# Building Resilience and Sustaining Livelihoods

## -APFNet's Agroforestry Projects



**Information Office, APFNet Secretariat, 6th Floor, Baoneng Center, 12 Futong Dongdajie, Wangjing Area, Chaoyang District, Beijing 100102, People's Republic of China**

**Email: info@apfnet.cn.**

# 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.

In spite of an increasing awareness of the importance of managing forests sustainably toward achieving green growth, reducing poverty and responding to climate change, large gaps still exist in knowledge and capacities at global and regional levels. The establishment of the organization was proposed in this context 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 the APEC Leaders and incorporated in the *Sydney Declaration on Climate Change, Energy Security and Clean Development*, in an effort to "enhance capacity building and strengthen information sharing on sustainable forest management in the forestry sector" in the region.

The APFNet was officially launched in September 2008, with its arrangement and operations guided by the Operational Framework, evolved from the Framework Document jointly developed by China, Australia and the United States.

# Preface

The forests of Asia-pacific comprise some of the world's most valuable and productive forests, forming unique ecosystems of high biodiversity and high carbon stocks. However, there still are issues such as the poverty, gender equity, illegal timber harvest, land degradation, soil erosion, loss of biodiversity, heavy deforestation and forest degradation threatening ecosecurity. FAO (2017) believes that the restoration of degraded landscapes with agroforestry can help solve some of these "common issues". The Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet) "respects diversity in development, being action-oriented and thinking innovatively" and adopts agroforestry as a useful "tool" to improve people's livelihoods and environment in the Asia-Pacific region. APFNet understands the opportunities agroforestry brings, not just for improving livelihoods, but also restoring forests and adding a dimension of functionality to them. To date, APFNet has funded **10 projects that either mainly or as part of the overarching project** have used agroforestry to improve people's lives and forests.

In the first part of this brochure, there are four projects that have focused on using agroforestry to provide solutions for livelihood improvement and enterprise development. Amongst them are projects that empowered local women, intercropped woody crops in traditional landscapes or fought poverty by improving traditional homegarden systems.

In the second part, projects that have focused on using agroforestry for forest restoration will be showcased, including projects that used agroforestry to fight desertification, prevent erosion in hilly areas and watersheds and used multi-strata agroforestry to improve the ecological functioning of a forest while providing important medicinal herbs.

Finally, as it is important to go beyond the demonstration of current best-management practices, but also help researchers to obtain further agroforestry knowledge, the third part is dedicated to introducing two research-focused projects. One tested a new system of land classification for agroforestry based on zoning and slope properties in Chinese Taipei, while the other investigates specific soil and water conservation functions of a number of agroforestry models in Cambodia.

Agroforestry is a living system that will keep on evolving. We sincerely hope that our demonstration and research projects will contribute to greater understanding of both the opportunities and challenges associated with agroforestry and its wider application in forest rehabilitation and sustainable forest management within and beyond the Asia-Pacific Region.

# Acknowledgements

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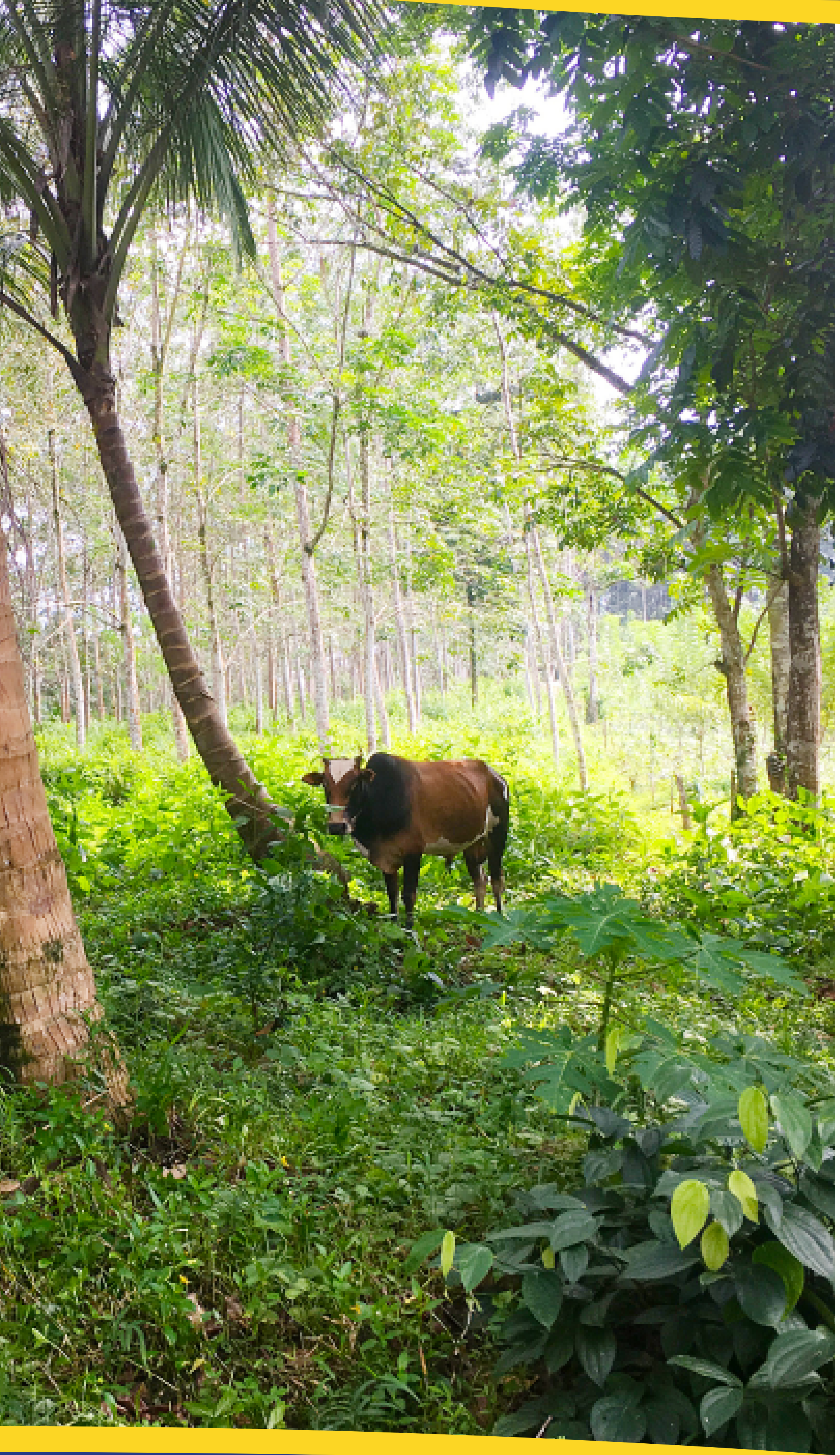

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# Background

Agroforestry seems to many of us like a recent innovation, an innovation that over the past 30 years has slowly gained global attention as a tool intended to address many of the spatial and ecological problems traditional agriculture or unsustainable land use have brought. We hope that by integrating trees into farms and agricultural landscapes, we can diversify and sustain production for increased social, economic and environmental benefits for land users at all levels. This, at least, is how the World Agroforestry Centre describes agroforestry. Yet, agroforestry can be understood in a broader context and has a much longer history than commonly believed.

Some of the oldest agroforestry systems, tropical homegardens, go back as far as 13,000 years and the multifunctionality of a piece of land has been understood by wide groups of people throughout the years. Be they called "food forests", multi-strata forests or homegardens, clearly agroforestry is not a new idea. It is an idea, however, that throughout the "green revolution" and the general intensification of farming, has lost its appeal for many farmers in the developing world.

Yet agroforestry, especially in the tropics, can yield as much or even more than an intensively managed field, while often requiring less fertilizer and pesticides, and also providing ecological habitat and greater eco-security (Toensmeier 2016, De Schutter 2011, Reij 2009). In the face of climate change, increasing population and an ever-increasing demand for food, agroforestry can provide a new solution for tackling those problems.

These solutions, of course, are highly adapted to local conditions and can take many forms: be it traditional alley cropping or strip intercropping that combines annual crops with rows of trees, contour hedgerows or living terraces that are used to prevent erosion on slopes, windbreaks and shelterbelts to protect the valuable crops in their center; or successional intercropping and improved fallows, that give the soil more effective means to recover from the nutrient leaching agriculture often causes or even multistrata agroforests, including homegardens that produce an immense variety of food on an incredibly small amount of space.

Agroforestry approaches are as diverse as human culture itself. The APFNet projects below will showcase a number of the earlier described techniques.



# 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. Those agroforestry projects covered **seven economies** including Cambodia, China, Chinese Taipei, Indonesia, Lao PDR, Myanmar, and Nepal.

# Agroforestry Solutions for Livelihood Improvement and Enterprise Development

Over the last 11 years, APFNet has supported four projects whose primary focus was the improvement of livelihoods of people living in and near forest areas. These included projects focused on community resilience in the Montane Mainland of Southeast Asia (MMSEA), the economic empowerment of women living in and near forests in Nepal, and using zoned agroforestry and home gardens to reduce poverty and increasing livelihoods though increased productivity of homegardens in Cambodia.



## 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

**Implementing Agencies**

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

**Budget in USD (Total/APFNet Grant)**

650,000/500,000

**Project Duration**

01/2013-12/2015, completed

**Site Locations**

- 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 and especially forests has been an approach for economic development in 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 and 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 in 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 are 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 1675.6mm. 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. 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.

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

- Upper: Extensive rubber monoculture with high income but low ecosystem service capacity at Lianghe village (2013)
- Middle: Land preparation for planting other tree specie in the rubber plantation (2013)
- Bottom: Indigenous high-value tree species growing in between rubber plantations (2018)

### 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.

▲ Project plot before intervention in 2013

▲ Project plot after intervention in 2018

## 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.

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. But 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*)(Figure 1) in the second year;

**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 grow in-between.

Fruit trees 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. It was found that broom grass is very effective in protecting soil and water, with soil loss reduced to 0.52t/ha and water runoff reduced to 356m$^3$/ha. *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. Compared to that, soil loss and water runoff for mono-cropping of annual crops is much higher at 25 tons and 2,358m$^3$/ha.

**BOX 1**

Mrs Loy Chid is a middle-aged lady, who joined the project in early 2014. She owns 1.5ha 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. Apart from this, she also 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 banana, 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.

