Asia-Pacific Network for Sustainable Forest Management and Rehabilitation

Technical Handbook **for the Technologies Used by the project "*Integrated Forest Ecosystem Management Planning and Demonstration Project in Greater Mekong Sub-region (Cambodia)*"**

Final report

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Contents

Executive summary

The project "Integrated Forest Ecosystem Management Planning and Demonstration Project in Greater Mekong Sub-region (Cambodia)" aims to rehabilitate ecological services and product provisioning services of forests in Cambodia through improvement of community forest management and strengthening state-owned forest conservation, so as to contribute to sustainable forest management in Greater Mekong Sub-region.

The main purpose of this document is to summarize relevant technologies based on activities carried out and outputs obtained by the project. These technologies cover restoration of degraded forest (open area, severely degraded forest, and moderately degraded forest), establishment of cluster Miyawaki, sampling using K-Tree method, data collection and forest monitoring using geotagged photos, establishment of agroforestry and home garden farming systems, establishment and maintenance of woodlot, fuel management as well as the experiences of constructing and installing forest watcher system.

Besides, summarizing technology introduced in the project, the document also captured the challenges encountered during the project implementation with possible solution for each challenge. Therefore, this document will be useful to extension workers, forestry authorities, forestry practitioners such as local Forestry Administration and farmers for scaling up the relevant activities.

I Background

Prek Thnot is one of the watersheds that have the high risk of impairment of its watershed function. Most of the forest cover in Prek Thnot watershed are found in the northwestern part although few patches of forests could still found on the downstream part. Prek Thnot is facing threats from 1) Unabated illegal cutting of the forest areas, particularly those adjacent or within the Cardamom Mountains; 2) Fuelwood and charcoal industry - the forests in Prek Thnot watershed are major source of wood energy for Phnom Penh and nearby provincial towns; 3) Expansion of farms and agro-industries - The poor soil conditions of many smallholder farms and Economic Land Concession (ELC) contribute to soil erosion; and 4) Settlers migrating from the nearby districts within Kampong Speu province and from other provinces.

The project "**Integrated Forest Ecosystem Management Planning and Demonstration Project in Greater Mekong Sub-region (Cambodia**)" aims to rehabilitate ecological services and product provisioning services of forests in Cambodia through improvement of community forest management and strengthening state-owned forest conservation, so as to contribute to sustainable forest management in Greater Mekong Sub-region. The Cambodian sites of Integrated Forest Ecosystem Management Planning and Demonstration Project in Greater Mekong Sub-region are located in three provinces, i.e., Kampong Speu (for restoration, agroforestry and home garden models), Siem Reap (for the Forest Watcher system) and Takeo (for Forest Watcher system) provinces. The restoration models are implemented in Damrey Chakthlork CF. The CF has a total area of 1,452 hectares and selected to demonstrate the improvement of CF management through developing restoration technologies and demonstrating integrated management models.

The project has four specific objectives:

- To develop a model for community forest management by strengthening CF management and testing appropriate restoration and silviculture technology;
- To mitigate the dependence of community to forests by improving household farming systems;
- To enhance forest protection through adopting advanced forest monitoring system (Forest Watcher); and
- To extend achievements and related techniques in Cambodia and GMS by demonstration and experiences sharing.

The project will disseminate technologies to various groups such as forestry authorities, forestry practitioners (mainly local FA and farmers), and foresters in other economic entities of the Great Mekong Sub-regions. One of the outputs of the project is the formulation of a handbook for the integrated community forest management and for the forest watcher system operation.

II Purpose of the Document

The main purpose of this document is to summarize relevant technologies based on activities carried out and outputs obtained by the project. These technologies cover restoration of degraded community forest, establishment of agroforestry and home garden farming systems, as well as the experiences of constructing and installing forest watcher system.

III Target Users of the Handbook

The main target of this technical handbook is to provide technologies gained from this project to extension workers as well as forestry authorities, forestry practitioners such as local Forestry Administration and farmers, and foresters in other economic entities of the Great Mekong Sub-regions.

IV Toolkits

4.1 Restoration Design

This restoration design is intended for three types of degraded forestlands in the community forests, namely: deforested area, severely degraded forest, and moderately degraded forests. The different sites were classified into blocks where the different restoration models were applied. The proposed techniques were derived from the experience of the pilot restoration in each type of degraded forestlands. The site where the different restoration techniques were tested represented different degrees of forest disturbances (Figure 1). The restoration plots cover an area of 12 hectares representing deforested, severely degraded and moderately degraded sites (Figure 2). Another site, representing the dense forest was applied with tending and silvicultural treatments only.

