, Lao PDR and Vietnam, Yunnan Province of China, and the Kachin and Shan States of northeastern Myanmar. The MMSEA is home to a diversity of ethnic minority groups, tropical forests, and endangered and endemic species.

Due to rapid population growth and a lack of alternative livelihoods, the overexploitation of natural resources, especially forests, has been an economic development approach taken over the past decades. Past efforts to rehabilitate degraded land, while well-intentioned, were often marked by monocultures with a limited contribution to the restoration of ecosystem services and short-term income.

Agroforestry is considered a valuable approach to both retain biodiversity and improve community welfare. APFNet has supported pilot initiatives in the MMSEA region that demonstrate how agroforestry could be used to rehabilitate forests. The project selected three suitable pilot sites: Yunnan, China; Luang Prabang, Lao PDR; and Shan State, Myanmar.

Making Rubber Plantations More Environmentally Friendly in Yunnan, China

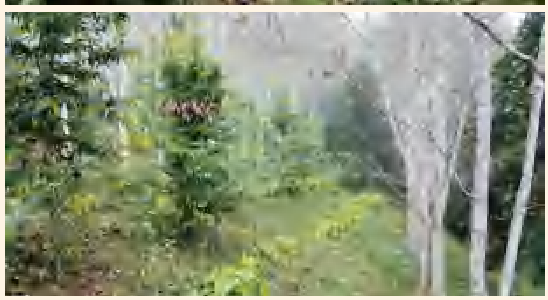
Rubber (*Hevea brasiliensis*) is native to the Amazon and was introduced to China in the 1950s (Pye-Smith, 2011). Rubber's economic benefit has led to a large expansion of monoculture rubber plantations. It is particularly true for the tropical biodiversity hotspot Xishuangbanna, Yunnan, resulting in a relatively large area of rubber plantations. The majority of natural and secondary forests outside of protected areas were replaced by rubber plantations. Even worse, steep slopes at high elevation, which are not suitable for rubber plantations, also became victims of this "goldrush".

In this context, APFNet supported this UNU project aiming to explore feasible strategies to make rubber plantations more environmentally friendly and provide a basis for policy reforms. The project operated on two sub-sites, one in Lianhe Village in Puwen Town, Jinghong City and the other at the Puwen Tropical Forestry Institute (TFI). The former mainly focused on improving smallholder rubber plantations while the latter had a stronger research component. Lianhe Village is adjacent to TFI and is home to the Han, Hani and Yi ethnic groups. The village owns a total land area of 200ha, most of which is mountainous. There is only a small area of valley bottom used for paddy fields. The climate type belongs to the northern subtropical and plateau monsoon climate with an average annual temperature of 20.2℃ and an annual precipitation of 1,675.6mm. The area is well suited for growing rice, corn and cash crops such as rubber, tea and coffee.

Model 1 Mixed Rubber Plantations

A total of 20 households participated in the project and, based on focus group discussions, high value timber species that can compensate for lost income from rubber were selected (Figure 15). Seedlings included *Aquilaria sinensis, Oroxylum indicum, Altingia chinensis, Dalbergia odorifera* and *Pterocarpus indicus*. They were provided to farmers free of charge and interplanted in the rubber and tea plantations (Figure 16).

The species mixed in the rubber plantations at TFI are different from those in the village. Considering the focus on conservation, indigenous rainforest tree species were selected and planted in alleys across 6.66ha of existing rubber plantations. *Parashorea chinensis, Altingia chinensis, Mesua ferrea,* and *Dipterocarpus turbinatus* were some of the selected species. When these trees grow up, the rubber plantations can be gradually replaced (Figure 17).



- Figure 15: Extensive rubber monoculture with high income but low ecosystem service capacity at Lianghe village (2013) (top)
- Figure 16: Land preparation for planting other tree specie in the rubber plantation (2013) (middle)
- Figure 17: Indigenous high-value tree species growing in between rubber plantations (2018) (bottom)

Model 2
Jungle Rubber Plantations in TFI

Jungle rubber plantations are, according to the World Agroforestry Center, formally defined as complex rubber systems with two-thirds of the trees being non-rubber species and are considered traditional practices in Indonesia (Pye-Smith, 2011). Their products—fruit, resin, timber, and medicine—may be more important to smallholders than rubber latex.

In the rubber plantation in China, rainforest trees, including *Parashorea chinensis, Mesua ferrea* and *Dipterocarpus turbinatus*, were randomly interplanted at a slightly lower density than in Indonesia (<50%). The low density of tree planting leaves enough space to facilitate natural regeneration at a later stage of rehabilitation (Figure 18).

Figure 18: Rubber plantation plot before (2013) and after (2018) intervention

Rich Rewards from Agroforestry in Lao PDR

The project site is located at the Koum Houaykot Village, Xiengngeun District, Luang Prabang Province. The total village area is 3,420ha of which natural forest covers 70%, fallow land 24.15%, current upland crop fields 3.5% and teak plantations 0.45%. The topography is classified as mountainous upland with slopes steeper than 25%. The villagers traditionally practice slash-and-burn shifting cultivation. Nowadays, each household is allocated 2–5ha of degraded forest land, but many are still living in poverty (Box 3).

Scarcity of timber species in the village forest area leads farmers to illegally cut trees in natural forests. NTFPs, especially broom grass (*Thysanolaena latifolia*), are often overharvested as they are easy to sell on the market. Shortened fallow periods and soil degradation have caused lower crop yields and further encroachment on village conservation forests. Farmers often lack skills to produce multiple crops on their land. Thus, the project introduced agroforestry systems that intercrop cash crops, NTFP species and valuable timber trees to allow for faster assisted natural regeneration and a higher diversity of short-term income sources.

This involved introducing rotational agroforestry starting with annual crops for short-term income, continuing with semi-perennials with medium-term income, culminating in perennial crop/tree gardens with long-term income. Models used include:

- **Model 1** Teak (*Tectona grandis*) intercropped with annual crops like upland rice in the first year; corns and Job's tears (*Coix lacryme-jobi*) in the second year (Figure 19);
- **Model 2** Rubber intercropped with banana and *Oroxylum indicum*;
- **Model 3** Fruit tree species, such as mango (*Mangifera indica*), longan (*Dimocarpus longan*) intercropped with the annual Job's tears;
- **Model 4** Broom grass intercropped with upland rice in the first year and banana in the second year. Broom grass or banana was planted along the contour lines while Job's tears or other annual crops were grown in-between.

Figure 19: Teak intercropped with Job's tears, banana and broom grass

Farmers earned USD 986/ha for broom grass in the first year and USD 1498/ha in the second year. Broom grass was found to be very effective in conserving soil and water, with soil loss reduced to 0.52t/ha and water runoff reduced to 356m^3/ha annually. *Tectona grandis* intercropped with annual crops is also effective in reducing soil and water erosion, with soil losses of 1.18t/ha and water runoff 875 m^3/ha. In comparison, soil loss and water runoff for mono-cropping of annual crops is much higher at 25 tons and 2,358m^3/ha respectively.

Box 3

Figure 20: Case of Mrs Loy Chid

Loy Chid: A Brighter Future with Agroforestry

Mrs Loy Chid joined the project in early 2014 (Figure 20). She is a mother of four children and owns 1.5 ha of farm land, which was traditionally used for slash-and-burn agriculture, cropping upland rice for a year and then leaving it fallow for another three to four years. The rice yield was low and could barely meet the needs of the family. With the help of the project, she changed the traditional system to an agroforestry system, integrating annual crops with semi- and full perennials to balance short- and long-term benefits. In addition, she introduced chickens and pigs into this system.

"I have four children, two years ago one had to give up her education as I could not support the related expenses. This year (2015), I can earn USD 5 per day by selling bananas, not yet including income from chicken and pigs. Now I can support my second son to go to school. In the next three years, I expect more harvests from other fruit trees including mango, longan and lychee. So, taking this opportunity, I would like to thank APFNet for improving our livelihoods and bringing a brighter future for my son."

—**Mrs. Loy Chid, Jan 14, 2016.**

Agroforestry to Reclaim Degraded Land and Diversify Incomes in Myanmar

The project site is located at the Nyaung Ktauk Reserve Forest (NKRF) as well as Nyaung Htauk village nearby the reserved forest, approximately 200 miles from the Myanmar-China border. Nearly 60% of the village is agricultural land and other land uses include bare land (18%), scrub land (13%) and forest (8%).

The village has a population of 800, of which 87% are Shan and Danu ethnic groups. Agriculture is one of the main sources of income, but it is evolving from a slash-and-burn system to sedentary agriculture. Unfortunately, accompanying this trend are heavy inputs of agrochemicals and further encroachment upon reserved forest areas, also resulting in soil degradation.

Agroforestry is a potentially useful solution. It can use nutrient cycling between tree and crop layers as a means of boosting yields and diversifying income sources. The project tested three different models for agroforestry on degraded lands in Myanmar.

The community forestry group has access to all crops grown in the agroforestry plots. These crops are used for household consumption or sold in local markets. *Sterculia versicolor* can generate income 5 years after planting (Figure 21) and the estimated income per tree per year is about USD 110. The key product of Sterculia versicola is gum, mainly used for car mirrors and medicinal purposes.

Figure 21: *Sterculia versicola* planted in 2014 (left) and 2018 (right)

Model 1: Agroforestry in Community Forests

Village meetings were organized, and nine community forest user group members indicated strong interest in planting tree species based on their preference in their agricultural fields where maize, rice and ground nut were grown seasonally.

The project provided seeds, seedlings and training to local farmers to master the planting techniques. They planted tree seedlings in 2013, 2014 and 2015. Alley cropping was practiced by interplanting *Sterculia versicola* — a native tree species well-suited to the local topography and climate, with the potential to generate high income in a short time — between rows of crops in July and August. Weeding was carried out twice in June and October for the first two years when the crops were planted and harvested. Along the farm boundary, *Cassia siamea, Gmelina arborea,* and *Mangifera indica* were planted to enrich the soil and provide fuelwood and poles.

The comparison of soil conditions before and after agroforestry showed that nitrogen and pH values of soil have changed for the better (Figure 22).

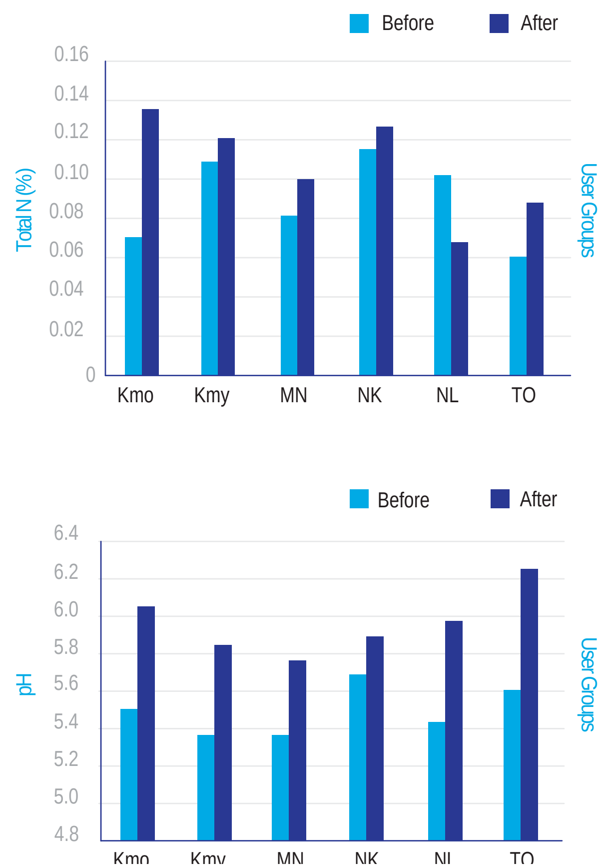


Figure 22: Total nitrogen content (top) pH (bottom) before and after the agroforestry sytems were put in place

Model 2: Planting Teak and Other Species around the Farm Boundary

Farmers' preferred tree species—*Tectona grandis*, *Cassia siamea* and *Eucalyptus camaldulensis*—were planted along the farm boundary in July and August 2014, using a spacing of 3m × 4m. Weeding and mulching was carried out when necessary. Trees around the farm have positive effects by improving soil nutrients with litter from trees and protecting annual crops from strong winds. Farmers can also easily mark the boundaries between different farms, as well as collect timber and fuel.