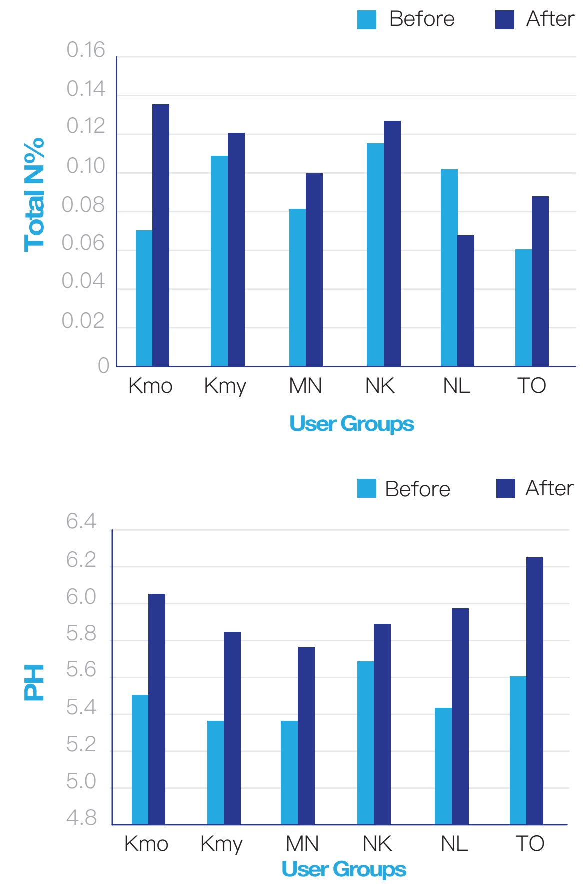
Agroforestry is a potentially useful solution. It can use nutrient cycling between tree and crop layers as a means of boosting yields and diversifying income sources. The project tested **three different models** for agroforestry on degraded lands in Myanmar:

### 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 used, where *Sterculia versicola*, a native tree with the potential to generate high income within a short period of time and is highly suited to the local topography and weather conditions, was interplanted in 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*, *Gmelian arborea*, and *Mangifra 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.




Total nitrogen content (top)/ PH (bottom) before and after the agroforestry sytems were put in place

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 and the estimated income per tree per year is about USD 110. The key products of *Sterculia versicolor* are gum mainly used for car mirrors and medicinal purposes.

*Sterculia versicolor* planted in 2014 (left) and 2018 (right)

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

Farmers' preferred tree species *Tectona grandis, Cassia siame* and *Eucalyptus camendulensis* were planted along the farm boundary in July and August 2014, using a spacing of 3x4m, based on their preferences. 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 (see Box 3, p.19). Common annual crops are eggplant, pumpkin, lemon, various kinds of beans, chili, ladies' finger, bitter guard, 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.

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

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.

In the village, there are several village self-governance administration bodies, but a user group specifically for forest rehabilitation practices didn't exist until this project was initiated. Now, a self-running user group, which plans, practices and maintains agroforestry models, is in operation, leading 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 12 farmers, replicated this model with the help of the Nyaung-Cho Forest Department township office.

# 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)**

USD 559,208/412,238

**Project Duration**

10/2014-03/2018, completed

**Site Location**

Sarlahi District, Nepal

Located in Himalayan region, Nepal has traditionally been influenced by Hinduism, leading to a unique and fascinating culture. While such culture is to be celebrated, the Hindu system's emphasis on patrilineal descent led to women being regarded as subordinate to men in virtually every aspect of life. In cities these attitudes are changing, but in the countryside, between rugged mountains, traditional values still limit women's empowerment.

As such women mainly manage household chores and do farming work, but they are also strongly dependent on community forests for making their livelihood in Nepal. 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 such a form of socio-economic empowerment, as they can instill a sense of agency through entrepreneurship in women, one of the strongest indicators for effective empowerment of this group (Malhotra *et al*, 2002).

In 2014, APFNet, together with the Himalayan Grassroots Women's Natural Resource Management Association (HIMAWANTI), set out to support women 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 km² and has a population of 769,729 (National Population and Housing Census 2011). The forests are mostly being degraded due to rapid population growth. Degraded forests, located under high transmission lines, are underutilized and only shrubs and invasive species are growing there. In a number of other areas different small trees, such as *Shorea robusta, Termelia tomentosa, Syzygium cumunii, Emblica officinalis, Bombax ceiba, Tectona grandis and Lagerstroemia parviflora* are abundantly growing. In some areas, *Eucalyptus camadulensis* plantations are still remaining.

The area itself is plagued by problems, such as 1) a lack of sustainable forest management, 2) a lack of women empowerment, 3) a general lack of alternative livelihood options, and 4) insufficient production and marketing of possible products. The community forests are also suffering from natural disasters including floods and fire.

# 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. 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 management, and forest rehabilitation. At the same time the local women learned how to plant and market those MAPs.

## Aromatic Herbs Species in Agroforestry

- Citronella (*Cymbopogon nardus*): Essential oils are extracted from the aerial parts, and are applied topically as an insect repellent (Nakahara *et al.*, 2013)
- Lemon grass (*Cymbopogon citratus*): Widely used in Brazil and India as traditional medicine. Often used in treating staph infections and combating skin infections. Prevents body odor; improves body metabolism (Cheel *et al.*, 2005)
- 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

Top Left: *Cymbopogon martinii*
Top Right: *Cymbopogon nardus*
Bottom: *Cymbopogon citratus*

Lemongrass plantation grown in the community forest (left)
Women are planting the seedlings grown in the nurseries in community forest land (right)

BOX 2

# 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*) (see Table 1). The planting of aromatic herbs can be considered a form of forest restoration through species enrichment. In Janajvoti and Nandeswor, under-utilized land under a high transmission line has been put back into use through planting aromatic herbs (Table 2). Overall 12ha in 3 communities in Sarlahi, a total of 509,100 aromatic herb seedlings were planted. Irrigation facilities through pumping underground water have been 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 martinii, Cymbopogon nardus, Cymbopogon citratus* |

**Table 2.**
**Aromatic plantation status and number of planted seedlings in CFs**

| Species \ CF | Radhakrishna | Janajyoti | Nandeswor | Total Seedlings |
|---|---|---|---|---|
| Lemon grass | 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 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–no small task for local women who previously have mostly taken care of the household before. 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 in the group and earned USD 4,000. The 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 has made an agreement with the private company "Himalayan Bio-trade of Kathmandu" for producing and selling the harvested materials of the aromatic herbs and the produced organic essential oil. Himalayan Bio-trade will facilitate getting an 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 herbs business. In fact, they are now much more independent and regard themselves as entrepreneurs with unique skill sets.

## Achievements

Through APFNet's project support, poor women have improved their socioeconomic status, decreased their dependence on the male counterparts and have become entrepreneurs collectively owning a MAP business. Major achievements include 1) Agroforestry systems established to generate diversified income sources for women; 2) First-time documentation of income and expenditure for the CFUGs started; 3) Supplementary income generating programs started to promote disadvantaged groups in community forest through mobilization of CFUG fund; 4) Poor women took leadership positions in local-level organizations and cooperatives.



# 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)**

1,792,663.60/1,515,465.60

**Project Duration**

06/2017-06/2021, ongoing

**Site Locations**

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 degraded 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 is supporting 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 are selected as suitable ways since farmers already practice farming and many have low yielding home gardens. The main challenge is using improved techniques. Current techniques prevent farmers from using the land to its full potential, as on any given piece of land farmers only plant one type of crop or one tree species that provides them with a limited income. The project involves farmers who are interested and have 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 intercrops high-value cash tree species such as macadamia trees, pomelo, cashew and vegetables. This system aims to improve farm productivity and soil conditions by increasing soil organic matter and improving nutrient cycling. This agroforestry model is divided into three zones (see Figure 1).

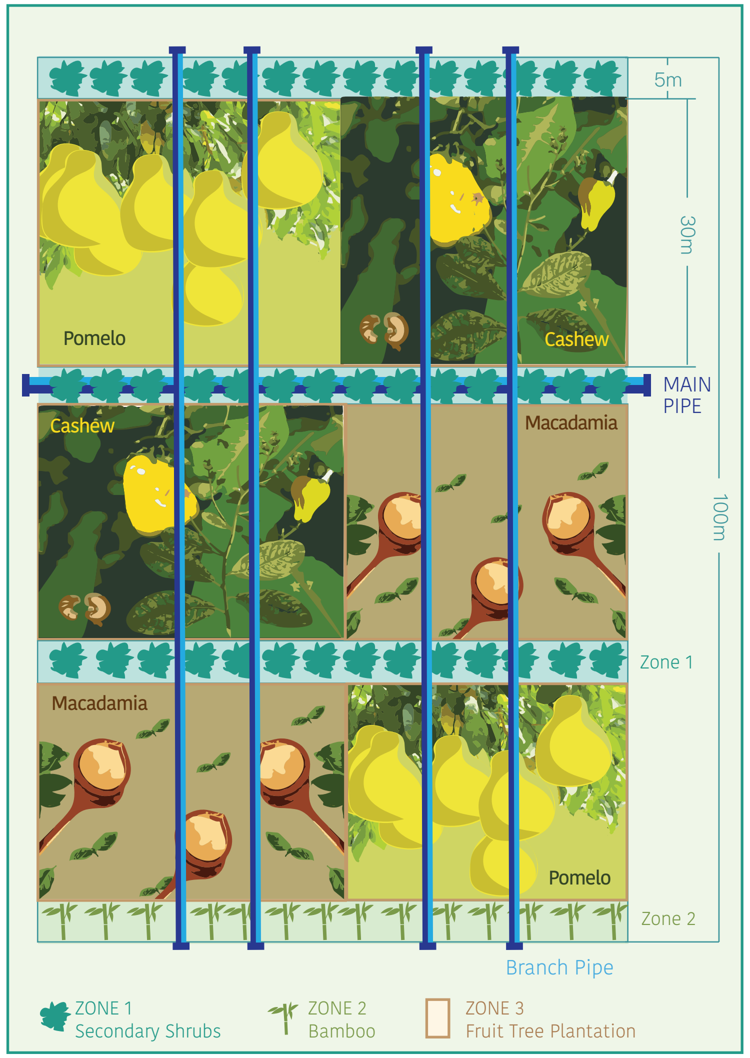



Figure 1. Zoning for agroforestry system with irrigation system

### Zone 1 - Erosion Control Strips

3 strips are created for water and soil erosion control by keeping the original vegetation, the secondary shrubs. The width of this strip is 5m and the distance between each strip is 30m.

### Zone 2 - Bamboo Border Control Line

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

### Zone 3 - Fruit Tree Plantation

This is the main agroforestry area and is divided into 6 sub-areas (each area is 30*50m), separated by erosion control strips. The recommended fruit and nut-producing tree species are macadamia, pomelo and cashew. The grafted seedlings of macadamia and pomelo are imported from China. These fruit trees will be planted in a spacing of 5x4m and annual vegetables or agricultural crops will be planted in the spaces of those alleys based on the farmers' preference and market conditions.