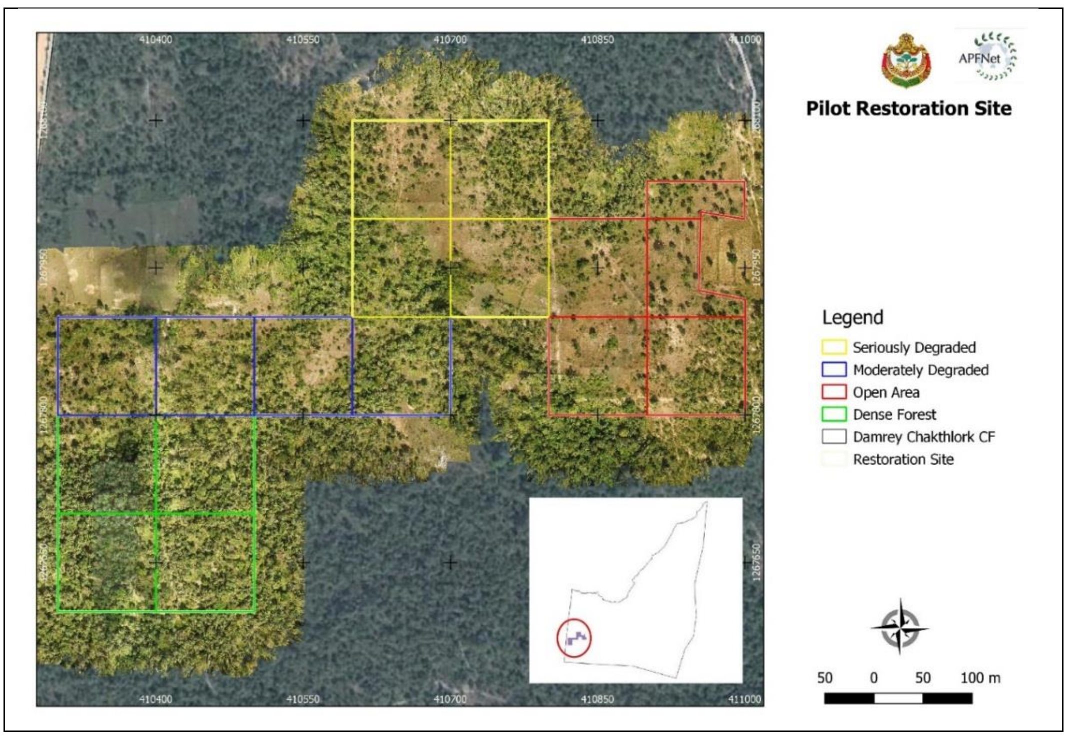

Figure 1. Vegetative cover of the site

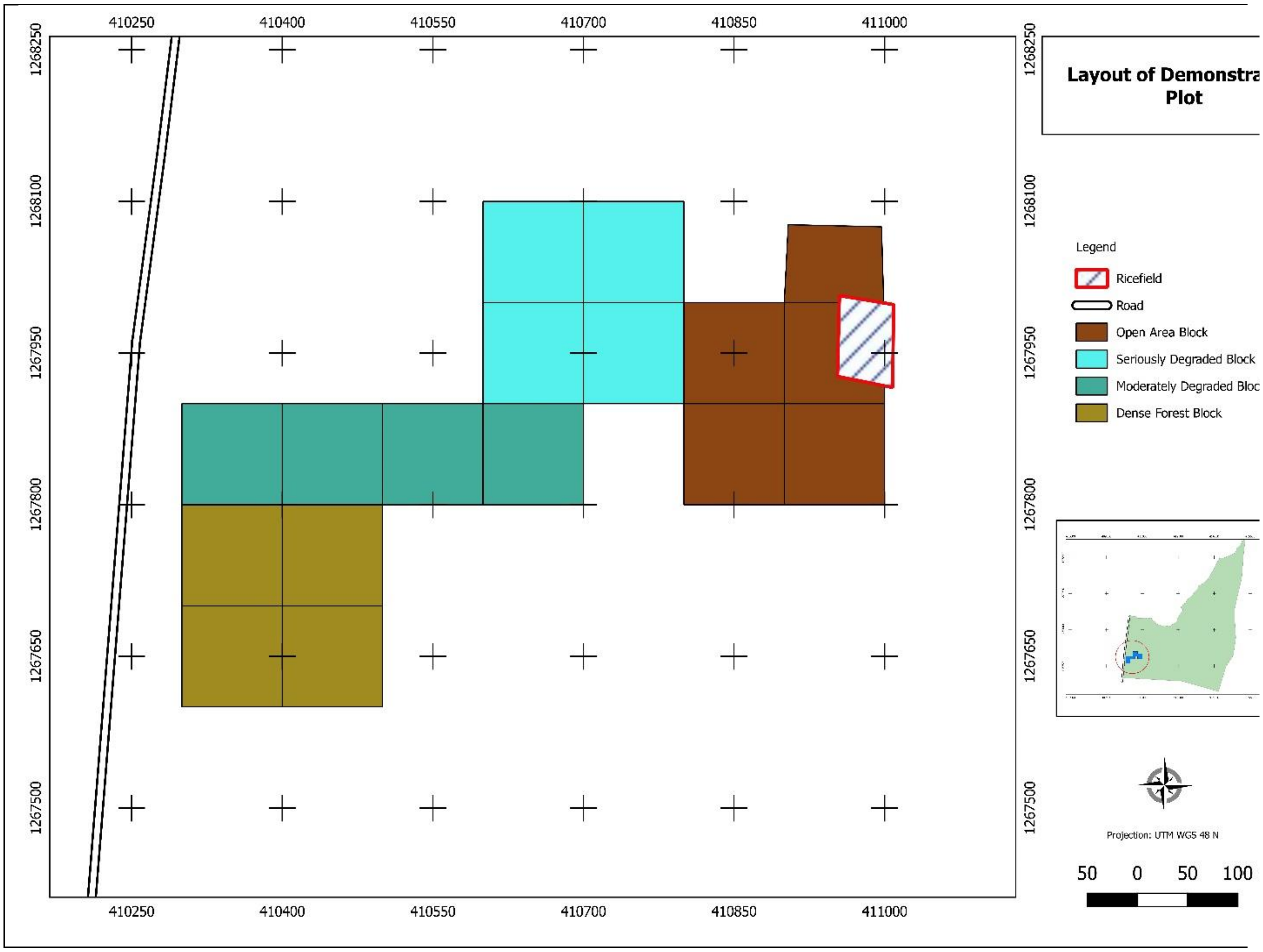

Figure 2. Layout of the restoration blocks

Soil Condition: Restoring degraded lands, particularly in Siem Reap is very challenging since the soils are exposed to physical elements after logging and slash and burn farming. The soils get dry very fast as they could hardly hold moisture.

Drainage: Some restoration areas are flat and waterlogged making restoration very challenging. During rainy season the site was too much water while during dry season it was too dry which need a drainage system during rainy season and also watering during dry season.

Restoration Design: The contents of restoration design include tree species to be used, existing plants to be retained, soil preparation method, planting density/spacing, planting method and time, and maintenance requirements. The design was carried out in the field block by block, while referring to advices given by international consultants and plot data of forest investigation.

Weed Infestation: Weeds were observed in the restoration area. The weeds do not only compete with seedlings for nutrient, but also become potential fuel during dry season. Therefore, clearing competing weeds to speed up the progress of forest succession is needed. Clearing was conducted twice a year to release the desirable timber crops from weed competition and also minimizing forest fires.

Stray Animals: The project has constructed a fence around the demonstration plots to keep away stray animals, like cattle, from grazing and damaging planted seedlings. The fence has to be maintained or repaired annually because the project experienced fences damaged caused by cattle.