Model 3: Homegardens

Myanmar homegardens, like those in Cambodia, are a traditional practice of local farmers. Common annual crops are eggplant, pumpkin, lemon, various kinds of beans, chilli, ladies' fingers, bitter gourd, mustard and tomato, while fruit species include banana, papaya, mango, coconut and coffee.

The project provided seedlings of ornamental species, timber and fruit species to 40 farmers to plant in their gardens, creating an even more diverse, multi-story agroforestry landscape (Figure 23).

Among them is 65-year-old Daw Tin Kyi. Due to his age he cannot work on the field anymore. But thanks to the seasonal vegetables, fruits and flowers from his homegarden, he can earn USD 150 per year, which is enough to get by while not endangering his health.

Figure 23: Seedlings were provided to farmers to plant in their homegardens

Securing Achievements and Scaling Up

The villagers have been cultivating seasonal crops in the degraded Nyaung Ktauk Reserve Forest for years. With the initiation of this project, secure tenure with 30-year land use rights was provided to local farmers in the form of an official Community Forest *Certificate. "Gradually, the members are aware of benefits from the Community Forests, which is not only providing secure land and forest resource tenure but also the possibility of getting cash income from selling crops as well as Sterculia versicolor in near future"*, U Kyaw Myo, one user group member said.

Before this project began, the village had several self-governance administrative bodies, but no dedicated group for forest rehabilitation practices. Now, a self-managed group focused on planning, implementing, and maintaining agroforestry models has been established. This group currently includes 70% of the 220 households participating in the project.

Showing its potential for wider dissemination, right after project completion, another two community forest user groups, consisting of 12 farmers, replicated this model with the help of the Nyaung-Cho Forest Department township office (Figure 24).

Figure 24: Seedling distribution to the target community

Case 2

Agroforestry for a Promising Life: Women Leading Community-Based Enterprises

Project Title

Supporting Community-Based Sustainable Forest Management and Economic Empowerment of Women in Central Region of Nepal
[2013P4-NPL]

Executing Agency

HIMAWANTI-Nepal

Budget in USD (Total/APFNet Grant)

559,208/412,238

Project Duration

10/2014–03/2018, completed

Site Location

Sarlahi District, Nepal

Located in the Himalayan region, Nepal has traditionally been influenced by Hinduism, which has shaped a unique and fascinating culture. While this cultural heritage is rich and to be celebrated, the traditional emphasis on patrilineal descent has historically contributed to gender roles that often place women in subordinate positions within family and society. In cities these attitudes are changing, but in the countryside, women still face significant challenges.

As such, women mainly manage household chores and do farming work (Figure 25), and their livelihoods are strongly dependent on community forests. While all of these areas of responsibility are important, none contribute cash income for them. Yet, community forests and, especially, agroforestry hold strong potential for socioeconomic empowerment by instilling a sense of agency through entrepreneurship among women, which is one of the most effective indicators of their empowerment. (Malhotra et al., 2002).

In 2014, APFNet, together with the Himalayan Grassroots Women's Natural Resource Management Association (HIMAWANTI), set out to support women's entrepreneurship in Nepal through the establishment of forest-based enterprises. The project sites are located in Sarlahi District of Province No. 2, which covers an area of 1,259 km^2 and has a population of 769,729 (National Population and Housing Census, 2011). The forests at the project site were degraded, due to rapid population growth. Located under high transmission lines, the forests were underutilized and dominated by shrubs and invasive species. In a number of other areas different small trees, such as *Shorea robusta*, *Terminalia tomentosa, Syzygium cumuni, Emblica officinalis, Bombax ceiba, Tectona grandis* and *Lagerstroemia parviflora* were growing abundantly. In some areas, *Eucalyptus camadulensis* plantations still remained.

The area itself faced multiple problems, such as a lack of sustainable forest management, women's empowerment, and alternative livelihood options, as well as insufficient production and marketing of products. The community forests were also affected by natural disasters including floods and fire.

Figure 25: Harvesting of aromatic herbs

Growing Aromatic Plants in Community Forests

Based on the earlier mentioned issues, it was important to make use of forest products that would at the same time promote SFM and offer entrepreneurial opportunities. Nepal is especially suitable for growing medicinal and aromatic plants (MAPs), with the advantage that aromatic plants in agroforestry systems can be grown underneath tree cover and are able to fully make use of the growing space in the understory (Figure 26, Box 4). This includes traditionally underused spaces, such as high voltage transmission lines and forests fringes. As part of the project, such herbs were planted in the Terai lowland areas and an essential oil producing enterprise in Sarlahi district was established as a good example of combining of agroforestry, forest rehabilitation and post-harvest value-added product manufacturing, At the same time local women were trained in how to plant and market MAPs (Figure 27 and 28).

Figure 26: Lemongrass plantation grown in the community forest (top left)
Figure 27: Women are planting the seedlings grown in the nurseries in community forest land (bottom left)
Figure 28: Clearing the land for agroforestry plantation (right)

Box 4

Aromatic Herbs Species in Agroforestry

Palmarosa (*Cymbopogon martinii* var. *motia*): widely used for rose-smelling perfumes and cosmetics around the world. It is also known to help repel mosquitoes and flavor tobacco products. It has been used in medicinal solutions and for aromatherapy (Figure 29).

Citronella (*Cymbopogon nardus*): Essential oils are extracted from the aerial parts, and are applied topically as an insect repellent (Nakahara et al., 2013) (Figure 30).

Lemongrass (*Cymbopogon citratus*): Widely used in Brazil and India as traditional medicine. Traditionally used to treat Staph infections and combating skin infections. Prevents body odor and improves body metabolism (Cheel et al., 2005) (Figure 31).

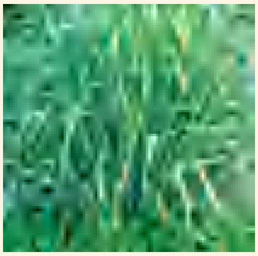


Figure 29: *Cymbopogon martinii* var. *motia* (top left)
Figure 30: *Cymbopogon nardus* (top right)
Figure 31: *Cymbopogon citratus* (bottom)

Agroforestry for MAPs

The tree and shrub species are mostly local species and have been enriched with the planting of fodder and forage species, such as Nepalese broom grass (*Thysanolaena maxima*) (Table 1). The planting of aromatic herbs can be considered a form of forest restoration through species enrichment. In Janajvoti and Nandeswor, underutilized land under a high transmission line was put back into use through planting aromatic herbs (Table 2). Overall a total of 509,100 aromatic herb seedlings were planted across 12ha in 3 communities in Sarlahi. Irrigation facilities through pumping underground water were provided in the planting sites, while weeding efforts focused on uprooting *Lantana camara*, an invasive species.

Table 1:

Species on agroforestry plots

Local trees and shrubs	*Shorea robusta, Syzygium cumunii, Emblica officinalis, Bombax ceiba, Tectona grandis, Lagerstroemia parviflora*
Planted fodder and forage species	*Thysanolaena maxima, Bauhinia variegata*
Planted aromatic herbs	*Cymbopogon martini, Cymbopogon nardus, Cymbopogon citratus*

Table 2:

Aromatic plantation status and number of planted seedlings in CFs

Species	Radhakrishna	Janajyoti	Nandeswor	Total Seedlings
Lemongrass	55,200	80,000	65,000	200,200
Citronella	55,900	78,000	35,000	168,900
Palmarosa	35,000	70,000	35,000	140,000
Total	146,100	228,000	135,000	509,100

Women's Empowerment through Setting Up Aromatic Herb Businesses

Growing medicinal herbs in community forests was the first step, but those products also needed a business to sell them. Three women-led community forest user groups (CFUGs), Radhakrishna with 13 women, Janajyoti with 20 women and Nandeshwor with 48 women, were formed after receiving an introduction to aromatic herb businesses and participating in a study tour. These women were trained in aromatic herb site preparation, planting techniques, plant harvesting, and the essential oil distillation process. They were also involved in the sale of aromatic herbs, and each community generated an income of USD 3,200 during the entire project period, respectively. In the first year after project completion, Radhakrishna CFUG added 13 more women, and earned USD 4,500. Janjyoti CFUG also generated an income of USD 4,000 in a year. For Nandeswor CFUG, they increased the planting area of aromatic herbs, added 12 other members to the group and earned USD 4,000. Other landless women generated income during their spare time by working in the lands provided by the CFUGs. In July 2017, a NTFP cooperative was registered in Sarlahi.

The Sunaulo Hariyali Aromatic Herbs Plantation Women Group of Radhakrishna CFUG made an agreement with the private company "Himalayan Bio-trade of Kathmandu" for producing and selling the harvested materials of the aromatic herbs and organic essential oils. Himalayan Bio-trade will facilitate getting organic certification, while the CFUG will support women groups to find available community forest land and establish distillation plants. Thanks to the additional training the women have also become more adept at managing an aromatic herb business. In fact, they are now much more independent and regard themselves as entrepreneurs with unique skill sets.

Achievements

Through APFNet's project support, women have improved their socio-economic status, strengthened their self-reliance and autonomy and have become entrepreneurs (Figure 32) collectively owning a MAP business. Major achievements include: 1) Established agroforestry systems generating diversified income sources for women; 2) First-time documentation of income and expenditure for the CFUGs; 3) Supplementary income generating programs started to promote disadvantaged groups in community forest through mobilization of CFUG funds; 4) Women in leadership positions in local-level organizations and cooperatives.

Figure 32: Establishment of an aromatic herb enterprise (Photo: Community Resource Management Centre, Nepal)

Case 3

Addressing Poverty in the Community through the Adoption of Agroforestry and Zoned Homegarden Technology

Project Title

Integrated Forest Ecosystem Management Planning and Demonstration Project in Greater Mekong Sub-region (Cambodia) **[2017P2-CAM]**

Executing Agency

The Institute of Forest and Wildlife Research and Development

Supervisory Agency

Forestry Administration, Cambodia

Budget in USD (Total/APFNet Grant)

1,792,663/1,515,465

Project Duration

06/2017–06/2021, completed

Site Location

Siem Reap and Takeo Province, and Damrey Chak Thlork Community Forest in Kampong Speu Province

Introduction

Both timber and Non-Timber Forest Products (NTFPs) are important sources of income for local people living in rural areas - second only to agriculture. About 183 community forest members in Damrey Chakthlork, located in Kampong Speu province, depend heavily on agriculture and their 1,452ha of forests for their livelihood. They use the forests to produce charcoal, collect firewood, cut timber for construction and gather various kinds of NTFPs. However, this has led to the loss and degradation of forest resources.

APFNet supported the Institute of Forest and Wildlife Research and Development to develop and test agroforestry methodologies that better support this community by providing more livelihood options to mitigate their dependence on the already degraded forest. Agroforestry farming systems and home gardens were selected as suitable ways since farmers already practiced farming and many already had low yielding home gardens. The main challenge was using improved techniques. Current techniques prevented farmers from using the land to its full potential, as on any given piece of land farmers only planted one type of crop or one tree species that provided them with a limited income. The project involved farmers who were interested and had land available to convert to sustainable agriculture and agroforestry using zoned multi-cropping systems.

Agroforestry Farming System

The agroforestry system was established on two farmers' private land of overall about 1ha, located next to the community forest. Previously the land was used for rice farming, but due to the lack of management and increasingly poor soil conditions, eventually only secondary shrubs without economic value grew there. In consultation with the land owners, the project helped to establish an alley cropping agroforestry system that intercropped high-value cash tree species such as macadamia trees, pomelo, cashew and vegetables. This system aimed to improve farm productivity and soil conditions by increasing soil organic matter and improving nutrient cycling. This agroforestry model was divided into three zones (Figure 33).