Figure 2. 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 soil water storage, low soil fertility, and low soil PH, which are likely to limit upland farming systems for their sustainable use. Organic manure and compound fertilizers will be 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 plant) will be installed on the site.



## Zoned Homegarden Farming System

The site selected for establishing a zoned homegarden model is in the yard of a household (for a general description of homegardens, refer to Box 3 p.19). This area is comprised of two parts, the first being an open area and part two being a degraded secondary forest. It is common practice to retain some fruit trees and other tree species for household use. The new model of the zoned home garden farming system will make full use of the farmer's land. This model will also demonstrate the utilization of shade-tolerant plants underneath forest stands for multi-story management. The zones of this 0.5ha demonstration area are the following:

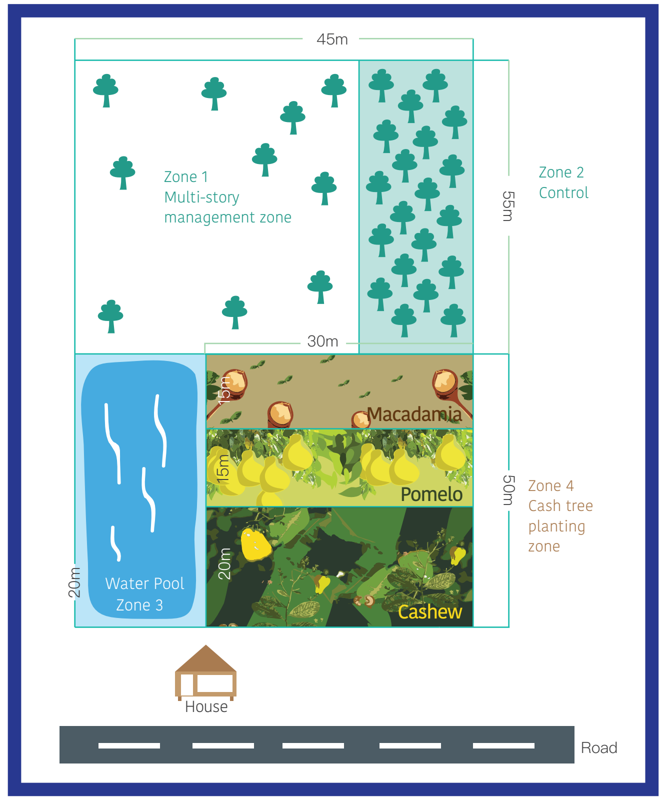



Figure 3. Design of the zoned homegarden

### Zone 1 Multi-story Management Zone

A multi-story management model will be introduced in the degraded secondary forest on an area of about 0.25ha, which will improve biomass and economic benefits through thinning and intercropping the area with pepper vines. Originally this area was a woodlot the farmer used for firewood and to obtain timber for construction. Through this application, this woodlot area will be transformed into an agroforestry system that provides a wider range of benefits, including agriculture and forest products. Shrubs, vines and unhealthy trees in this area are cleared and valuable tree species, such as *Xylia xylocarpa, Pterocarpus macrocarpus, Shorea roxbourghii, Ochna integerrima, Sindora siamensis*, that are healthy and have a DBH larger than 3cm and straight stems, as well as other useful trees, remain. Pepper is a perennial woody vine growing up to 4m in height when it is attached to suitable trees, poles, or trellises. It is a spreading vine, rooting readily where trailing stems touch the ground. It can grow well underneath the canopy and is suitable for multi-story management, where it can provide a high income for the farmer. After thinning, pepper will be planted close to the remaining trees, with a density of about 300 clusters (2-3 seedlings per cluster planted next to each tree), around 900 seedlings in total. Decomposed dung and superphosphate fertilizer are applied in the hole before planting, later manure and compound fertilizer are applied once per year. Normally it can provide fruit in the third year after planting and its price range is USD 10-15/kg. One cluster of pepper can yield 4-6kg per year.

The remaining tree species will function as providers of shade for the pepper, as well as protect water and soil in the area.

Figure 4. Farmer planting pepper close to the tree so it can easily grow up the trunk (left) and a close-up of a pepper plant (right)

## Zone 2 Control

0.1ha of the degraded secondary forest remain as control. The control plot will be 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 will be applied in the open area using cash tree species including macadamia, pomelo and cashew. These trees will be planted with a spacing of 5×4m in different strips (Figure 5). Macadamia and pomelo will be planted on 450m$^2$ (15×30m) using 22 seedlings for each species, while the area to plant cashew is 600m$^2$ (20×30m) using 30 seedlings. Most of the trees are expected to bear fruit after 3 years.

The agroforestry and homegarden models are expected to quickly generate income for the farmer since annual vegetables and crops were incorporated. Additionally, at later stages farmers can get long-term benefits from cash trees. It is expected that these new models will show how to fully make use of the farm space across multiple stories to generate more income, thus improving livelihoods, and can be expanded to other households in the future.

Figure 5. 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 Fxing 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, ongoing

**Site Locations**

Bos Thom village, Khna Por commune, Soth Nikum, district, Siem Reap province, Cambodia

## Introduction

Poverty reduction is a major challenge for the economic progress of a developing economy like Cambodia, where about 20.5% of people are living in poverty (Cambodia Poverty Assessment 2013). In Cambodia, 90% of poor people are living in rural areas and mainly depend on agricultural and forest products. Promoting improved agricultural production and forest-based livelihood activities is one of the prime strategies to reduce poverty and maintain economic growth. However, this effort remains a challenge since existing practices can only produce low yields and support the farmers for household consumption rather than selling to the market.

In Bos Thom village of Khna Por commune in Soth Nikum district, Siem Reap province, 99 families, that is overall 522 villagers, are poor and mainly depend on agricultural products. Traditionally, local households in rural villages live in a wooden house on a small piece of land (less than 1ha, sometimes larger for higher income families) on which several tree species, crops and vegetables are growing. These are called homegardens. However, this setup can usually only cover the basic needs of a single household. Transforming these small patches into more productive homegardens can enable families to earn an income instead of only barely subsisting on their land. In the project, 10ha of homegardens will be established as demonstration sites, involving about 15 households in the village.

## BOX 3

### 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 display amongst the highest biodiversity of all man-made ecosystems and have some of the highest levels of carbon sequestration in agriculture. Unfortunately, in some regions, those homegardens have been stripped down to comparatively few species, resulting in suboptimal yields and biodiversity levels.

▲A common folk house of local people
▼A traditional homegarden practice

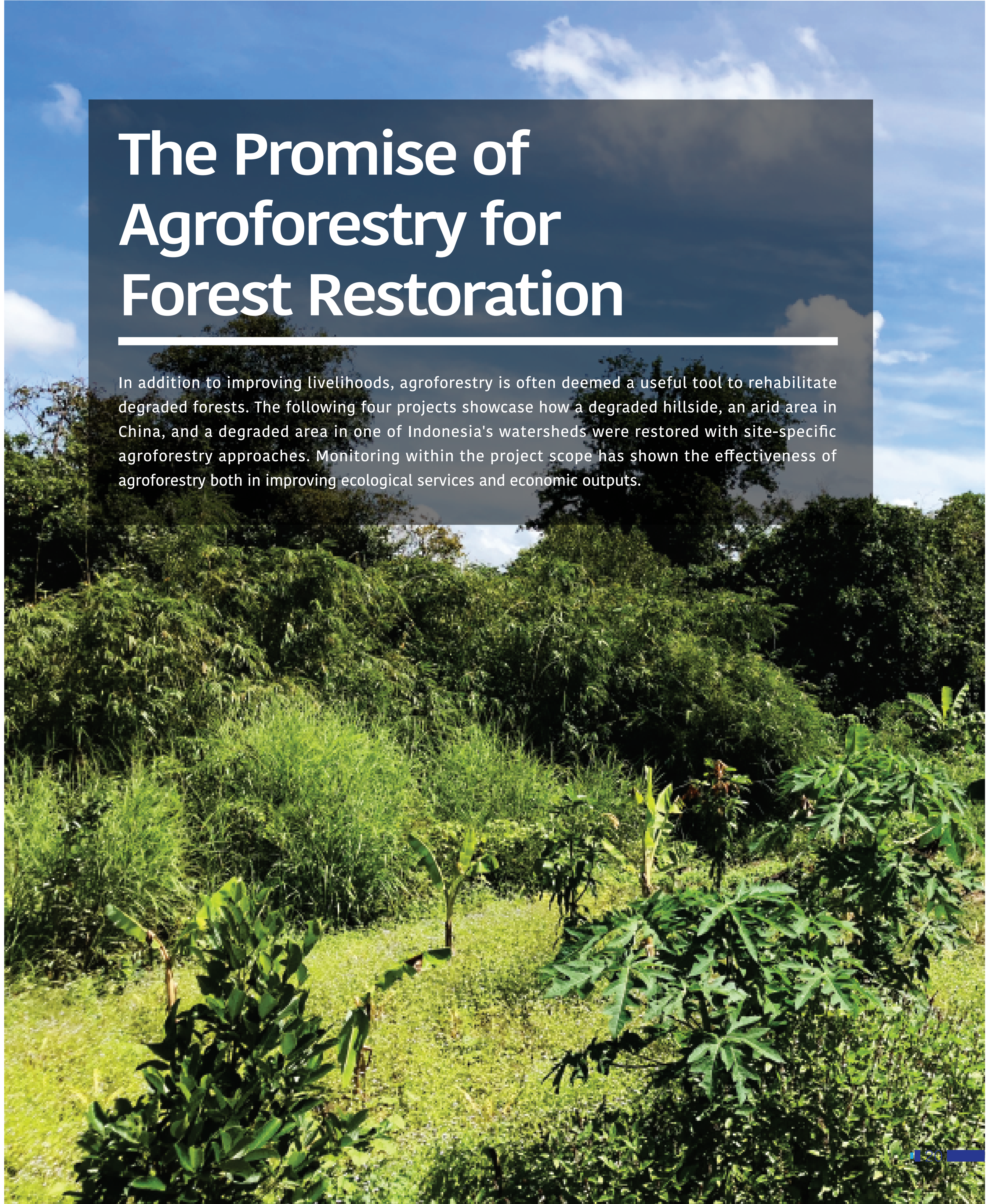
In the project area, local people plant fruit species (jack fruit, orange, mango, banana, etc.) combined with short-term crops such as beans, eggplant, cucumber and so on at the yard of their households. In order to increase both biodiversity and local income, this project will support the farmers to diversify and intensify their homegardens by interplanting high value timber trees (*Dalbergia cochinchinensis, Pterocarpus pedatus*), as well as fruit species like banana, papaya, orange, coconut and cashew nut and combine them with short-term crops and existing plants around their households. The farmers will select the crops based on their preference and market demand. This will give local people an opportunity to improve the food diversity of their own daily consumption, up carbon sequestration and increase local biodiversity. Finally, we expect that the improvement of homegardens will increase local livelihoods overall by enabling them to sell to the local market, thus inspiring other farmers to adopt this technique at their own respective farms.

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

Mrs. Cheuy Buot, a Bos Thom CF member owning 0.6ha of farmland in her backyard, is growing a single crop of long bean under the canopy of a few tree species such as *Hopea ordorata* and *Xylia xylocarpa*, from which she can earn about 40,000 Riel per day (about USD 10). However, this amount is not sufficient for her to support her family, while a homegarden can support her already after a short period of time. During the primary survey, she showed interest in intensifying her homegarden using techniques introduced by the project. She expects that she can grow various cash crops, fruit trees and high value tree species such as *Dalbergia cochinchinensis* on her land to increase its inherent production through Dalbergia's nitrogen-fixing abilities, as well as generate more income.

BOX 4





# The Promise of Agroforestry for Forest Restoration

In addition to improving livelihoods, agroforestry is often deemed a useful tool to rehabilitate degraded forests. The following four projects showcase how a degraded hillside, an arid area in China, and a degraded area in one of Indonesia's watersheds 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 outputs.

# 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**

1. Forestry Department of Anhui Province, China through Qingyang Forestry Bureau,
2. 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, ongoing

**Site Locations**

1. Qingyang, Anhui Province, China;
2. Lin'an, Zhejiang Province, China

### Introduction

The hilly areas of southern China, influenced by a subtropical humid monsoon climate, enjoy favorable conditions which have great potential to harbor forests with high productivity and biodiversity. 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, as well as improper forest management, the degradation of forest resources in China has been accelerating. 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 began a project with local forestry departments and bureaus in southern China which focuses on conservation and restoration of degraded forest ecosystems in typical hilly areas. Agroforestry systems are being demonstrated in Lin'an, Zhejiang Province, which receives around 1,613mm of precipitation annually and works with Chinese hickory plantations to both restore the ecosystem and improve local livelihoods. The main soil types are Ultisols and high-ridge moist Oxisols.

### Chinese Hickory + Medical Herb Plantations

The demonstrated site is a 3ha large 7-14 year-old Chinese hickory (*Carya cathayensis*) plantation with a slope of 29 degrees and soil depth of 62cm. Chinese hickory was planted in a 4 × 5m spacing, so there are around 500 Chinese hickory trees per ha. The young plantation could not fully cover the ground surface, which resulted in soil erosion and also affected the hickory nut yields. With the objectives of conserving the soil and increasing land productivity, under the project two types of medicinal herbs, Siberia landpick (*Polygonatum sibiricum*) and Sanyeqing (*Tetrastigma hemsleyanum*), which can enlarge the land cover and have high economic values, were interplanted.

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

Figure 1. Sanyeqing planted underneath Chinese hickory

Siberia landpick was planted in 1 meter wide strips under Chinese hickory, with 0.25×0.2m planting spacing, while Sanyeqing was planted in blocks under the same tree. The estimated harvesting date of both are three years after planting. Each year weeding and fertilization is done in July and October; for Siberia landpick farmyard manure is used, while for Sanyeqing potassium carbonate is the preferred option. Watering is done once 3 to 5 days after planting and afterwards only as needed. After three years both species are fully harvested, as their roots will be used.

**Table 1. 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 |

**BOX 5**

Chinese hickory nut

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. The small round nut is rich in protein, amino acids and 22 trace elements needed by the human body. The nutritional value of the nut is said to be twice as high as that of beef. Additionally, those nutrients are more easily absorbed than nutrients from beef, eggs and other foods. Peeled and roasted hickory nuts are served as snacks and are also used as an ingredient for candy and cake.

The root of *Polygonatum sibiricum*

Siberia landpick (*Polygonatum sibiricum*) is a perennial 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. It lowers blood pressure and prevents atherosclerosis and fatty infiltration of the liver. It is used in the treatment of dry coughs due to chronic bronchitis, pulmonary tuberculosis, fatigue and poor appetite.

*Tetrastigma hemsleyanum*

Sanyeqing (*Tetrastigma hemsleyanum*) is a perennial climber and is traditionally used as a folk medicine for the treatment of cancer. 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.

# 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, ongoing

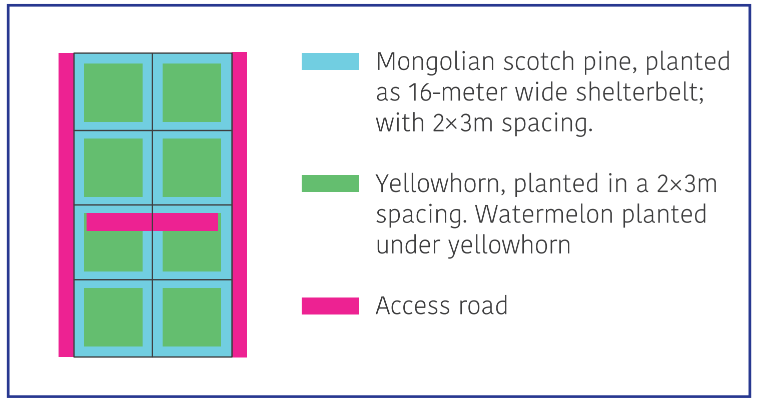
**Site Location** Aohan Banner, Chifeng City, Inner Mongolia

### Introduction

In Aohanqi, as part of the steppe of Inner Mongolia, it is often hard to get anything to grow. In 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 wood 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 was planted in a "net" structure. There, Mongolian scotch pine was planted on the outside, surrounding the yellowhorn and watermelon plantings inside, actively working as a shelterbelt. Yellowhorn and watermelon were in the meantime evenly mixed in the inner squares, with yellowhorn planted in a 2×3m spacing and watermelon planted in a 0.3×0.5m spacing. There are around 1,665 yellowhorn seedlings planted per ha. Every 4m a drip irrigation tube crosses through the plantings to provide water to yellowhorn and watermelon. Watermelons, while excellently adapted to semi-arid climates and in fact need the constant sun areas like Aohanqi provide to produce sweet fruit, need a constant water supply until the fruit is fully formed. In contrast to this, while benefitting from the drip irrigation for the watermelon, yellowhorn, as a drought-adapted plant, does not need a great amount of additional watering. Only young seedlings have to be watered 3 to 5 times in the first year to ensure a high survival rate. The planting area is weeded two times a year in June and July, and is fertilized with manure (7,500kg/ha) in March. No herbicide is added.

It is expected that most of the yellowhorn plants will form their first fruit after 3 years, while the pine can be harvested after 40 years when the DBH is larger than 30cm. With the current density yellowhorn will produce around 1,200–1,500kg of fruit/ha after 3 years, and it will enter its most productive period in 7 to 8 years and can produce fruit until about 30 years with fruit yields of 3,750 – 5,000kg /ha, earning an additional USD 16,000/ha/year. Watermelon sales will contribute around USD 4,400/ha/year. As the land was leased from local farmers, they will receive all the money earned.

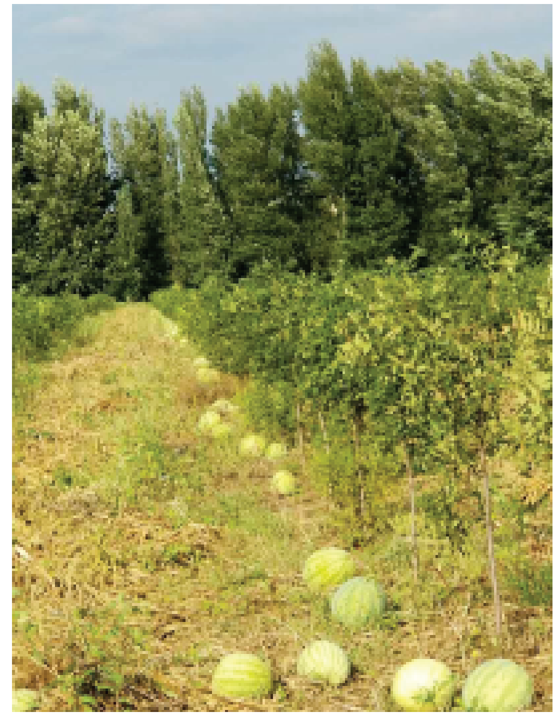


Figure 1. Watermelons intercropped with Mongolian scotch pine and yellowhorn

### Yellowhorn (*Xanthoceras sorbifolium*)

Fruits of Yellowhorn


Yellowhorn, despite its long history (by some even referred to as a "living fossil"), has remained an underappreciated NTPF. With increasing aridity threatening the survival of other species, however, the extremely drought-resistant and generally very hardy yellowhorn, able to survive temperatures as low as -41℃, and growing on both sandy and rocky soils, has moved to the center stage when it comes to fighting desertification while providing a livelihood for local people.

While only growing up to 5m tall, this member of the soapberry family (that is the same family as maple or horse chestnut) grows large fruits containing 6-18 seeds, 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 and skin care products. Having such a potential for versatile products, the average price per 100ml of oil is around USD 15, which is likely to increase as the product becomes more well-known. Another product is tea made out of the tree's leaves and flowers.

## Poplar-Pine-Liquorice "Net" Planting

Traditional medicinal herbs have a large domestic demand. This especially applies to Chinese liquorice (*Glycyrrhiza uralnesis*) root. Liquorice is one of the 50 fundamental herbs used in Traditional Chinese Medicine (TCM) and, after being collected in spring and fall, is dried in the sun. 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. As such, on 30ha Xinjiang poplar (*Populus alba* var. *pyramidalis*) was planted as a shelterbelt in a net pattern around an alley cropping of Mongolian scotch pine (*Pinus sylvestris* var. *mongolica*), planted in a 3x3m spacing, and Chinese liquorice (*Glycyrrhiza uralensis*) was planted in two 0.5m wide strips between lines of Mongolian scotch pine (demonstrated on 1.33ha) (Figure 2). Irrigation pipes were laid in lines and used for watering the liquorice. The demonstration area is fertilized once in May with compound fertilizer and weeded three times in spring and summer. No herbicide is used on the site.

About 6,750kg/ha of dried roots can be harvested in the third year after planting, earning around USD 6,500/ha. Poplar and pine can be harvested at around 20 and 40 years, with an average DBH of 40 cm and 30 cm, respectively. The wood is mostly used for construction and furniture.