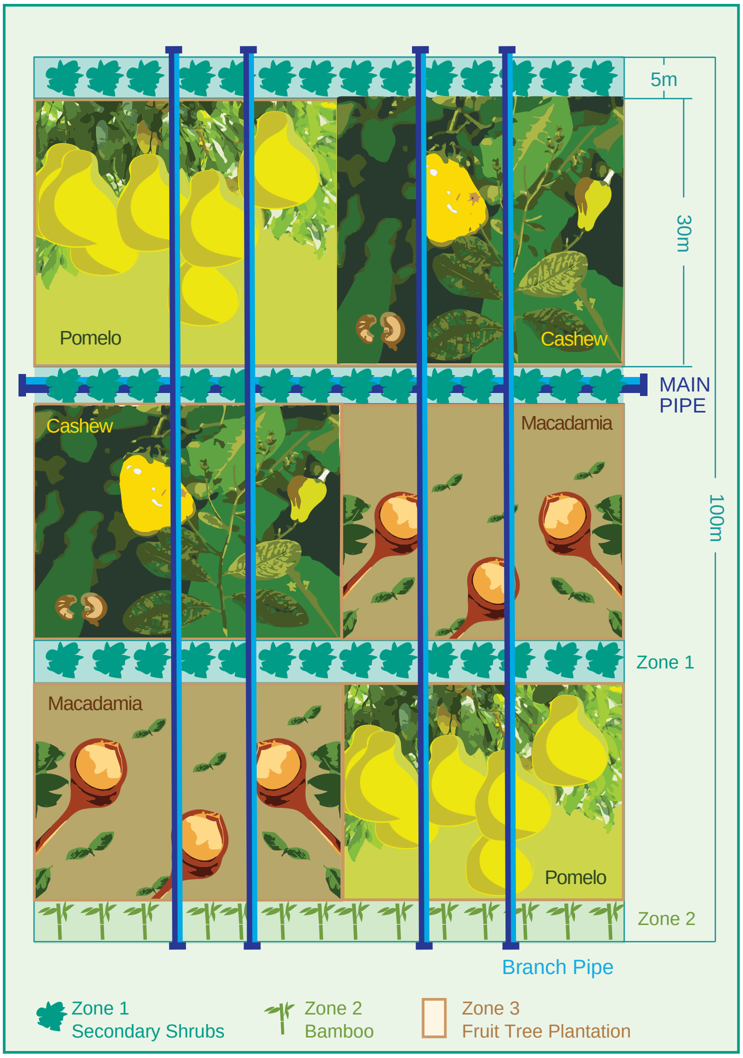


Figure 33: Zoning for agroforestry system with irrigation system

Zone 1 - Erosion Control Strips

Three strips, planted with secondary shrubs, were created to reduce water runoff and soil erosion. The width of these strips is 5m and the distance between each strip is 30m.

Zone 2 - Bamboo Border Control Line

This part was designed to separate the agroforestry system from the community forest downhill. Sweet bamboo (*Dendrocalamus brandisii*) is planted in this zone. The distance between each cluster of sweet bamboo is 5m and a total of 20 clusters were planted. Bamboo planting not only brings economic benefits to farmers, but also plays an important role in water and soil conservation, acts as a mitigating force against windstorms and stabilizes sand and loose soil.

Zone 3 - Fruit Tree Plantation

This is the main agroforestry area and is divided into 6 sub-areas (each area is 30m × 50m), separated by the erosion control strips. The recommended fruit and nut-producing tree species were macadamia, pomelo and cashew. The grafted seedlings of macadamia and pomelo were imported from China. These fruit trees were planted in a spacing of 5m × 4m and annual vegetables or agricultural crops were planted in the spaces of those alleys based on the farmers' preference and market conditions (Figure 34).

Figure 34: Farmers interplanting agricultural crops in Zone 3

Soil and Water Preparation:

The soil in this area is sandy and highly permeable. The surface layer is composed of <18% clay and >65% sand, the deeper layer is mostly dense soil. Such soil has different characteristics, such as low water storage, low fertility, and low pH, which are likely to limit upland farming systems for their sustainable use. Organic manure and compound fertilizers were applied to improve survival rates of the crops. During the dry season from November to May, there is insufficient water stored in the soil, so a water irrigation system and a water retaining agent (a non-toxic and harmless absorbent polymer material, which is composed of various absorbent resin and microelements, providing sufficient moisture and microelements for the growth of the plants) was installed on the site.

Zoned Homegarden Farming System

The site selected for establishing a zoned homegarden model was in the yard of a household (for a general description of homegardens, refer to Box 5). Homegardens are typically composed of two parts, the first being an open area and the second being a secondary forest that has often been degraded. It is common practice to retain some fruit trees and other tree species for household use. The new model of the zoned homegarden farming system makes full use of the farmer's land (Figure 35). This model also demonstrates the utilization of shade-tolerant plants underneath forest stands for multi-story management. The zones of this 0.5ha demonstration area are the following:

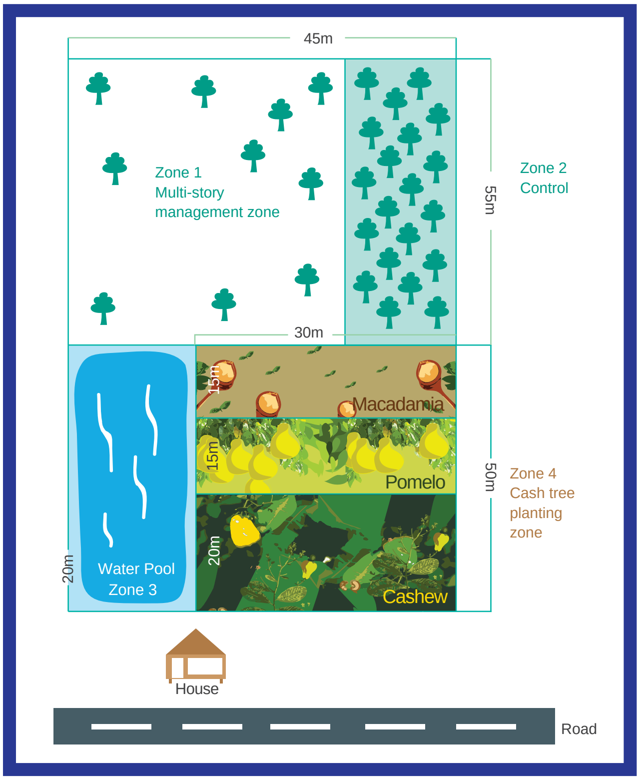


Figure 35: Design of the zoned homegarden

Zone 1 Multistory Management Zone

A multi-story management model was introduced in a degraded secondary forest covering approximately 0.25ha to improve biomass and economic benefits through thinning and intercropping with pepper vines (Figure 36). Originally, this area was a woodlot used by the farmer for firewood and timber for construction. Through this application, this woodlot area was transformed into an agroforestry system that provides a wider range of benefits, including agricultural and forest products. Shrubs, vines and unhealthy trees were cleared, valuable tree species, such as *Xylia xylocarpa, Pterocarpus macrocarpus, Shorea roxbourghii, Ochna integerrima, Sindora siamensis,* — those that were healthy, had a DBH greater than 3cm, and straight stems — were retained. Pepper, a perennial woody vine that can grow up to 4m in height when supported by trees, poles, or trellises, was selected for intercropping. It readily roots where trailing stems touch the ground and thrives under forest canopy, making it well-suited for multi-story management and capable of generating substantial income. Following thinning, pepper was planted close to the remaining trees, with a density of about 300 clusters (2-3 seedlings per cluster planted next to each tree), totaling around 900 seedlings. Decomposed dung and superphosphate fertilizer were applied in the hole before planting, followed by annual applications of manure and compound fertilizer. Normally it can provide fruit in the third year after planting, with a market price ranging from USD 10–15 per kilogram. One cluster of pepper can yield 4–6kg of pepper annually.

The remaining tree species will provide shade for the pepper and help conserve water and soil in the area.

Figure 36: Farmer planting pepper close to the tree so it can easily grow up the trunk

Zone 2 Control

0.1ha of the degraded secondary forest remains as control. The control plot was monitored every year to compare the environmental and economic differences with the multi-story management model.

Zone 3 Water Pool

This area contains a small water pool used to store water for the dry season to support irrigation of the homegarden.

Zone 4 Cash Tree Planting Zone

An intercropping model was applied in the open area using cash tree species including macadamia, pomelo and cashew. These trees were planted in different strips with a spacing of 5m × 4m (Figure 37). Macadamia and pomelo were planted on a 450m^2 plot (15m × 30m) using 22 seedlings for each species, while cashew was planted on a 600m^2 plot (20m × 30m) using 30 seedlings. Most of the trees were expected to bear fruit after 3 years.

The agroforestry and homegarden models were designed to generate quick income for the farmer by incorporating annual vegetables and crops. In the longer term, farmers could benefit from the cash trees. These new models demonstrated how to efficiently utilize farm space across multiple vertical layers to increase income, improve livelihoods, and serve as a reference for expansion to other households in the future.

Figure 37: The development of a homegarden in the open area at the backyard of a farmer's house

Case 4

Increasing Agricultural Production of Farmers by Intensifying Homegardens

Project Title

Reconstruction and Sustainable Management of Degraded Forests Based on the Combination of Inter Planting Nitrogen Fixing Rare Tree Species and Thinning
[2018P4-CAF]

Executing Agency

Experimental Center of Tropical Forestry, Chinese Academy of Forestry

Implementing Agency

Institute of Forest and Wildlife Research and Development, Cambodia

Budget in USD (Total/APFNet Grant)

503,000/378,000

Project Duration

01/2019–12/2021, completed

Site Location

Bos Thom Village, Khna Por Commune, Soth Nikum District, Siem Reap Province, Cambodia

Introduction

Poverty reduction remains a major challenge for the economic development of economies like Cambodia, where approximately 20.5% of the population lives below the poverty line (Cambodia Poverty Assessment, 2013). In Cambodia, 90% of the poor reside in rural areas and primarily depend on agriculture and forest products for their livelihoods. Promoting improved agricultural production and forest-based livelihood activities is a key strategy for reducing poverty and sustaining economic growth. However, this effort continues to face difficulties, as traditional practices often result in low yields, providing only enough for household consumption rather than for sale in the market.

In Bos Thom Village, Khna Por Commune, Soth Nikum District of Siem Reap Province, 99 families—comprising a total of 522 villagers—are living in poverty and primarily depend on agricultural production. Traditionally, rural households in this region live in wooden houses on small plots of land (typically less than 1ha, though wealthier families may own more), where they cultivate a variety of tree species, crops, and vegetables—commonly referred to as homegardens. However, these homegardens generally meet only the basic needs of the family.

By transforming these small plots into more productive homegardens, families can generate income rather than merely subsist. As part of the project, 10ha of homegardens were established as demonstration sites, involving approximately 15 households in the village.

Box 5

Homegardens

Homegardens are arguably one of the oldest forms of agroforestry and their history might reach as far back as 13,000 years. They have been defined as "intimate, multi-story combinations of various trees and crops, sometimes in association with domestic animals, around the homestead" (Toensmeier, 2016), and are considered a highly sophisticated form of agroforestry. In fact, homegardens exhibit some of the highest biodiversity levels among all man-made ecosystems and demonstrate significant carbon sequestration potential in agricultural systems. Unfortunately, in some regions, these homegardens have been reduced to a limited number of species, resulting in suboptimal yields and biodiversity levels (Figure 38 and 39).

▲ Figure 38: A typical house in the project area

▼ Figure 39: A traditional homegarden

In the project area, local people had traditionally planted fruit species such as jackfruit, orange, mango, and banana, combined with short-term crops like beans, eggplant, and cucumber in the yards of their homes. In order to increase both biodiversity and local income, the project supported farmers in diversifying and intensifying their homegardens by interplanting high-value timber species (e.g., *Dalbergia cochinchinensis, Pterocarpus pedatus*), as well as fruit species like banana, papaya, orange, coconut and cashew. These were integrated with short-term crops and the existing vegetation around their homesteads (Box 6). The farmers selected the crops based on their preference and market demand. This intervention provided an opportunity to improve the nutritional diversity of household diets, enhance carbon sequestration, and increase local biodiversity. As a result, the improved homegardens helped boost household incomes through the sale of surplus produce in local markets and served as a successful example for neighboring farmers to replicate on their own land.

Cheuy Buot's Path to Sustainable Income

Mrs. Cheuy Buot, a Bos Thom CF member owns 0.6ha of farmland in her backyard. She was previously cultivating a single crop of long bean under the canopy of a few tree species, such as *Hopea ordorata* and *Xylia xylocarpa*, from which she earned about 40,000 Riel per day (about USD 10). However, this income was insufficient to support her family, whereas a diversified homegarden could provide greater benefits within a short period of time. During the primary survey, she showed interest in intensifying her homegarden using techniques introduced by the project. She expected that she could grow various cash crops, fruit trees and high-value timber species such as *Dalbergia cochinchinensis* to increase her land's productivity—leveraging Dalbergia's nitrogen-fixing properties—and to generate more income (Figure 40).

Figure 40: Mrs. Cheuy Buot is willing to diversify her farm into a homegarden with the project's support

Box 6

4.2 The Promise of Agroforestry for Forest Restoration

In addition to improving livelihoods, agroforestry is often considered an effective tool to rehabilitate degraded forests. The following four projects showcase how a degraded hillside, an arid area in China, and a degraded watershed area in Indonesia were restored with site-specific agroforestry approaches. Monitoring within the project scope has shown the effectiveness of agroforestry both in improving ecological services and economic outcomes.

Case 5

Benefiting Farmers While Restoring the Hilly Areas of Southern China

Project Title

Demonstration on Sustainable Forest Management and Restoration in Hilly Area of Southern China
[2016P2-CAF]

Executing Agency

Research Institute of Forestry, Chinese Academy of Forestry

Implementing Agencies

- Forestry Department of Anhui Province, China through Qingyang Forestry Bureau,
- Forestry Department of Zhejiang Province, China through Lin'an Forestry Bureau

Budget in USD (Total/APFNet Grant)

1,410,207/695,207

Project Duration

10/2017–09/2019, completed

Site Location

- Qingyang, Anhui Province, China;
- Lin'an, Zhejiang Province, China

Introduction

The hilly areas of southern China, influenced by a subtropical humid monsoon climate, offer favorable conditions with high potential for supporting productive and biodiverse forests. However, due to rapid population growth from 554.4 million in 1950 to more than 1.3 billion in 2010[1], coupled with agricultural expansion and improper forest management practices, the degradation of forest resources in China has accelerated. The situation of forests in hilly areas of southern China is critical, as due to the steep slopes and high rainfall the land is more vulnerable and has a high risk of soil erosion.

In 2017, APFNet launched a project in collaboration with local forestry departments and bureaus in southern China, aiming to conserve and restore degraded forest ecosystems in representative hilly regions. Agroforestry systems have been demonstrated in Lin'an, Zhejiang Province, which receives around 1,613mm of precipitation annually, integrating Chinese hickory plantations to restore the ecosystem while enhancing local livelihoods. The predominant soil types are Ultisols and high-ridge moist Oxisols.

Chinese Hickory + Medical Herb Plantations

The demonstration site is a 3-ha Chinese hickory (*Carya cathayensis*) plantation, aged between 7 years and 14 years, situated on a slope of 29 degrees with an average soil depth of 62cm. Chinese hickory was planted at 4m × 5m spacing, so there are around 500 Chinese hickory trees per hectare. Due to the young age of the plantation, the canopy did not fully cover the ground, leading to soil erosion and reduced hickory nut yields. With the objectives of conserving the soil and increasing land productivity, two types of medicinal herbs, *Polygonatum sibiricum* and *Tetrastigma hemsleyanum*, which can enlarge the ground cover and have high economic values, were interplanted (Figure 41).

[1] Date sources: http://www.worldometers.info/world-population/china-population/.

Figure 41: *Tetrastigma hemsleyanum* planted underneath Chinese hickory (Photo: Chinese Academy of Forestry)

Polygonatum sibiricum was planted in 1-meter-wide strips under Chinese hickory, with 0.25×0.2m planting spacing, while *Tetrastigma hemsleyanum* was planted in blocks under the same trees. The estimated harvest time for both species is three years after planting. Weeding and fertilization were conducted annually in July and October. Farmyard manure was applied for *Polygonatum sibiricum*, whereas potassium carbonate was used for *Tetrastigma hemsleyanum*. Watering was carried out once 3 to 5 days after planting and subsequently only as needed. After three years, both species were fully harvested for their roots (Table 3, Box 7).

Table 3: Prospective costs and benefits of medicinal plants

Medicinal plant	Size (ha)	Estimated costs in 3 years (CNY)	Expected yield after 3 years (kg /ha)	Current unit price (CNY/kg)	Gross income (CNY)	Net income (CNY)
Polygonatum sibiricum	2.53	370,000	30,000	13	986,700	616,700
Tetrastigma hemsleyanum	0.4	120,000	11,250	80	360,000	240,000

Valuable Native Plants for Nutrition and Traditional Medicine

Chinese hickory (*Carya cathayensis*) naturally occurs in the deep mountains of southern China. It takes 10 years for a hickory tree to reach maturity and its height can be up to 20 meters. Hickory trees only bear fruit when they are mature and the nuts grow on top of the tree.

Chinese hickory nuts are considered a cherished gift by nature (Figure 42). The small round nut is rich in protein, amino acids and 22 trace elements needed by the human body. Peeled and roasted hickory nuts are served as snacks and are also used as an ingredient for candy and cake.

Figure 42: Chinese hickory nut

Polygonatum sibiricum is a perennial plant growing up to 1m high. It's a native plant used in Traditional Chinese Medicine (TCM) and has various uses associated with a number of its components. The root of *P. sibiricum* is fleshy, yellow-white, slightly flat round with several stem scars and is used medicinally (Figure 43). It is used in TCM to lower blood pressure, prevent atherosclerosis and fatty infiltration of the liver, as well as treating dry coughs due to chronic bronchitis, pulmonary tuberculosis, fatigue and poor appetite.

Figure 43: The root of *Polygonatum sibiricum*

Tetrastigma hemsleyanum is a perennial climber and is traditionally used as a folk medicine for the treatment of cancer (Figure 44). It stimulates blood circulation and relaxes the muscles. The root is used in the treatment of diphtheria, boils and ulcers, traumatic bleeding, snakebites, rheumatoid aches and pains in the back and legs.

Figure 44: *Tetrastigma hemsleyanum*

Box 7

Case 6

Fighting Desertification and Bringing Fruit to the Desert

Project Title

Demonstration Project of Vegetation Restoration and Management and Utilization of Forest Resources in Greater Central Asia (Chifeng sites)
[2016P3-INM]

Supervisory Agency

Chifeng Municipal Forestry Bureau

Executing Agency

Sanyijing State-owned Forest Farm, Aohan Banner

Budget in USD (Total/APFNet Grant)

744,000/500,000

Project Duration

01/2017–12/2019, completed

Site Location

Aohan Banner, Chifeng City, Inner Mongolia

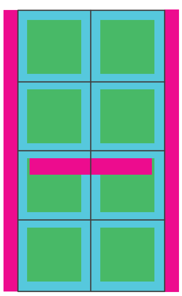


Figure 45: "Net" planting model of Pine–Yellowhorn–Melon

Introduction

In Aohan Banner, part of the steppe region of Inner Mongolia, growing vegetation has always been a challenge. Over the past decades desertification has threatened the area time and again, while people were fighting back with mixed results. In the context of this challenge, in 2017 this project set out to not only restore vegetation in areas threatened by desertification, but even go a step further and integrate multiple crops in the same area, showcasing new dryland agroforestry models.

Two different models were demonstrated, each combining the value of long-term timber production with short-term income from fruits and agricultural crops.

Pine – Yellowhorn – Melon "Net" Planting

On 40ha, a combination of Mongolian Scotch pine (*Pinus sylvestris* var. *mongolica*), the nut-bearing Yellowhorn (*Xanthoceras sorbifolium*) and watermelon were planted in a "net" structure (Figure 45). In this design, Mongolian Scotch pine was planted along the outer edges, forming a shelterbelt around the inner plantings of Yellowhorn and watermelon. Yellowhorn and watermelon were in the meantime evenly interplanted in the inner squares, with yellowhorn spaced at 2m × 3m and watermelon at 0.3m × 0.5m intervals (Figure 46).

Approximately 1,665 yellowhorn seedlings were planted per hectare. Drip irrigation tubes were laid in the demonstration site to supply water to both yellowhorn and watermelon plants. While watermelons were well adapted to semi-arid climates and relied on constant sunshine to produce sweet fruit, they still required a steady water supply until fruit development was complete. In contrast, yellowhorn (Box 8), being a drought-resistant species, required less water. Only the young seedlings were irrigated 3 to 5 times during their first year to ensure a high survival rate. The planting area was weeded twice annually in June and July, and fertilized with 7,500kg/ha of manure in March. No herbicides were applied.

Most yellowhorn trees began bearing fruit after three years. The pine trees are expected to be harvested after 40 years, once they reach a DBH of more than 30cm. With the given planting density, yellowhorn yielded approximately 1,200–1,500kg of fruit per hectare after three years. The trees entered their most productive phase in years 7–8 and are expected to continue fruiting for up to 30 years, producing an estimated 3,750–5,000kg/ha annually, generating up to USD 16,000/ha/year. Watermelon sales contributed an additional USD 4,400/ha/year. Since the land had been leased from local farmers, all income generated was returned to them.

Figure 46: Watermelons intercropped with Mongolian Scotch pine and yellowhorn

Yellowhorn (*Xanthoceras sorbifolium*)

Yellowhorn, despite its long history (even referred to by some as a “living fossil”), has remained an underappreciated NTPF. With increasing aridity threatening the survival of many species, the extremely drought-resistant and generally very hardy Yellowhorn—able to survive temperatures as low as -41°C and grow on both sandy and rocky soils—has become a key species in combating desertification while supporting local livelihoods.

Although it grows to a modest height of only 5 meters, this member of the soapberry family (the same family as maple and horse chestnut) produces large fruits containing 6–18 seeds (Figure 47), of which up to 70% of each seed can be made into oil. This oil then can be used as medicine for relieving pain and swelling, lubrication oil, or be made into paint, plasticizer or skincare products. Having such a potential for versatile products, the average price per 100ml of yellowhorn oil is around USD 15, which is likely to increase as the product becomes more well-known. Additionally, tea can be made from the tree’s leaves and flowers, offering another valuable byproduct.

Figure 47: Fruits of yellowhorn

Box 8

Poplar-Pine-Liquorice "Net" Planting

Traditional medicinal herbs have long enjoyed strong domestic demand, particularly Chinese liquorice (*Glycyrrhiza uralensis*) root. As one of the 50 fundamental herbs used in Traditional Chinese Medicine (TCM), liquorice is typically harvested in spring and autumn and then sun-dried. Although Chinese liquorice is traditionally a light-loving plant, it is capable of enduring the kind of partial shade often provided by an agroforestry system, while receiving the benefit of wind protection. To demonstrate this, a 30ha site was planted with Xinjiang poplar (*Populus alba* var. *pyramidalis*) in a net-pattern shelterbelt around alleys of Mongolian Scotch pine (*Pinus sylvestris* var. *mongolica*), which was planted at a spacing of 3m × 3m. Chinese liquorice was intercropped in two 0.5-meter-wide strips between the pine rows on a 1.33ha demonstration area (Figure 48). Irrigation pipes were laid in lines and used for watering the liquorice. The demonstration area was fertilized once in May with compound fertilizer and weeded three times in spring and summer. No herbicide was used on the site.

About 6,750kg/ha of dried liquorice roots were harvested in the third year after planting, generating an income of around USD 6,500/ha. Poplar and pine trees are expected to be harvested at around 20 years and 40 years, with an average DBH of 40cm and 30cm, respectively. The wood will mostly be used for construction and furniture.