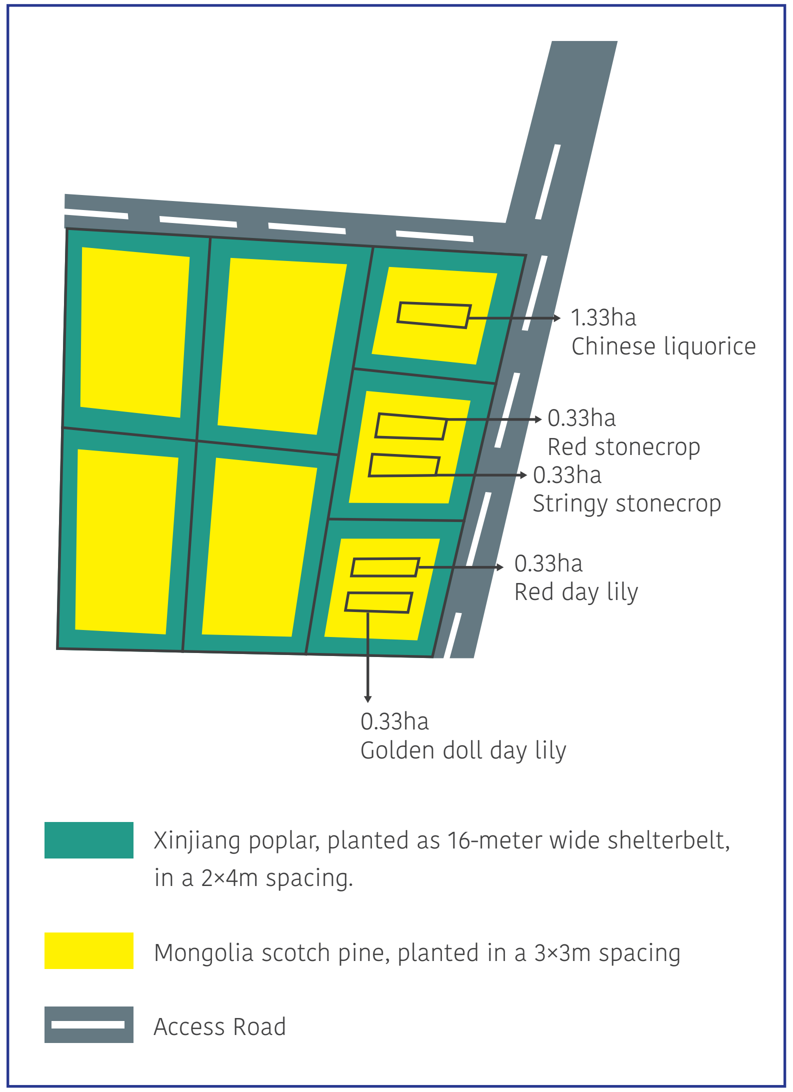



Figure 2. Model of "Net" planting

## 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 day lily (*Hemerocallis fulva*) and golden doll day lily (*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]**

**Executing Agency**

Wanzhangshan Forest Farm

**Budget in USD (Total/APFNet Grant)**

1,094,022/740,306

**Project Duration**

01/2017 – 12/2021, ongoing

**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 Yunnan Province, southern China and part of the watershed, deforestation that occurred earlier in the 20 century has largely been addressed by government-financed reforestation programs. The focus on planting mainly fast-growing and economically valuable species in monocultures, however, has been described by Frayer et. al (2014) as a "tree cover transition" rather than a "forest transition". The focus now lies 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 7), to demonstrate that such multi-functional forest ecosystems are both ecologically and economically viable. The stated project goal is 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.

BOX 7

## State-owned Forest Farms

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 forests, which is about 23% of the total forest area in China.

The Wanzhangshan Forest Farm was established in 2001 and manages 19,133ha of forests. 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 *Denfrobium nobile*, *Anoectochilus formosanus* and *Rhizoma bletillae*, have been planted. These were also selected because of the possible medicinal products that can be extracted from these epiphytes (see Box 8).

Figure 1. Trunk planting using nails to fix epiphytes (left), close-up of trunk planting (right).

The epiphytes were mostly planted on the ground and on the trunks of major tree species (*Pinus kesiya* and *Betula alnoides*), sometimes using transplanted tissue culture seedlings. The seedlings were sterilized before planting, 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 are stabilized by non-woven or wooden structures on the trunk (see Figure 1). The trunks for planting should be rough to favor the rooting of the seedlings.

BOX 8

## Vascular Epiphytes

Vascular epiphytes are plants that practically 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 rain forests. Trunk planting with epiphytic plants provides a unique micro-climate 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 some important ecosystems and they may even act as keystone species.

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

The project manager and staff visited the project site from time to time and conducted an investigation of research on the understory plantings. They also went to other successful peer units 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 may cooperate with them on high-value epiphyte planting, collection and production, which can demonstrate a successful model for achieving socio-economical value.

BOX 9

## 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).

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, ongoing

**Site Locations**

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 the river's upper basin is facing serious soil erosion problems. The Keduang Watershed, located in the Upper Bengawan Solo Basin, is one of the biggest causes of sedimentation in the Multipurpose Reservoir of Gajah Mungkur (MRGM). This has become a national issue, because the reservoir is now inhibited in its function as a flood control and water supplier for downstream agriculture. Large-scale deforestation to open up land for agriculture happened in 1930-40, which destroyed the natural forests in the upper watershed (Senin, 2009). Today mainly privately owned intensive farming of annual crops on the highly erosive and steep-sloped uplands 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 part of which 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 they have 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 litter fall 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 crop combinations, multi-story tree gardens, alley croppings, and shelterbelts.



## Assessment of Land Use Capability

In this project, the focus was placed on the development of a land capability assessment and the development of agroforestry plans for each household. In order to develop a more suitable and comprehensive agroforestry plan, a Land Use Capability (LUC) 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, meaning 56% of the land has been classified as category VI and 42% has been classified as category VII (Figure 1). The higher the LUC class, the more limited the possible land uses. LUC V-VII is not suitable for seasonal crops. It is only suitable for grassland, agroforestry and forestry use.

**BOX 10**

The Land Use Capability system (Lynn *et al.*, 2009) classifies different kinds of land according to its capacity to support long-term sustainable production after taking into account the physical limitations of the land. The limitations include the overarching influence of climate; susceptibility to erosion; slope steepness; susceptibility to flooding; liability to wetness or drought; salinity; depth of soil; 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 forests. Classes V to VII are not suitable for arable cropping but are suitable for pastoral grazing, tree crop or production forestry, and in some cases vineyards and berry fields. The limitations of usage reach a 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.

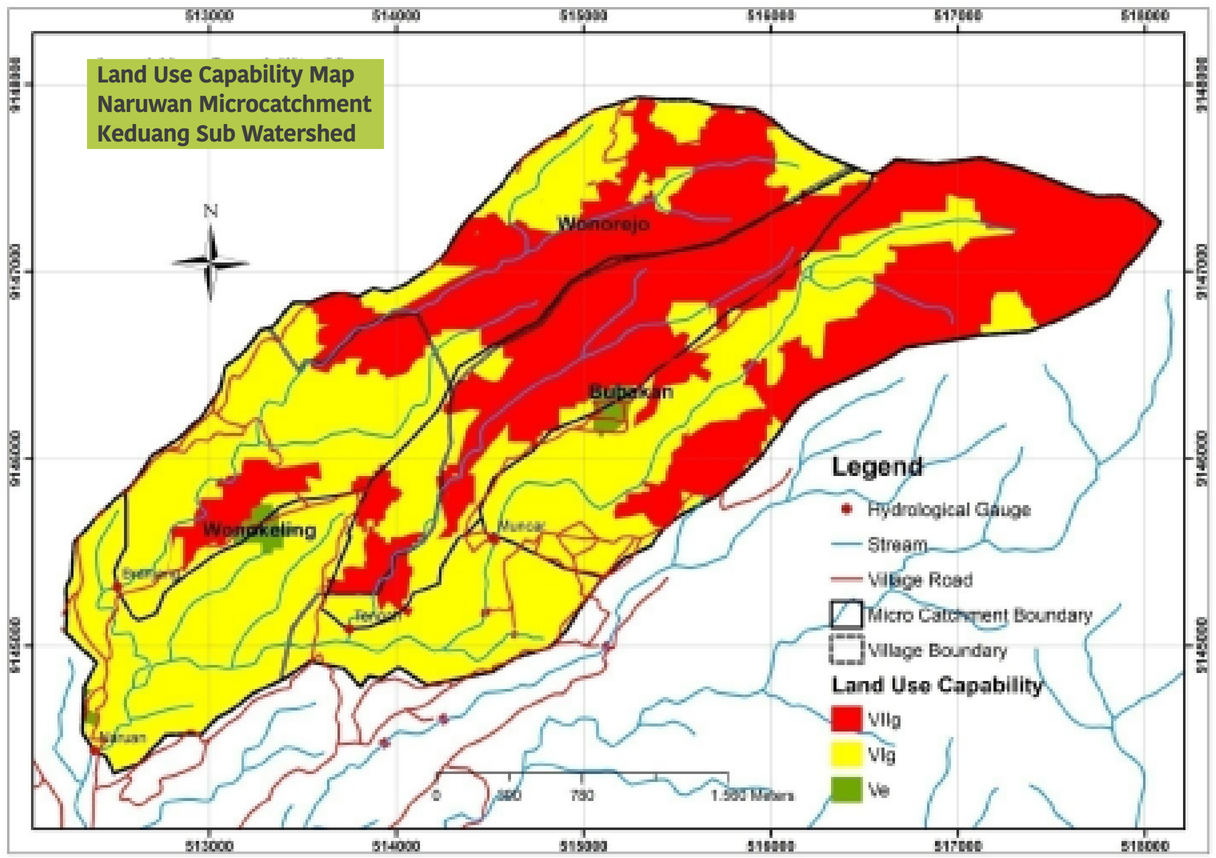



Figure 1. LUC Map of Naruan Microcatchment

Along with the LUC assessment, the soil erosion rate has also been 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. In addition, the dominant land cover is seasonal crops (see Figure 2).

## Combining 4 Categories in a Multistory Agroforestry System

Based on the biophysical conditions, the NMC area is not suitable for seasonal crops, but for agroforestry or undisturbed forest instead. With support of the project, 30ha of agroforestry demonstration sites in three villages, totaling around 60 households, were established to demonstrate sustainable agroforestry. The agroforestry system in NMC aims to:

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

Figure 2. The sloping farm land in the study area has only few trees before the project intervention, resulting in a high erosion rate

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 was an effort to make the community aware of the condition of their land, and devise a plan on how to overcome it. Furthermore, the project encouraged local households to select trees and crops from the local species described in Table 1. 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 will not only be planted on the boundary but throughout the field with appropriate spacing, which also reduces soil erosion. Some of the species can provide short- and long-term benefits, such as increasing incomes and thereby improving quality of life. At the end of the rotation (7 years), the average price of for an Albizia log is USD 10.69/$m^3$, meaning the farmer's overall income from Albizia through agroforestry is USD 5,557/ha after 7 years. This number is higher than the revenue from seasonal crops, which is 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, the soil erosion problem will be reduced through conservation agriculture and agroforestry practices. Conservation agriculture, signified by minimal soil disturbance, year-round land cover, and crop rotations, improves water-use efficiency, reduces soil erosion, and increases crop production.

### Table 1.

### Common local species

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

In general, there are 3 types of agroforestry models chosen by farmers (Figure 3), each of which is 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.

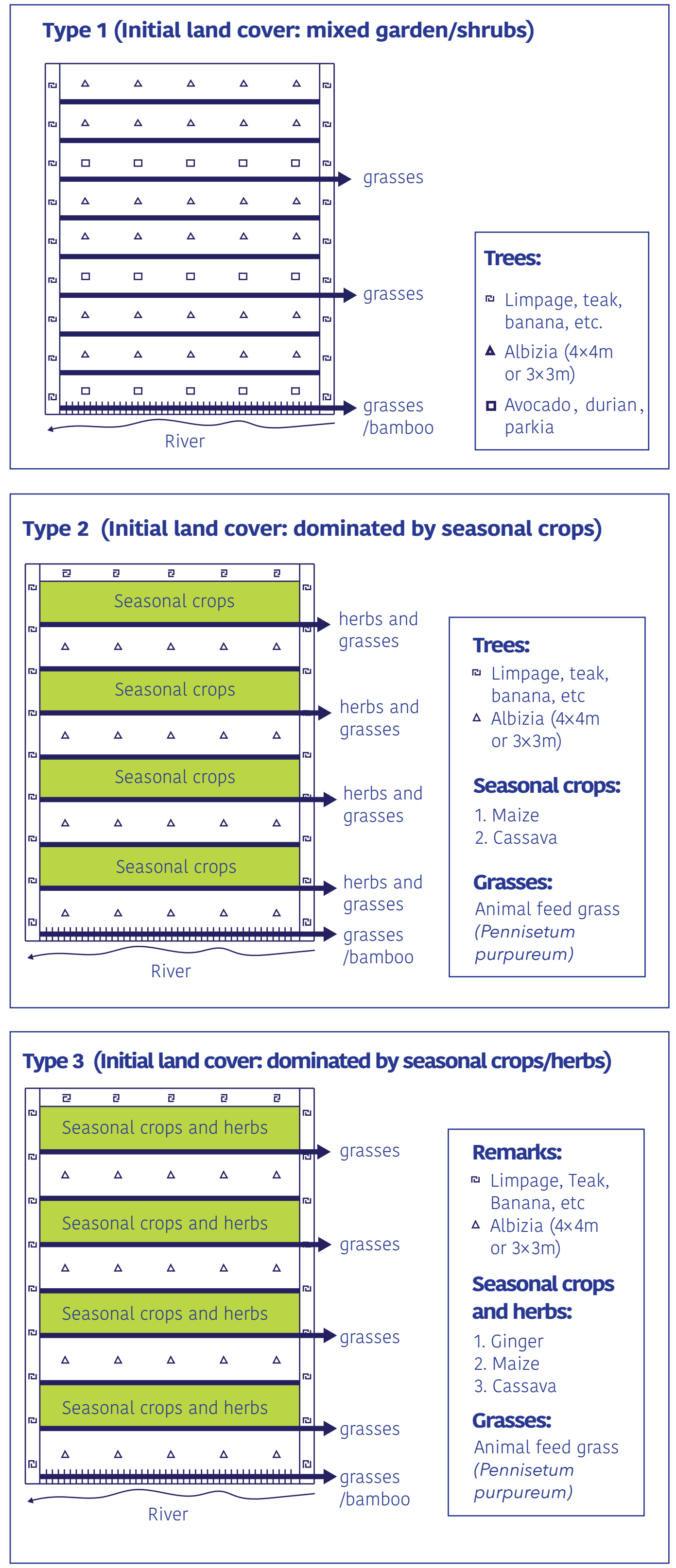



Figure 3. 3 types of agroforestry chosen by farmers

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 3). Years of intensive seasonal cropping have resulted in severe soil erosion and the formation of gullies on his land, while 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), evenly mixed in approximately 4×4m spacing, were planted. The spacing is not rigid because it considers the existing plants. Albizia is important since it is a fast-growing pioneer species that can improve land fertility through its nitrogen-fixing abilities, decrease erosion on slopes, provide fodder for chickens and goats, act as a shade and nurse crop and supply timber in the long term. The fruit trees can also improve soil conditions, increase land productivity and generate extra income for farmers in the short term. Additionally, herbs and grasses like ginger, turmeric and cardamom have been planted in even spacing along the borders and understory for soil conservation and fodder use. In the understory they will be cultivated until the canopy grows too dense and thus too little light remains, which is about 3-4 years.

Figure 4. One month after planting, from left to right, the species are albizia, avocado, durian and parkia

## Pictures of Mr. Sido's Plot

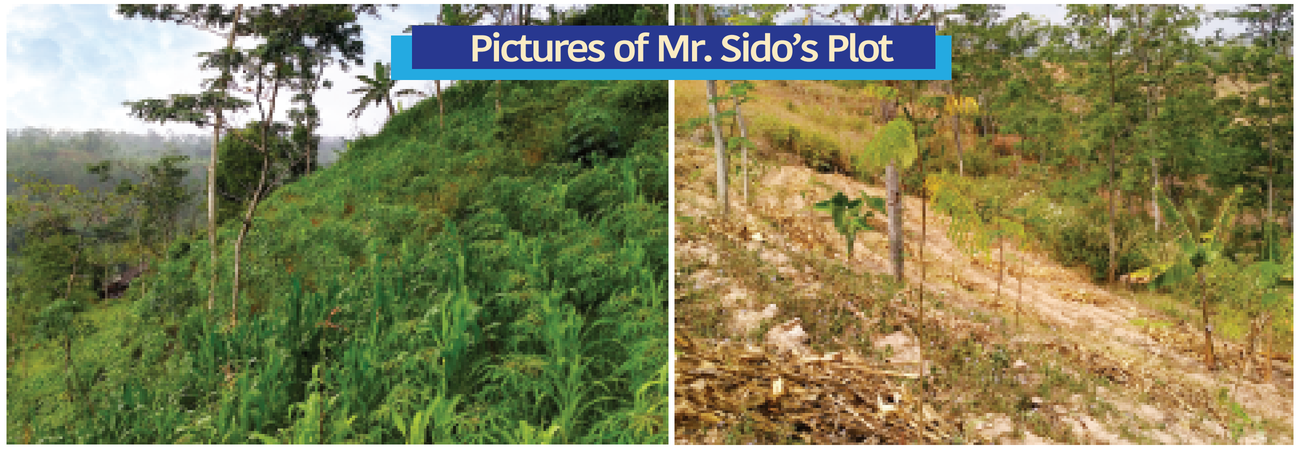


Figure 5. Initial condition before planting in January 2018 (left) and 6 months after planting albizia in July 2018 (dry season, right)

# Research in Agroforestry

Aiming to offer more effective agroforestry, APFNet worked with two research institutes in Chinese Taipei and Cambodia to examine the effectiveness of different agroforestry in controlling soil erosion. The two circumstances are different, but both partners have 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 Locations**

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

## Introduction

Chinese Taipei is rich in forests, about 58.5% of the land are covered by them. Many of those are located on rugged terrain in the uplands. In past decades, some of those uplands have been changed in their land use to agriculture, with at times detrimental environmental effects such as erosion and landslides. Convincing farmers to re-establish 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, Chinese Taipei (TFB), APFNet set out to demonstrate sustainable agroforestry systems and sustainable agroforestry practices for uplands in Chinese Taipei. This included 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 improved agroforestry practices were developed.

## Political Constraints

Although the Chinese Taipei administration has encouraged farmers to restore their surrounding environment by e.g. providing free seedlings, agroforestry sites are often not qualified for those rewards, as one of the requirements is that no agricultural crops on forestland are allowed when a site is marked for “reforestation” . This effectively disincentivizes farmers to work with integrated systems. One of the goals of the project was to show the administration that making such regulations more flexible can be beneficial for all parties.

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



## Land Assessment

The evaluation of the proposed areas for agroforestry, as much as the evaluation of the performance of existing agroforestry systems, is crucial to develop stronger, more suitable agroforestry systems in the future. As such, this was practiced by the projects in two forms, the development of a forest land classification system and the development 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 really expect any form of agricultural output from the land.

TFRI put the different soil types and depths into a “soil score” ranging from 1 to 5 (green), and divided slope degrees into scores 1 (gentle slope) to 6 (steep slope)(orange). This was then all multiplied in a matrix for classification, which resulted in the Land Use Classes (Table 1)

## Table 1. Classification of soil and slope

| Slope \ Soil | (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) |

In parenthesis 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 were still able to disqualify the site at large, such as its wildlife or conversation habitat value, its proximity to road systems and the mountain communities themselves and the interest/willingness of farmers to engage in agroforestry in the first place.

## Table 2. 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 |

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

## Criteria & Indicators for Agroforestry Systems

Based on the data collected and reviewed literature different criteria & indicators for evaluating the site sustainability of the agroforestry systems were developed. These criteria can be subdivided into 3 areas: social, environmental and economical. A selection of indicators is listed below in Table 3.

### Table 3. Selected Indicators

| Social | Environmental | Economical |
|---|---|---|
| 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/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 |

These indicators were at the point of project completion still preliminary and subject to further discussion with communities and decision makers in terms of whether and how they could be used on a national level.

## Demonstration of Agroforestry Systems

The project constructed three demonstration agroforestry systems in Pinglin, Yuchi and Kalala respectively, two of them working with betel nut, one working with tea, thus representing fairly commonly grown agricultural crops.

## Betel nut plantations

Betel nut (*Areca catechu*) plantations are ubiquitous throughout Chinese Taipei. In 1997 the annual betel nut production income was USD 400 million and accounted for 4.2% of the total value of all agricultural products in the economy, covering 56,542ha. Of special attraction were the 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 searching for a boost to their current income.