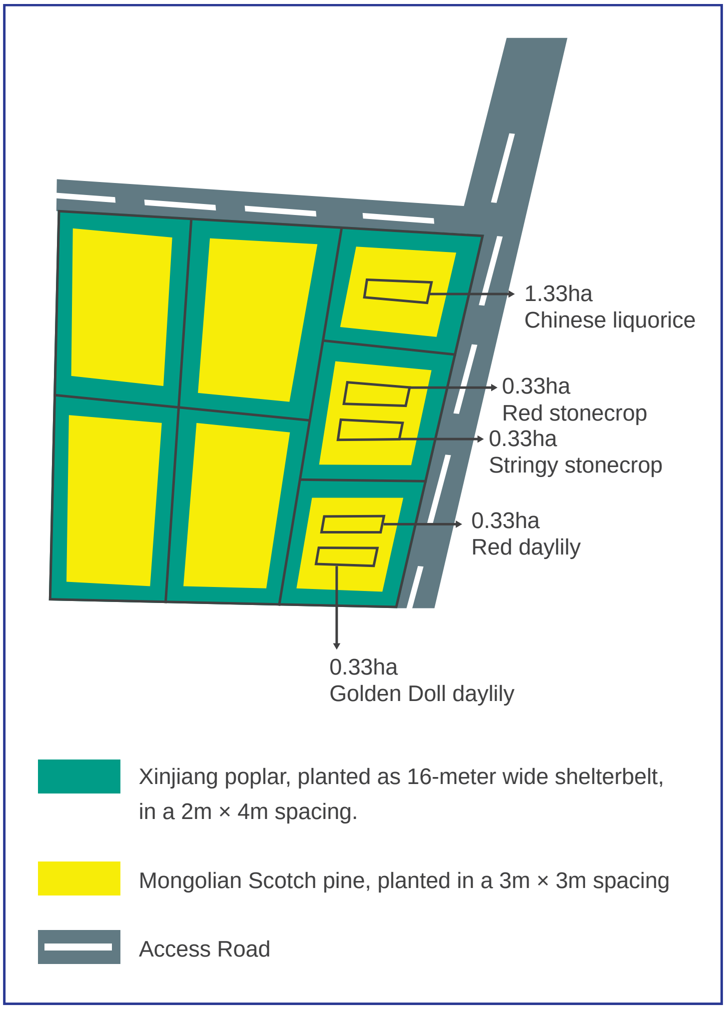


Figure 48. "Net" planting model of Poplar-Pine-Liquorice

Flower Variations

In a variation of the above model, instead of Chinese liquorice, a number of different flower cultivars, such as red stonecrop (*Rhodiola rosea*), stringy stonecrop (*Sedum sarmentosum*), red daylily (*Hemerocallis fulva*) and Golden Doll daylily (*Hemerocallis fulva* 'Golden Doll') were planted on 0.33ha sections, respectively. These flowers are expected to be sold for decorative purposes, retailing at about USD 14,000/ha.

Case 7

Forest Restoration through Extensive, Multi-Strata Agroforestry

Project Title

Integrated Forest Ecosystem Management Planning and Demonstration Project in Greater Mekong Sub-region (Pu'er Project Site, P.R.China)
[2016P1-GMS-PE]

Supervisory Agency

Pu'er Forestry and Grassland Bureau

Executing Agency

Wanzhangshan Forest Farm

Budget in USD (Total/APFNet Grant)

1,094,022/740,306

Project Duration

01/2017–05/2022, completed

Site Location

Simao District, Yunnan Province

Introduction

The Lancang-Mekong River is one of the largest rivers on earth and a biodiversity hotspot, while also playing an important role in promoting social development, water conservation, and agricultural production.

In part of the watershed in Yunnan Province, southern China, deforestation that occurred earlier in the 20th century has largely been addressed by government-financed reforestation programs. However, the focus on planting mainly fast-growing and economically valuable species in monocultures, has been described by Frayer et al. (2014) as a "tree cover transition" rather than a "forest transition". The current focus is now on improving the ecological functioning of those forests while simultaneously providing a greater diversity of products.

In 2017, in Pu'er, Yunnan Province, China, APFNet initiated a project with Wanzhangshan Forest Farm, a state-owned forest farm (see Box 9), to demonstrate that such multi-functional forest ecosystems are both ecologically and economically viable. The stated project goal was to establish a demonstration model of integrated forest ecosystem management and sustainable forest management in the upstream regions of the Mekong River, thereby improving the quality of forest ecosystems and promoting economic and social development in the GMS.

State-Owned Forest Farms

Box 9

China's state-owned forest farms were established through government investments shortly after the People's Republic of China was founded in 1949. Forest farms aim to manage and cultivate forest resources while also protecting and improving the natural environment. Most state-owned forest farms operate as public institutions and are financed by the government, while only a few operate as a form of enterprise in which their expenses are solely covered by their own earnings. The state-owned forest farms play an important role in China's forestry system. After more than 50 years of development, there are now 4,507 forest farms managing 40 million hectares of forest, which is about 23% of the total forest area in China.

The Wanzhangshan Forest Farm was established in 2001 and manages 19,133ha of forest. It is the only state-owned forest farm out of the 148 in Yunnan Province that operates as an enterprise without any financial support from the government.

While there are several different project activities targeting areas ranging from forest planning to general silvicultural measures, one of the methods used for integrated forest management is agroforestry. Based on recent developments in villages in Yunnan, where many farmers choose agroforestry for water conservation purposes and a lowering of required labor (as they often engage in migrant labor in larger cities), the agroforestry demonstration in the area primarily focused on ecological improvement.

A 5ha agroforestry plot in Simao Town is one of the demonstration sites. This plot is part of a secondary forest where high-value epiphytic species such as *Dendrobium nobile*, *Anoectochilus formosanus* and *Rhizoma bletillae*, have been planted. These species were also selected because of the potential medicinal products that can be extracted from them (see Box 10).

Box 10

Vascular Epiphytes

Vascular epiphytes are plants that grow on the surface of trees but remain physiologically independent. They play an important role and represent an important element of biodiversity in tropical and subtropical rainforests. Trunk planting with epiphytic plants provides a unique microclimate and habitat for other species. Epiphytes are known to be major contributors to vascular plant diversity, biomass, as well as nutrient and water cycling. These plants play a key role in the ecological functioning of certain ecosystems and they may even act as keystone species.

Vascular epiphytes are important components of tropical forests. While some farmers remove epiphytes to improve the main crop's production in agroforestry management, others in some South Asian economies consider trunk planting of epiphytes one type of “complex agroforestry system”. Vascular epiphytes have a long cultivation history in southern China, both trunk planting and understory planting.

The epiphytes were mostly planted on the ground and on the trunks of major tree species (*Pinus kesiya* and *Betula alnoides*) using transplanted tissue culture seedlings. The seedlings were sterilized before planting, and then cultivated on a special substrate. All the epiphytes were planted in December after the rainy season. For trunk planting, the density is 3–5 clusters per tree, about 4,200 clusters per ha. The seedlings were stabilized on the trunk using non-woven or wooden structures (Figure 49). Trunks selected for planting should have rough bark to facilitate the rooting of the seedlings.

Figure 49: Trunk planting using nails to fix epiphytes (left), close-up of trunk planting (right)

The project manager and staff visited the project site from time to time and conducted research on the understory plantings. They also visited other successful peer organizations in Pu'er, such as the Dendrobium Farm and Tianchang Biology Pharmacy Company to learn more about their experiences in understory planting. Wanzhangshan Forest Farm intends to collaborate with these organizations on the planting, collection, and production of high-value epiphytes (Box 11, Figure 50), which can demonstrate a successful model for achieving socio-economic value.

Box 11

Vascular Epiphytic Species Selected in Agroforestry

- *Dendrobium nobile* is one of 50 fundamental herbs used in Traditional Chinese Medicine (TCM), known as shí hú (Chinese: 石斛). It is also a popular cultivated decorative house plant since it produces colorful blooms in winter and spring (Lee et al., 1995).
- *Anoectochilus formosanus*, widely used in Chinese Taipei for treating many diseases such as diabetes, high blood pressure and tumors (Lin et al., 2000).
- *Rhizoma bletillae*, a famous Chinese medicinal plant, stops bleeding, nourishes the Yin of a person, cools heat, and preserves body fluids, as well as reduces swelling and promotes the regeneration of tissue (Song et al., 2013).

Figure 50: Trunk planting in APFNet Pu'er Base (Photo: Wanzhangshan Forest Farm)

Case 8

Agroforestry for Soil Erosion Control —A Case in Bengawan Solo Upper Watershed, Indonesia

Project Title

Development of Participatory Management of Micro Catchment at the Bengawan Solo Upper Watershed **[2017P6-INA]**

Supervisory Agency

Extension and Human Resources Development Agency, Ministry of Environment and Forestry, Indonesia

Executing Agency

Watershed Management Technology Center, Indonesia

Budget in USD (Total/APFNet Grant)

242,784/97,928

Project Duration

10/2017–09/2019, completed

Site Location

Naruan Micro Catchment, Wonogiri and Karanganyar Districts, Central Java, Indonesia

Bengawan Solo Watershed

The Bengawan Solo River is the longest river in the Indonesian island of Java, and its upper basin is facing serious soil erosion problems. The Keduang Watershed, located in the Upper Bengawan Solo Basin, is one of the major contributors of sedimentation in the Multipurpose Reservoir of Gajah Mungkur (MRGM). This has become a national issue, because the reservoir's capacity for flood control and water supply to downstream agriculture has been significantly reduced. Large-scale deforestation to open up land for agriculture happened in the 1930s and 1940s, which destroyed the natural forests in the upper watershed (Senin, 2009). Today, intensive farming of annual crops—mostly on privately owned, steep-sloped, and highly erosion-prone uplands—continues to exacerbate the problem.

Together with the Watershed Management Technology Center of Indonesia, APFNet set out to implement a project titled "Development of Participatory Management of Micro Catchment at the Bengawan Solo Upper Watershed". One component of the project was to demonstrate a sustainable agroforestry system in the Naruan Microcatchment (NMC), located in the Bengawan Solo Upper Watershed, to tackle the local soil erosion problem.

When it comes to addressing soil erosion, agroforestry is one of the most important land use systems for small scale agriculture in hilly areas (Wolde, 2015), as it has been proven to be effective in soil conservation, meaning the maintenance of soil fertility and erosion control. Soil fertility maintenance in agroforestry systems is achieved through the addition of organic matter, typically through litterfall and mulching, while erosion control is achieved through the mitigation of soil losses (Atangana, 2014). Agroforestry practices are widely used in the tropics for erosion control and include mixed cropping, multi-story tree gardens, alley croppings, and shelterbelts.

Assessment of Land Use Capability

In this project, the focus was placed on developing land capability assessments and agroforestry plans for each household. In order to develop a more suitable and comprehensive agroforestry plan, a Land Use Capability (LUC, Box12) assessment for the NMC area was conducted in the beginning. The LUC analyses shows that most of the NMC can be classified as high LUC classes, with 56% of the land classified as category Ⅵ and 42% as category Ⅶ. The higher the LUC class, the more limited the potential land uses. Land classified as LUC Ⅴ–Ⅶ is not suitable for conventional cropping; it is only appropriate for grassland, agroforestry, and forestry use.

Box 12

Land Use Capability

The Land Use Capability (LUC) system (Lynn et al., 2009) classifies different types of land according to its capability to support long-term sustainable production, taking into account the physical limitations of the land. These limitations include the overarching influence of climate; susceptibility to erosion; slope steepness; susceptibility to flooding; liability to waterlogging or drought; salinity; soil depth; soil texture; soil structure and nutrient supply. "LUC Classes I to IV are suitable for arable cropping (including vegetable cropping), horticulture (including vineyards and berry fields), pastoral grazing, tree crops or production forestry. Classes V to VII are not suitable for arable cropping but are suitable for pastoral grazing, tree crops, or production forestry, and in some cases vineyards and berry fields. Land use limitations reach their maximum with LUC Class VIII. Class VIII land is unsuitable for grazing or production forestry and is best managed for catchment protection and/or conservation of biodiversity" (Lynn et al., 2009).

Along with the LUC assessment, the soil erosion rate was also analyzed, and it can be concluded that the study area is vulnerable to erosion since the area is dominated by very steep slopes (>45%) with an annual precipitation of 2,979mm.

Combining 4 Categories in a Multistory Agroforestry System

The dominant land cover of the project site was originally seasonal crops (Figure 51). However, the LUC assessment found that due to the biophysical conditions of the NMC area, the site was not suitable for seasonal crops and is better suited to agroforestry or undisturbed forest. With support of the project, 30ha of agroforestry demonstration sites were established across three villages, involving around 60 households, to demonstrate sustainable agroforestry practices. The agroforestry system in NMC aims to:

- reduce soil erosion;
- increase land productivity;
- guarantee food security;
- generate additional income for farmers.

Figure 51: The sloping farm land in the study area has only few trees before the project intervention, resulting in a high erosion rate (Photo: Watershed Management Technology Center, Indonesia)

A detailed agroforestry plan for each household based on its specific land condition (especially the land slope) was developed through a participatory approach. The approach supported the community in deepening their understanding of their land's condition, including issues such as erosion, and in developing a plan on how to enhance it. Furthermore, the project encouraged local households to select trees and crops from the local species described in Table 4. The seedlings were provided for free. Additionally, the project gave specific suggestions on the planting patterns and combination of trees, crops, fruits and understory species. The trees were not only planted on the boundary but throughout the field with appropriate spacing, which also reduced soil erosion. Some of the species can provide short- and long-term benefits, increase income and thereby improve quality of life. At the end of the rotation (7 years), the average price of an Albizia log was USD 10.69/m^3, meaning the farmer's overall income from Albizia through agroforestry was USD 5,557/ha after 7 years. This number is higher than the revenue from seasonal crops, which was annually only USD 260/ha or USD 1,825/ha for the equivalent Albizia rotational period of 7 years. Sales of Albizia logs are done individually by the farm to local traders.