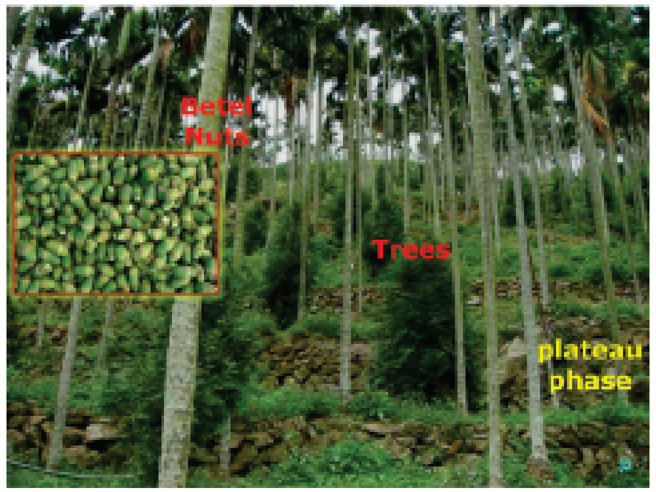


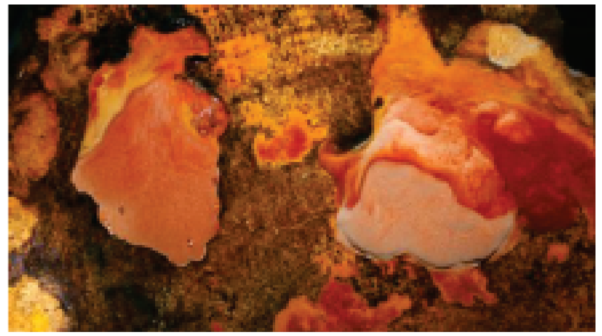

Figure 1. Betel nut agroforestry systems



One of the problems with betel nut plantations is the soil erosion they cause on steeper slopes as the crown cover is comparatively low, while soil organic content and soil porosity are even lower. This has led to an outcry by public and conservation groups regarding its negative hydrological effects. Agroforestry has been suggested as a possible 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, betel nut plantations were interplanted with different other species in three different treatments: no thinning, thinning and clear-cutting, to see which of the treatments would be hydrologically most beneficial. Surface runoff and soil losses were measured afterwards. Generally, if possible, betel nuts should be planted on flat terraces, while the slopes themselves are preferred for tree interplanting. In Yuchi the plantations were at about 750m, while in Kalala they were located at 200m above sea level.

### Betel nut + Stout camphor tree

The Stout camphor tree (*Cinnamomum kanehirae*) is an endangered native tree in Chinese Taipei, for a long time overharvested as it was the host of one of the most valuable brown rot fungi in the world, *Antrodia cinnamomea*. It is a broad-leafed evergreen tree that grows at altitudes of 450-2000 meters in low-elevation mountainous terrain.



*Antrodia cinnamomea*

*Antrodia cinnamomea* is a rare medicinal mushroom, used by indigenous people, and well-known for its ability to heal health conditions,, especially those pertaining to the liver and cancerous growths. It can improve the metabolism, strength, and longevity and act against 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 produced artificially, significantly reducing the pressure on *C. kanehirae*.

### Agroforestry Recommendations

Generally, Betel nut palms can be used as nursing crops for *C. kanehirae* to be planted below and the palms only have to be thinned down from their original density. That being said, in the project it was first tested which approach – no treatment, thinning or clearcut – would yield better results, with the results showing clearly that even from an environmental hydrological perspective a complete replacement of the plantation with a different species would exacerbate the erosion problem. If replacement is desired, it may make sense to only gradually remove the trees. 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. The recommended interplanting density is 600 trees/ha.

*C. kanehirae* can grow as high as 2m within two years, making maintenance of the agroforestry system primarily a concern of the first year.

### 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 incomes are the sales of coffee, which made the integration of coffee into a multi-cropping system a fairly intuitive choice. Taiwanese camphor (*Cinnamomum osmophloeum*) was interplanted, while 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, parts of the betel nut plantations were left unmodified and coffee + *C. osmophloeum* were added, some received a thinning before interplanting and some were clear-cut. Afterwards runoff and soil losses were measured. Partial thinning was the best solution.

## Tea + Stout camphor tree

In Pinglin, a town very famous for its tea in Northern Chinese Taipei, the owners agreed to interplant *C. kanehirae*. Due to erosion issues, some old tea trees needed replacing and the general decrease of the tea price further incentivized farmers to look for alternatives. The trees were interplanted at different densities, at 2x1.5m, 3x3m and 4x4m.

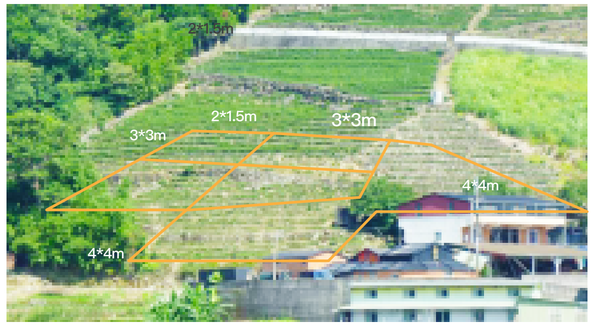
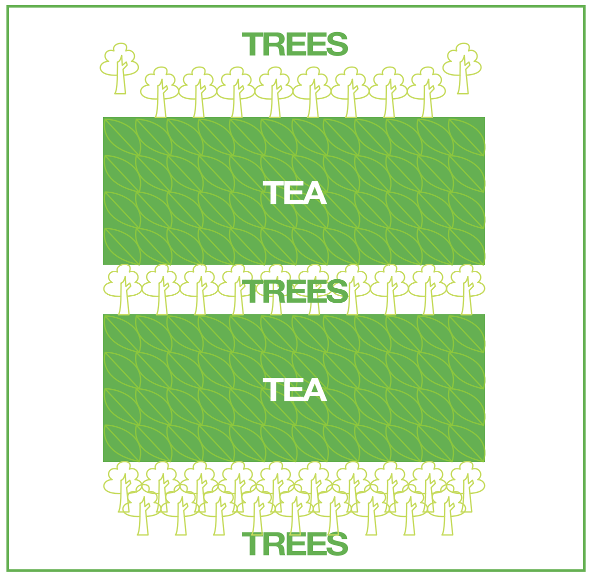



Figure. 2. *C. kanehirae* was interplanted at different densities




## Agroforestry Recommendations

Generally 600 trees/ha, that corresponds roughly to the widest spacing tested, are preferred if distributed evenly over the area. However, on steeper slopes or inaccessible sites, a tighter spacing can be used on the bottom edge of the area to establish a forest buffer strip. For the benches it is then (as described earlier) all the more important to have more than 70% grass cover.

If no bench terraces are part of the area, the trees should be planted in patches or contour strips throughout and the distance between the contour planting strips should be less than 10m. Same rules for the bottom forest buffer and grass.


## Other Research Suggestions

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 in horizontal direction to the slope and be about 10m apart.
- Intercropped trees should be deep rooted.
- Grass should cover bare land and exceed 70%.



# 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**

01/2015-12/2017, extended

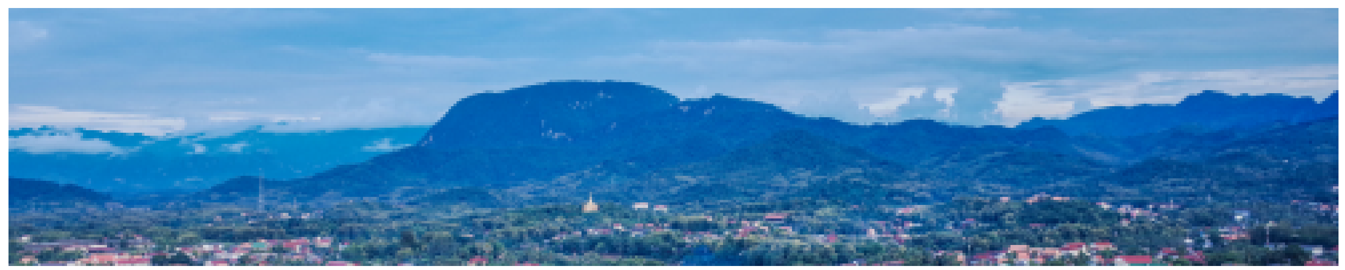
**Site Location**

Prek Thnot Watershed, Kampong Speu province, Cambodia

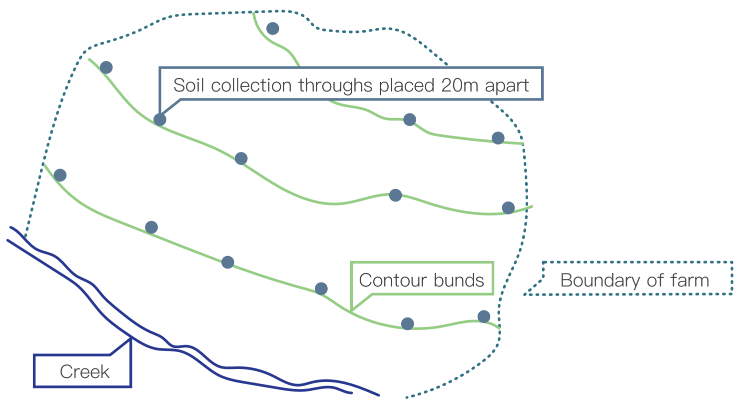
### Introduction

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 pediment covered with poor soils, mostly red-yellow podzols with low fertility. Farmers have long practiced and cultivated their crops in traditional ways without considering impacts on the ecological services of the watershed. Meanwhile, land use change, forest encroachment and other activities have also caused negative effects such as soil erosion, soil nutrient depletion, reservoir sedimentation, and flooding of low lying downstream areas.

The Institute of Forest and Wildlife Research and Development (IRD), with the support of APFNet, set out to improve current practices in such a way that it both provides important watershed ecosystem services and furthers socio-economic development in the landscape while also demonstrating agroforestry as a tool for soil and water conservation technologies. 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 slope close to the stream. A number of soil and water conservation techniques were tested. The project supported the farmers with seedlings, crops and other materials, provided technical knowledge and taught new skills through training programs and field practice. Through theoretical and hands-on training, the farmers learned how to design agroforestry plots and use soil and water conservation techniques on their farm. The sites were terraced using an A-frame, a simple tool for laying out contour lines across a slope to locate contour lines on their land, which will eventually help to retain topsoil and slow surface runoff.