At the same time, soil erosion was reduced through conservation agriculture and agroforestry practices. Conservation agriculture involves minimal soil disturbance, year-round land cover, appropriate crop rotations, and improved water-use efficiency to reduce soil erosion, and increase crop production.

Table 4:

Common local species

Timber trees	Albizia (*Paraserianthes falcataria*)
	Limpaga (*Toona sureni*)
	Teak (*Tectona grandis*)
	Jabon (*Anthocephalus cadamba*)
Fruit trees	Avocado (*Persea americana*)
	Parkia (*Parkia speciosa*)
	Durian (*Durio zibethinus*)
	Cacao (*Theobroma cacao*)
	Mango (*Mangifera indica*)
	Longan (*Dimocarpus longan*)
	Breadfruit (*Artocarpus altilis*)
	Cempedak (*Artocarpus integer*)
	Coffee (*Coffea* sp.)
	Orange (*Citrus* sp.)
Crops	Maize (*Zea mays*)
	Cassava (*Manihot utilissima*)
	Tobacco (*Nicotiana tabacum*)
	Chili (*Capsicum* sp.)
Understory herbs and grasses	Ginger (*Zingiber officinale*)
	Turmeric (*Curcuma domestica*)
	Cardamom (*Amomum compactum*)
	Taro (*Colocasia esculenta*)

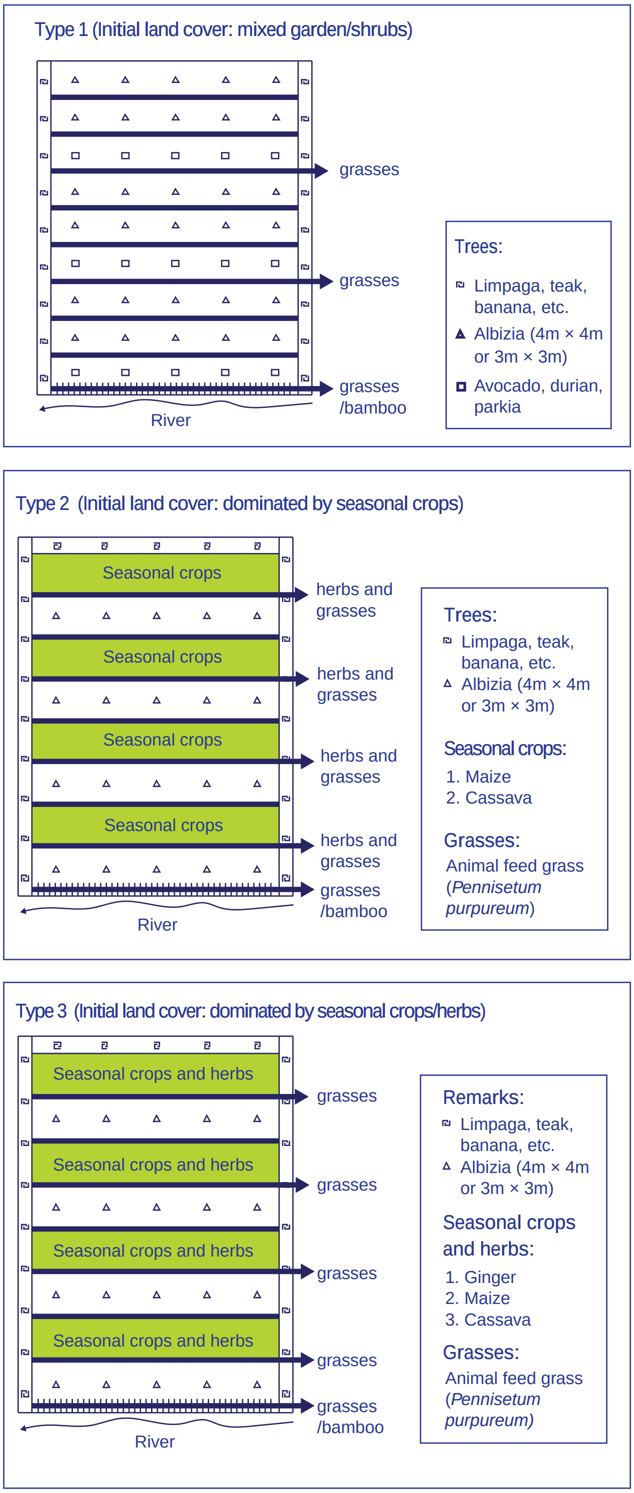


Figure 52: 3 types of agroforestry models chosen by farmers

In general, there were 3 types of agroforestry models chosen by farmers (Figure 52), each of which was different due to the initial land cover, namely 1) mixed gardens with poor woody plants and dominated by shrubs, 2) land cover dominated by seasonal crops, and 3) land cover dominated by both herbs and seasonal crops.

Mr. Sido RT is a farmer from Wonokeling village and has 0.8ha of farmland (slope 25%–45%, LUC IV), on which he traditionally grew maize and cassava on terraces (Figure 53). Years of intensive seasonal cropping have resulted in severe soil erosion and the formation of gullies on his land, and the yields have constantly declined. The timber tree albizia, as well as the fruit trees parkia, durian and avocado (the ratio of wood tree and fruit tree is 60:40), were planted evenly mixed in approximately 4m x 4m spacing. The spacing was not rigid to consider the existing plants. Albizia is important since it is a fast-growing pioneer species that can improve land fertility through its nitrogen-fixing abilities. It also decreases erosion on slopes, provides fodder for chickens and goats, acts as a shade and nurse crop and supplies timber in the long term. The fruit trees can also improve soil condition, increase land productivity and generate extra income for farmers in the short term. Additionally, herbs and grasses like ginger, turmeric and cardamom were planted in even spacing along the borders and understory for soil conservation and fodder use. In the understory, they were cultivated until the canopy grew too dense and thus too little light remained, which was about 3–4 years.

Figure 53: One month after planting, from left to right, the species are albizia, avocado, durian and parkia (Photo: Watershed Management Technology Center, Indonesia)

4.3 Research in Agroforestry

Aiming to promote more effective agroforestry practices, APFNet collaborated with two research institutes in Chinese Taipei and Cambodia to examine the effectiveness of different agroforestry models in controlling soil erosion. Although the conditions in the two locations differ, both partners recommended preferred approaches that agroforestry farmers should adopt in their future practices.

Case 9

Research on Sustainable Upland Agroforestry Systems in Chinese Taipei

Project Title

Demonstration of Sustainable Upland Agroforestry Systems in Chinese Taipei
[2011P1/6-CTN]

Executing Agency

Taiwan Forestry Research Institute, Chinese Taipei

Budget in USD (Total/APFNet Grant)

400,000/263,000

Project Duration

09/2011–08/2013, completed

Site Location

1) Pinglin; 2) Yuchi; 3) Kalala, Chinese Taipei

Introduction

Chinese Taipei is rich in forests, with about 58.5% of its land covered by forest. Many of these forests are located on rugged terrain in the uplands. In past decades, some of these uplands have been converted to agricultural use, often resulting in detrimental environmental effects such as soil erosion and landslides. Convincing farmers to restore forest cover, however, has been difficult both due to the lack of short-term economic income and unfavorable environmental regulations.

Together with the Taiwan Forestry Research Institute (TFRI) and the Forestry Bureau of Chinese Taipei (TFB), APFNet set out to demonstrate sustainable agroforestry systems and sustainable agroforestry practices for upland areas in Chinese Taipei. This included developing a new system to classify forest land and thus identify suitable agroforestry sites to demonstrate different agroforestry models, and develop a series of criteria and indicators to assess the sustainability of existing agroforestry sites. Finally, a set of recommendations for improving agroforestry practices was developed.

Political Constraints

Although the administration in Chinese Taipei encourages farmers to restore their surrounding environment, for example by providing free seedlings, agroforestry sites often do not qualify for these incentives, as one of the requirements is that no agricultural crops are allowed when a site is marked for “reforestation”. This regulation effectively disincentivizes farmers from adopting integrated systems. One of the goals of the project was to show the administration that making such regulations more flexible could be beneficial for all parties.

Additionally, agroforestry is not permitted in publicly owned forest areas. This restriction prevented the original project plan to set up study sites showing potential positive environmental impacts of agroforestry systems on these types of lands.

Land Assessment

The evaluation of the proposed areas for agroforestry, as well as the assessment of the performance of existing agroforestry systems, is crucial to develop stronger and more suitable agroforestry systems in the future. Accordingly, the project implemented two key approaches: the development of a forest land classification system and the creation of a set of criteria and indicators to determine the sustainability of existing agroforestry systems.

Forest Land Classification and Zoning

Agroforestry is not suitable on all land types, as on some sites the slope may be too steep, while on others the soil may be too degraded to expect any form of agricultural output.

TFRI assigned soil types and depths (Table 5) a "soil score" ranging from 1 to 5 (green), and divided slope degrees into scores from 1 (gentle slope) to 6 (steep slope)(orange). These values were then multiplied in a matrix for classification, which resulted in the Land Use Classes (Table 6).

Table 5: Classification of soil and slope

Soil / Slope	(5) Very deep >90cm	(4) Deep 50–90cm	(3) Shallow 20–50cm	(2) Very shallow <20cm	(1) Exposed parent material or recent landslide
(6) <5%	I (30)	I (24)	II (18)	III (12)	IV (6)
(5) 5-15%	I (25)	II (20)	II (15)	III (10)	IV (5)
(4) 15-30%	II (20)	II (16)	III (12)	III (8)	IV (4)
(3) 30-40%	II (15)	III (12)	III (9)	IV (6)	IV (3)
(2) 40-55%	III (10)	III (8)	IV (6)	IV (4)	V (2)
(1) >55%	IV (5)	IV (4)	IV (3)	V (2)	V (1)

Note: In parentheses are the multiplied points from slope and soil for the resulting classes: Class I: 21-30 points (pts); Class II: 13-20 pts; Class III: 7-12 pts; Class IV: 3-6 pts; Class V: 1-2 pts.

Once the land had been classified, certain factors could still disqualify a site entirely, such as its wildlife or conversation habitat value, its proximity to road systems and the mountain communities themselves and the interest or willingness of farmers to engage in agroforestry in the first place.

Furthermore, any trees used in sloped agroforestry systems should be deep-rooted. Based on these basic recommendations, more detailed guidelines were developed for the specific species grown in the respective sites.

Table 6: Classification of Land Use

Class	Land Use
I	Agroforestry system, >70% grass cover, **no slope stabilization engineering necessary**
II	Agroforestry system, >70% grass cover, slope stabilization engineering: **hillside ditch**
III	Agroforestry system, >70% grass cover, slope stabilization engineering: **bench terrace**
IV	Agroforestry system, planting >600 trees/ha, no fruit trees; if 600 trees can't be planted evenly, **contour planting** of the remaining trees along the bottom edge to establish a **forest buffer strip** for the protection of soil and water
V	No agroforestry, set aside for conservation

Criteria and Indicators for Agroforestry Systems

Based on the collected data and reviewed literature, a set of criteria and indicators was developed to evaluate the site-level sustainability of agroforestry systems. These criteria can be subdivided into 3 areas: social, environmental and economic. A selection of indicators is listed below in Table 7.

Table 7: Selected Indicators

Social	Environmental	Economic
Population density	Change in biodiversity	Area of organic cultivation
Number of people returning to the village from city	Tree/agricultural crop coverage ratio	Area of agroforestry land
Structural change in population	Water supply	Change rate from agriculture to agroforestry
Civil participation in agroforestry	Landslide area/ratio	Labor productivity index
Financial support in promoting agroforestry	Degree of erosion	Subsidies for green production/Payments for Environment Services (PES)
Technical support	Greenhouse gas emissions	Production value of agroforestry
	CO_2 sequestration	Annual income per person/household
	Pesticide use/ha	Ratio of low-income families
	Fertilizer use/ha	Visits from eco-tourism

At the time of project completion, these indicators were still considered preliminary and remained subject to further discussion with communities and decision makers in terms of whether and how they could be used at the national level.

Demonstration of Agroforestry Systems

The project established three demonstration agroforestry systems in Pinglin, Yuchi and Kalala, respectively. Two of these systems involved betel nut, while one focused on tea, representing agricultural crops that are commonly grown in the region (Figure 54).