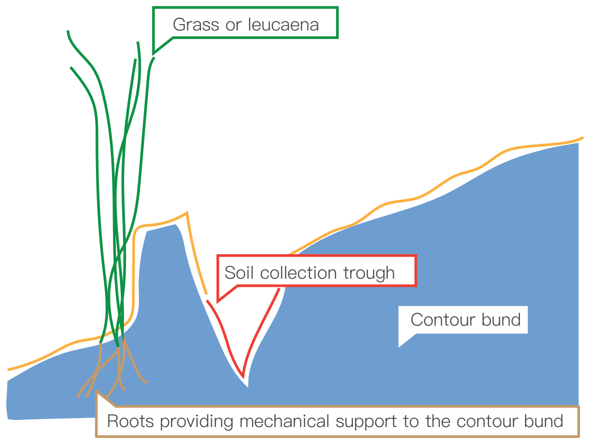




Figure 1. A layout of contour lines in the agroforestry plot (left); a design of the contour bund and the set-up of soil collection troughs (right)

Soil and water control measures include contour canals planted with hedgerows, and also fascines (bundle of twigs), which are ideal for controlling runoff of fine sandy soils. Some farmers planted lemongrass to stabilize the contour bunds. The canal is intended to collect the topsoil eroded from the upper portion by using collecting troughs while rain collectors were also installed on the sites for estimating rainfall received in the area. The rim of the canal at the lower part will be a small mound/bund to help catch more water during heavy rains.

Figure 2. Farmers used an A-Frame to develop contour lines

Figure 3. Planting lemon grass on contour lines

Figure 4. Agroforestry research plot

Figure 5. Soil erosion collection

With the assistance and technical support from the project, the farmers used a new technique called tree intercropping, which integrates timber trees, fruit trees and annual crops in the same area. 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 (lemon grass, pineapple, cassava etc) and vegetables. Those selected trees and crops were based on the farmers' respective interest and needs in their household consumption. The fruit trees were mostly 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 trees on the boundary of the plot to help restore valuable timber species that have been lost in their forest area.

The project involved farmers in monitoring the soil erosion and rainfall on their farm, so they could understand the importance of the soil and water control measures. Along the contour canals, soil traps were installed to collect eroded soil, while rain collection jars were used to record rainfall. The data was collected by farmers every month. The concept of this research is to raise awareness amongst the farmers about the amount of soil lost and deposited to the waterways when working without appropriate soil and water control structures. In addition to proving that soil and water conservation measures can indeed control soil erosion, the soil traps can provide a quantitative estimate of the extent of erosion that can be contained by such structures.

After practicing the agroforestry techniques and soil and water conservation measures on their farmland, all of the participating farmers reported that the agroforestry techniques and soil and water conservation measures are beneficial to them. After only a few rainfall occurrences, farmers could see how contour canals and fascines trap a considerable amount of nutrient-rich topsoil (Table 1), which otherwise would have been lost.

**Table 1. Summary of soil properties**

| Soil properties | Location in the agroforestry plot | | Difference | Remarks |
|---|---|---|---|---|
| | Outside contour canal | Inside contour canal | | |
| Soil acidity % | 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 indicate that the average soil erosion in the Krang Deivay and Trapeang Chour communes are 14 and 32 metric tons per hectare per year, respectively. The results also indicate a significant increase in economic benefits compared to the baseline when using the new techniques (see the Table 2). The agroforestry products were used for household consumption rather than selling and some of the products were also shared with neighbors and relatives. The sales amount is very small at times but it has significantly reduced living expenses as various fruits and vegetables can be collected from their farms.

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 has increased. Mr. Siv Lim earned a total amount of USD 204/year in 2018 compared to only USD 81/year in 2016 (Table 2). He was able to buy a new smartphone and send his daughter to primary school; similarly, Mr Men Vorn said that because of his increased income, he now can support the education of his daughter who is also at primary school. The third farmer, Mr Kim Chap stated his income has improved since adopting the new techniques and he has been able to save enough money to build a new house. The last farmer, Mr Kim Mao was able to buy a new motorcycle, which he uses for local transport.

Figure 6. Pineapple was interplanted with other crops in an agroforestry plot.

Figure 7. Farmer Kim Chab showing various kinds of crops such as banana, pineapple and soursop on his agroforestry farm.

**Table 2. Income of 4 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 |

## Conclusion

Based on the clear evidence from this demonstration project, agroforestry measures reduced soil erosion and caused positive socioeconomic changes to the individual households. The changes include a decrease of erosion and runoff, an improvement of land productivity, as well as expense reductions leading to an income increase of the households. Agroforestry as an effective approach for soil and water conservation has been adopted among farmers to solve the problem of soil erosion on agricultural land.



# Conclusion

## Achievements

Over the past 11 years, APFNet worked together with policy makers, researchers, and farmers from seven economies, and a total land area of 118.56ha have been planted under agroforestry demonstration projects. 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 poor Nepalese women to improve their income, as well as their social status by helping them establish agroforestry systems focused on growing herbal aromatic species in the understory and supporting them to start their own business; (3) addressing poverty through the introduction of zoning techniques in agroforestry plots that maximize production on a small piece of land; and (4) reducing poverty while maintaining economic growth in Bos Thom village of Khna Por commune in Soth Nikum District, Siem Reap Province by 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) on the Indonesian island of Java 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 land productivity long-term; (9) in Chinese Taipei, an assessment system for proposed agroforestry plots and set of criteria & 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; (10) an agroforestry model to monitor soil and water indicators, while on-site convincing farmers of the importance of protection measures, has been developed.

## Opportunities and Challenges

Each of the projects has taught different lessons, with as many opportunities as challenges. When the international community is combining its 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 many 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, as the socio-economic and ecological circumstances vary as well. It is often even difficult to say with certainty which “technologies” are part of agroforestry and which ones are simply part of multifunctional forestry. Here, however, lies the beauty of the practice and many opportunities: as agroforestry often incorporates local practices into the system, it tends to be less viewed as something entirely new and more as an improvement, or alteration, of existing practices. The intensification of homegardens is a great example of this. Of course, these improvements also need to be disseminated to a wider audience through exchange visits, trainings and easily available materials.

In fact, 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 provide limited production for farmers, agroforestry can be a useful approach to increase that production. The same applies in the case of limited space: producing crops in 3 dimensions can easily top production in two dimensions, like traditional agriculture tends to focus on. 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 data is needed to determine in which situations this exactly is the case (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. A value chain analysis or marketing plan might be needed pre-project, while the possibility of teaching farmers how to further process their products to a) make them more accessible and b) 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.

## Lessons Learned

Successful agroforestry models bring policy makers, researchers, and farmers together. The policy makers 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 based on that may provide suggestions and recommendations for policy makers and farmers. The implementation, anything that is really happening on the ground, will finally be conducted by farmers. While such research is helpful, the actual agroforestry models, such as selecting trees and crops, should always be based on farmers' respective interest 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 one. 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. That being said, those priorities – should it be a jungle rubber plantation or rather a mixed rubber plantation – are on a continuum and need to be adapted to the respective situation. 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. If anything the diversity of approaches shown 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. At the current stage, we hope that by reading this brochure, you, the reader, will have learned a useful thing or two as well.

# References


Atangana, A., Khasa, D., Chang, S., & Degrande, A. (2014). Agroforestry for Soil Conservation. Tropical Agroforestry. 203-216. 10.1007/978-94-007-7723-1_9.

Cheel, J., Theoduloz, C., Rodríguez, J., & Schmeda-Hirschmann, G. (2005). Free radical scavengers and antioxidants from Lemongrass (*Cymbopogon citratus* (DC.) Stapf.). Journal of agricultural and food chemistry, 53(7), 2511-2517.

De Schutter, O. (2011). Agroecology and the Right to Food. Report presented at the 16th Session of the United Nations Human Rights Council [A/HRC/16/49]

FAO (2017). Agroforestry for landscape restoration. Rome.

Frayer, J., Müller, D., Sun, Z., Munroe, D., & Xu, J. (2014). Processes underlying 50 years of local forest-cover change in Yunnan, China. Forests, 5(12), 3257–3273.

Lynn IH, Manderson AK, Page MJ, Harmsworth GR, Eyles GO, Douglas GB, Mackay AD, Newsome PJF 2009, Land use capability survey handbook – a New Zealand handbook for the classification of land 3rd ed. https://www.landcareresearch.co.nz/__data/assets/pdf_file/0017/50048/luc_handbook.pdf

Lee, Y. H., Park, J. D., Beak, N. I., Kim, S. I., & Ahn, B. Z. (1995). In vitro and in vivo antitumoral phenanthrenes from the aerial parts of *Dendrobium nobile*. Planta medica, 61(02), 178-180.

Lin, C. C., Huang, P. C., & Lin, J. M. (2000). Antioxidant and hepatoprotective effects of *Anoectochilus formosanus* and *Gynostemma pentaphyllum*. The American journal of Chinese medicine, 28(01), 87-96.

Malhotra, A., Schuler, SR., Boender, C. (2002). Measuring women's empowerment as a variable in international development. World Bank.

Mallavarapu, G. R., Rao, B. R., Kaul, P. N., Ramesh, S., & Bhattacharya, A. K. (1998). Volatile constituents of the essential oils of the seeds and the herb of palmarosa (*Cymbopogon martinii* (Roxb.) Wats. var. *motia* Burk.). Flavour and fragrance journal, 13(3), 167-169.

Nakahara, K., Alzoreky, N. S., Yoshihashi, T., Nguyen, H. T., & Trakoontivakorn, G. (2013). Chemical composition and antifungal activity of essential oil from *Cymbopogon nardus* (citronella grass). Japan Agricultural Research Quarterly: JARQ, 37(4), 249-252.

National Population and Housing Census 2011, Volume 01. Government of Nepal, National Planning Commission Secretariat, Central Bureau of Statistics, Kathmandu, Nepal. November, 2012.

Pye-Smith, C. (2011). Rich rewards for rubber? Research in Indonesia is exploring how smallholders can increase rubber production, retain biodiversity and provide additional environmental benefits. World Agroforestry Centre, Library Department.

Reij, C. (2009). Agroenvironmental Transformation in the Sahel. IFPRI Discussion Paper 00914

Song, J. L., Wang, L., & Han, F. J. (2013). The retrospective analysis of *Rhizoma bletillae* used as an antitumor medicine. Inf. Tradit. Chin. Med, 30, 148-150.

Senin. (2009). Impact of Landuse changed on Upper Bengawan Solo Watershed. [Blog Post]. Retrieved 18 April 2019 from http://toto-atlasfordisaster.blogspot.com/2009/02/impact-of-landuse-changed-on-upper.html

The World Bank (2014). Where have all the poor gone? Cambodia Poverty Assessment 2013. A World Bank country study, second edition.

Toensmeier, E. (2016). The carbon farming solution: a global toolkit of perennial crops and regenerative agriculture practices for climate change mitigation and food security. Chapter 3. Chelsea Green Publishing.

Wolde, Zinabu. (2015). The Role of Agroforestry in Soil and Water Conservation. Lambert Academic publishing. Germany.