Betel nut plantations

Betel nut (*Areca catechu*) plantations are ubiquitous throughout Chinese Taipei. In 1997, betel nut production covered an area of 56,542ha and generated an annual income of USD 400 million, accounting for 4.2% of the total value of all agricultural products in the economy. The crop was particularly attractive due to its high profit margins, low production costs and the strong market demand. While in recent years the market price for betel nuts has decreased, a lot of farmers are still relying on the crop, but are now seeking ways to supplement their income.

Figure 54: Betel nut agroforestry systems

On steeper slopes, conventional betel nut plantations are associated with high levels of soil erosion, due to their relatively low crown cover, as well as low soil organic content and poor soil porosity. This has sparked concern among the public and conservation groups regarding its negative hydrological impacts. Agroforestry has been suggested as a potential solution to the erosion problem, and the assessment of hydrological impacts of different agroforestry solutions has been at the core of this project. In order to assess the hydrological effects and determine the best approach, betel nut plantations were interplanted with other species in three different treatments: no thinning, thinning and clear-cutting. Surface runoff and soil loss were measured afterwards. Generally, if possible, betel nuts should be planted on flat terraces, while the slopes themselves are more suitable for tree interplanting. In Yuchi, the plantations were located at about 750m above sea level while in Kalala, they were situated at 200m.

Model 1: Betel nut + Stout camphor tree

The stout camphor tree (*Cinnamomum kanehirae*) is an endangered native species in Chinese Taipei. It was overharvested for many years because it serves as the host for *Antrodia cinnamomea* (Figure 55), one of the most valuable brown rot fungi in the world. It is a broad-leaf evergreen tree that grows at altitudes between 450m and 2,000m in low-elevation mountainous terrain.

Figure 55: *Antrodia cinnamomea*

Antrodia cinnamomea is a rare medicinal mushroom, used by indigenous people, and well-known for its ability to heal health conditions, particularly in treating liver conditions and cancerous growths. It is also believed to improve metabolism, strength, and longevity, as well as combat fatigue. It is only found in Chinese Taipei and grows slowly in the rotting inner trunk cavities of the rare, indigenous, endangered camphor tree *Cinnamomum kanehirae*. This peculiar combination of slow growth and host-specific requirements makes this mushroom one of the highest priced food items in the world with prices up to USD 5,000 per kilogram. Nowadays, these mushrooms can also be cultivated artificially, which has significantly reduced the harvesting pressure on *C. kanehirae*.

Agroforestry Recommendations

Betel nut palms can be used as a nurse crop for *C. kanehirae*, which can be planted beneath them once the palms have been thinned down from their original density. That being said, in this project it was first tested which approach—no treatment, thinning or clearcut—would yield better results. The findings clearly showed that from an environmental and hydrological perspective, completely replacing the plantation with a different species would worsen the erosion problem. If replacement is desired, gradual removal of the existing trees may be more appropriate. No treatment, while not yielding negative results for the hydrology of the site, was not recommended as without thinning it is harder for *C. kanehirae* to grow underneath the betel palm crown.

C. kanehirae can grow as high as 2 meters within two years, meaning that the primary maintenance requirements for the agroforestry system occur during the first year.

Model 2: Betel nut + coffee + Taiwanese camphor tree

The Kalala study site, located 200m above sea level, is an aboriginal village where the A-mei tribe lives. One of their main sources of income is the sale of coffee, making the integration of coffee into a multi-cropping system a natural and intuitive choice. Taiwanese camphor (*Cinnamomum osmophloeum*) was interplanted, and on one site *Ficus pumila*, known as jelly fig and an endemic species in Chinese Taipei, was used as well.

Agroforestry Recommendations

Similar to the study site at Yuchi, portions of the betel nut plantations at Kalala were left unmodified, with coffee and *C. osmophloeum* interplanted. Some sections were thinned before interplanting, while some were completely clear-cut. Afterwards, surface runoff and soil loss were measured. Partial thinning proved to be the most effective solution.

Model 3: Tea + Stout camphor tree

In Pinglin, a town very famous for its tea in northern Chinese Taipei, the landowners agreed to interplant *C. kanehirae*. Due to erosion issues, some old tea trees needed to be replaced, and the general decrease of the tea price further encouraged farmers to explore alternative options. *C. kanehirae* trees were interplanted at different densities: 2m × 1.5m, 3m × 3m and 4m × 4m (Figure 56).

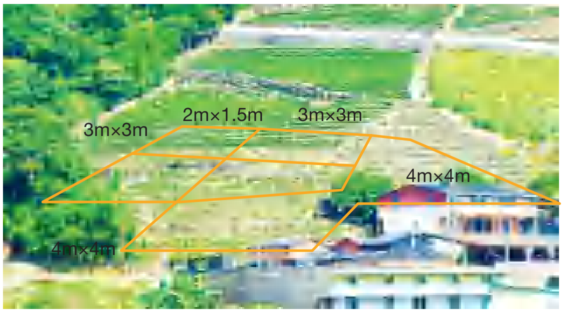


Figure 56: *C. kanehirae* was interplanted at dierent densities

Figure 57: Planting patterns of *C. kanehirae* and tea

Agroforestry Recommendations

In general, a spacing of 600 trees/ha—roughly corresponding to the widest spacing tested—is preferred if the trees are distributed evenly across the area. However, on steeper slopes or in less accessible locations a tighter spacing can be used on the bottom edge of the area to establish a forest buffer strip. For bench terraces, as described earlier, it is especially important to maintain more than 70% grass cover.

If bench terraces are not present, trees should be planted in patches or along contour strips throughout the area. In such cases, the distance between contour planting strips should be less than 10 meters (Figure 57). The same rules regarding the lower forest buffer and grass cover apply.

Additional Recommendations

A number of universal findings came from all sites, and are listed below:

- Alley cropping (with trees on slopes) is the most stabilizing form of intercropping. Alleys should be planted along the contour (i.e., horizontally to the slope) and spaced approximately 10 meters apart.
- Intercropped trees should be deep-rooted to enhance soil stability and reduce erosion.
- Grass cover should be established on bare ground and should exceed 70% to effectively control runoff and soil loss.

Case 10

Using Agroforestry Demonstration Sites to Monitor Soil and Water Conservation on Agriculture Land

Project Title

Landscape Approach to Sustainable Management of Forests in Prek Thnot Watersheds
[project ID: 2015P1-KHM]

Supervisory Agency

Ministry of Agriculture, Forestry and Fisheries

Executing Agency

The Institute of Forest and Wildlife Research and Development

Budget in USD (Total/APFNet Grant)

573,015/499,215

Project Duration

01/2015–06/2021, completed

Site Location

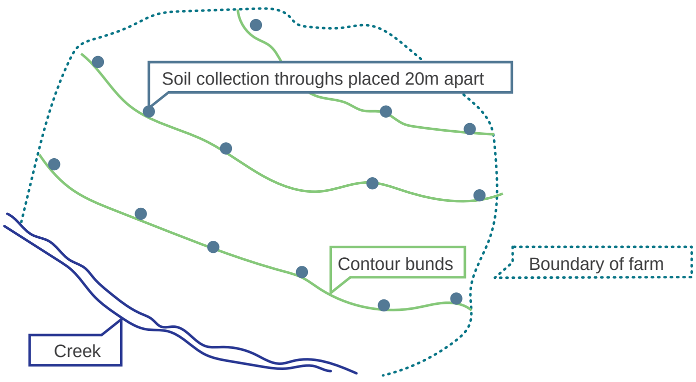
Prek Thnot Watershed, Kampong Speu Province, Cambodia

Introduction

Agriculture is identified as a major income among the Cambodian people, especially people living in Prek Thnot watershed where the area is a source of rice and other cash crops. The geology of the watershed is dominated by pediments covered with poor soils, primarily red-yellow podzols with low fertility. Farmers in the area have traditionally cultivated their crops without considering the impact on the watershed's ecological services. Meanwhile, land use changes, forest encroachment and other activities have contributed to negative effects such as soil erosion, nutrient depletion, reservoir sedimentation, and flooding in low-lying downstream areas.

To address these challenges, the Institute of Forest and Wildlife Research and Development (IRD), with support from APFNet, launched a project aimed at improving agricultural practices in ways that enhance both watershed ecosystem services and socio-economic development. The project also sought to demonstrate agroforestry as a practical tool for soil and water conservation. The project introduced those tools to farmers in order to minimize the harmful impacts of cultivation by preventing topsoil erosion while increasing farm productivity.

In the Trapeang Chour and Krang Deivay Communes in Prek Thnot Watershed, agroforestry plots totaling 2.31ha were established in four farmers' fields located on a sloped land close to a stream. A number of soil and water conservation techniques were tested. The project supported the farmers by providing seedlings, crops, and other materials, along with technical knowledge and skill-building through training programs and field-based practice. Through theoretical and hands-on training, the farmers learned how to design agroforestry plots and use soil and water conservation techniques on their farms. The sites were terraced using an A-frame, a simple tool for laying out contour lines across a slope, which will eventually help to retain topsoil and slow surface runoff (Figure 58).



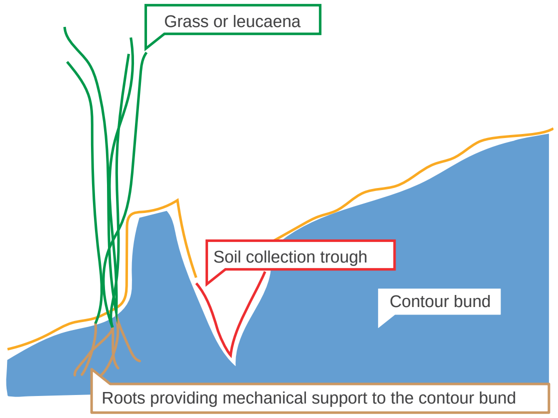


Figure 58: A layout of contour lines in the agroforestry plot (left); a design of the contour bund and the set-up of soil collection troughs (right)

Soil and water control measures included contour canals planted with hedgerows (Figure 59), as well as fascines (bundle of twigs), which are effective in controlling runoff on fine sandy soils. Some farmers planted lemongrass to stabilize the contour bunds (Figure 60). The canals were intended to collect topsoil eroded from the upper slopes by using collecting troughs, while rain collectors were also installed on-site for estimating the amount of rainfall received in the area. A small mound or bund was built along the lower rim of each canal to help retain additional water during heavy rainfall.

Figure 59: Farmers used an A-Frame to develop contour lines

Figure 60: Planting lemongrass on contour lines

Figure 61: Agroforestry research plot

Figure 62: Collecting soil erosion measurements

With the assistance and technical support from the project, the farmers adopted a technique called tree intercropping, which integrates timber trees, fruit trees and annual crops within the same area (Figure 61). Farmers selected high-value timber tree seedlings such as *Dalbergia cochinchinensis, Pterocarpus macrocarpus, Dipterocarpus alatus, Hopea odorata, Albizia lebbeck,* and *Moringa oleifera* to plant combined with perennial fruit species (mango, jackfruit, banana, papaya), seasonal crops (lemongrass, pineapple, cassava), and vegetables. Those selected trees and crops were based on the farmers' specific interests and household consumption needs. The fruit trees were primarily planted along farm boundaries and underplanted with cash crops such as ginger, pineapple and galangal, while seasonal crops and vegetables were interplanted to diversify agricultural production. The farmers preferred to plant native tree species on the plot boundaries to help restore valuable timber species that have been lost in their forest area.

The project engaged farmers in monitoring soil erosion and rainfall on their farm, so they could understand the importance of the soil and water control measures (Figure 62). Along the contour canals, soil traps were installed to collect eroded soil, while rain collection jars were placed in the fields to measure rainfall. The data was collected by farmers every month. The goal of this research was to raise awareness amongst the farmers about the amount of soil lost and deposited to the waterways when land is cultivated without appropriate soil and water control structures. In addition to demonstrating that soil and water conservation measures can effectively reduce soil erosion, the use of soil traps also provides a quantitative estimate of the extent of erosion that such measures can prevent.

After practicing the agroforestry techniques and soil and water conservation measures on their farmland, all participating farmers reported that these practices were beneficial to them. Even after just a few rainfall events, farmers observed that the contour canals and fascines were able to trap a considerable amount of nutrient-rich topsoil (Table 8), which otherwise would have been lost.

Table 8: Summary of soil properties

Soil properties	Location in the agroforestry plot		Difference	Remarks
	Outside contour canal	Inside contour canal		
Soil acidity (pH)	7.65	6.57	-1.08	Lower
Organic matter (%)	2.92	313.00	310.08	Significantly higher
Carbon (%)	1.70	1.82	0.12	Increased
Nitrogen (%)	0.16	0.17	0.01	Increased
Phosphorus (%)	0.044	0.045	0.001	Improved
Potassium (%)	0.96	1.44	0.48	Improved

Throughout project implementation, the farmers worked with the project team to analyze soil erosion from their fields. The results indicated that the average soil erosion in the Krang Deivay and Trapeang Chour communes were 14 and 32 metric tons per hectare per year, respectively. The results also showed a significant increase in economic benefits compared to the baseline when using the new techniques. The agroforestry products were primarily used for household consumption rather than for sale, with some of the products also shared with neighbors and relatives. Although the amount of sales was small at times, the ability to harvest a variety of fruits and vegetables from their farms significantly reduced living expenses (Figure 63).

Figure 63: Pineapple was interplanted with other crops in an agroforestry plot

Besides helping to reduce soil erosion, agroforestry has contributed to the economic welfare of the project beneficiaries. All four farmers involved in the demonstration confirmed that their income had increased. Mr. Siv Lim earned a total amount of USD 204 in 2018 compared to only USD 81 in 2016 (Table 9). With the additional income, he was able to purchase a new smartphone and send his daughter to primary school. Similarly, Mr. Men Vorn stated that his increased income enabled him to support his daughter's education, who is also in primary school. The third farmer, Mr Kim Chap stated his income had improved since adopting the new techniques and he had saved enough money to build a new house (Figure 64). The last farmer, Mr Kim Mao was able to buy a new motorcycle, which he uses for local trasportation.

Table 9: Income of four famers

Farmer	Land size (ha)	Total benefit (USD/year)	
		2016 (Baseline)	2018
Siv Lim	0.5	81	204
Men Vorn	0.8	80	203
Kim Chab	0.21	296	395
Kim Mao	0.8	119	179

Figure 64: Farmer Kim Chab showing various kinds of crops such as banana, pineapple and soursop on his agroforestry farm

Conclusion

Based on the clear evidence from this demonstration project, agroforestry measures reduced soil erosion and caused positive socioeconomic changes to individual households. These changes include reduced erosion and runoff, improved land productivity, and lower household expenses, which together have contributed to increased income. Agroforestry as an effective approach for soil and water conservation has been adopted among farmers to address soil erosion on agricultural land.

5
Conclusion

5.1 Achievements

Over the past 15 years, APFNet has worked together with policy makers, researchers, and farmers to improve resilience and livelihood through agroforestry in the region. The implementation of APFNet's agroforestry projects has had important impacts, and has received much positive feedback.

APFNet projects provided agroforestry solutions for livelihood improvement, such as 1) diversifying incomes from rubber plantations for local farmers; 2) empowering Nepalese women to improve their income and social status by helping them establish understory herbal aromatic species agroforestry systems and supporting them to start their own businesses; 3) addressing poverty through the introduction of zoning techniques in agroforestry plots that maximize production on a small pieces of land; and 4) reducing poverty while maintaining economic growth through intensifying homegardens.

Furthermore, these APFNet projects provided showcases for how agroforestry can be used in forest restoration, such as 5) to decrease soil erosion by planting medicinal herbs under Chinese hickory in hilly areas of southern China; 6) to combat desertification by planting the drought resistant species yellowhorn and other local species; and 7) to improve biodiversity by planting epiphytes on tree trunks.

Finally, a number of projects focused on researching agroforestry systems as much as on using them to achieve the above mentioned goals, for example 8) the land use capability of different areas was assessed through a locally adapted framework to develop a multi-story agroforestry system that will reduce erosion and improve long-term land productivity in Java, Indonesia; 9) in Taipei, an assessment system for proposed agroforestry plots and set of criteria and indicators to evaluate the performance of existing agroforestry system, which are crucial to develop stronger, more suitable agroforestry systems in the future, have been developed; while in Prek Thnot Watershed, Cambodia; and 10) in Prek Thnot Watershed, Cambodia, an agroforestry model to monitor soil and water indicators while convincing farmers of the importance of protection measures was developed.

5.2 Opportunities and Challenges

Each of the projects has taught different lessons, with as many opportunities as challenges. As the international community combines efforts to combat climate change, reduce poverty, and conserve biodiversity, agroforestry–with its high potential to provide multiple benefits and more sustainable land use options–offers significant opportunities.

As mentioned earlier, agroforestry does not deliver a one-size-fits-all solution. Agroforestry practices vary considerably from economy to economy, even from site to site, depending on the socio-economic and ecological circumstances. Here, however, lies the beauty of the practice as agroforestry often incorporates local practices into the system, it tends to be viewed less as something entirely new and more as an improvement, or alteration, of existing practices, making it more acceptable to local communities. The intensification of homegardens is a great example of this. Of course, to broaden its implementation these improvements also need to be disseminated to a wider audience through exchange visits, training and easily available materials.

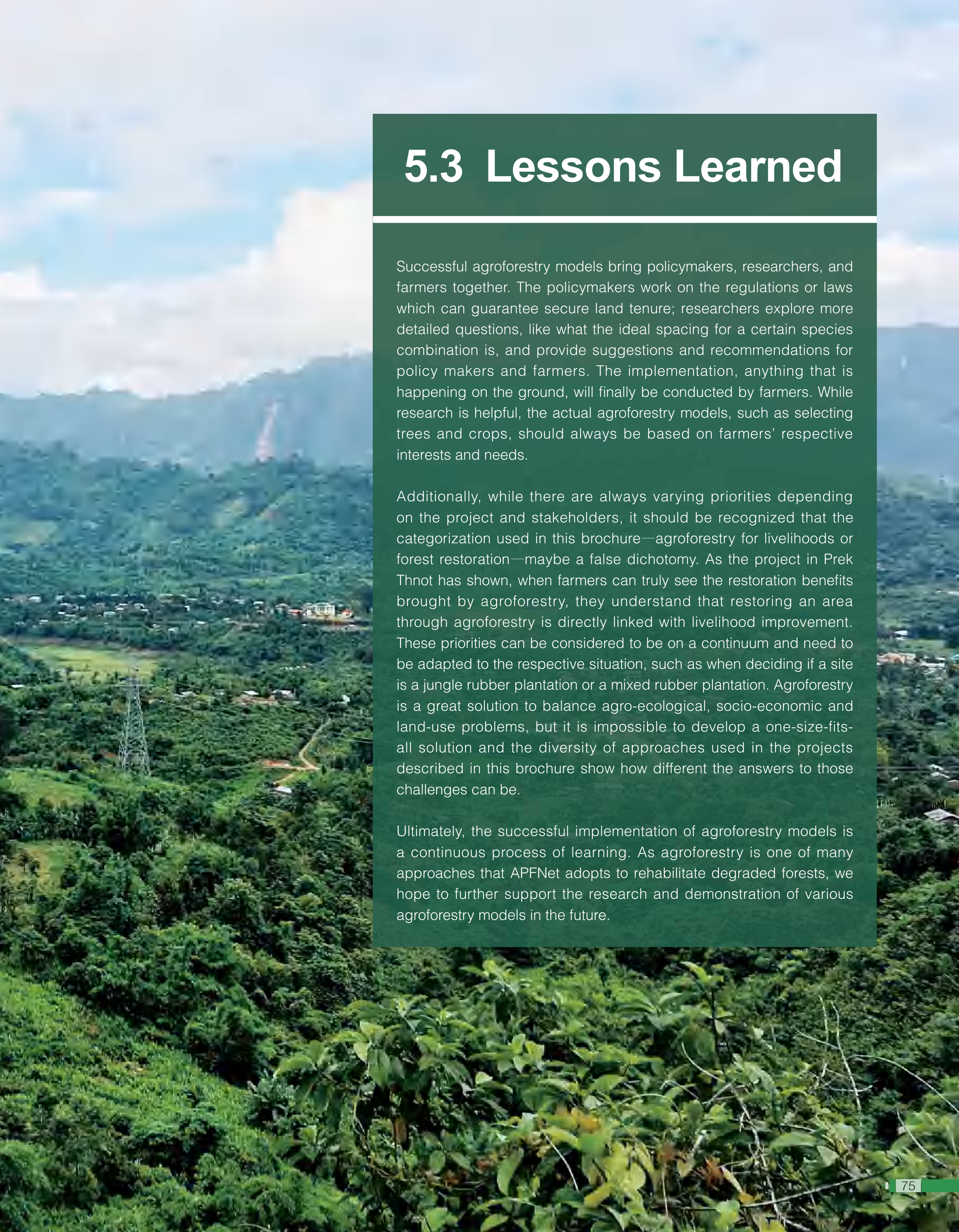
The participatory approach is vital in all stages of an agroforestry-related project to engage multiple stakeholders across all relevant sectors. Establishing strong networks between stakeholders is a great opportunity to further facilitate a living practice. By strengthening cooperation and enabling active community participation, while respecting community rights and including their traditional knowledge into agroforestry design and planning, the resulting agroforestry models can reach a whole new level.

On a practical level, in areas where poor soil conditions and water scarcity may limit productivity for farmers, agroforestry can be a useful approach to improve yields. The same applies in the case of limited space: producing crops in three dimensions–by using vertical space, as in agroforestry systems–can often surpass that of two-dimensional farming systems, which is typical of traditional agriculture. In fact, the simultaneous improvement of overall land productivity, biodiversity, soil health and household income should be considered the greatest opportunity agroforestry can provide.

While there are many opportunities, a number of challenges remain: for example, many projects did include a monitoring component, but a systematic monitoring framework is still far from being established, often limiting farmers in the amount they can learn from their own practices. There are also questions on a larger scale, such as how agroforestry contributes to carbon sequestration. First insights have shown that, particularly in arid areas, agroforestry systems have the potential to become a carbon source, rather than a carbon sink and further research is needed to determine in which situations this is the case and how it can be mitigated or avoided (Toensmeier, 2016).

Without that clear data, it is also sometimes hard for farmers to understand the significance and potential benefits of agroforestry. Agroforestry systems often need a few years to exceed the yields of traditional agricultural systems, an amount of time not all farmers are willing to wait, especially if the effects of erosion are not felt too severely. On the other hand, if agroforestry provides only secondary income, many farmers regard agroforestry systems and the necessary learning as too troublesome and rather invest their time in things that can provide immediate income. This is even more complicated in the case of agroforestry “niche” products that might be hard to get to the market. To address this, a value chain analysis or marketing plan might be needed pre-project, and the possibility of teaching farmers how to further process their products to 1) make them more accessible and 2) achieve higher prices should be considered. The case of the aromatic herb businesses in Nepal provides a good example of how this can be achieved.

Finally, post-project sustainability and upscaling remain challenges for many of the projects. Once again, supporting more cooperation and exchanges may help mitigate those challenges.



5.3 Lessons Learned

Successful agroforestry models bring policymakers, researchers, and farmers together. The policymakers work on the regulations or laws which can guarantee secure land tenure; researchers explore more detailed questions, like what the ideal spacing for a certain species combination is, and provide suggestions and recommendations for policy makers and farmers. The implementation, anything that is happening on the ground, will finally be conducted by farmers. While research is helpful, the actual agroforestry models, such as selecting trees and crops, should always be based on farmers' respective interests and needs.

Additionally, while there are always varying priorities depending on the project and stakeholders, it should be recognized that the categorization used in this brochure—agroforestry for livelihoods or forest restoration—maybe a false dichotomy. As the project in Prek Thnot has shown, when farmers can truly see the restoration benefits brought by agroforestry, they understand that restoring an area through agroforestry is directly linked with livelihood improvement. These priorities can be considered to be on a continuum and need to be adapted to the respective situation, such as when deciding if a site is a jungle rubber plantation or a mixed rubber plantation. Agroforestry is a great solution to balance agro-ecological, socio-economic and land-use problems, but it is impossible to develop a one-size-fits-all solution and the diversity of approaches used in the projects described in this brochure show how different the answers to those challenges can be.

Ultimately, the successful implementation of agroforestry models is a continuous process of learning. As agroforestry is one of many approaches that APFNet adopts to rehabilitate degraded forests, we hope to further support the research and demonstration of various agroforestry models in the future.

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