Forest Fires: The project site is continuously threated by fire that may emanate from torches and cigarette butts that are thrown by the passersby. Fire frequently happened in the adjoining areas which pose serious threat to the established plantations. To prevent the spread of fire, the project has constructed a fireline around the project site. This fireline needs to be maintained continuously. The project team also applied controlled burning to control fuel so as to reduce the risk of fires from the forest litters and grasses.

4.1.1 Tree selection

Understanding of the clear objectives of forest restoration is very important for species selection. Species used for the restoration project should be beneficial not only for ecological adaptability but also for social and economic benefits. Below are some criteria for species selection:

- Natural species dominance: This criterion evaluates dominance of individual species in the reference forest. Species that selected have to match with site condition in order to guarantee site adaptability and survival rate. In this regards, native tree species is encouraged.

- Social value: This criterion identified locally outstanding species that are considered important to the local people in terms of food, materials, medicine and/or cultural practices.

- Technical constraints: Some tree species which may grow well but have limited technical constrain and thus lead to very high cost for restoration. This criterion identifies cost-effective techniques for successful species propagation.

- Economic benefits: Beside the above mentioned criteria, economic benefit of species selection for restoration project have to be considered for successful and sustainability of restoration activities.

4.1.2 Technical design for restoration

4.1.2.1 Restoration for deforested area

Condition of the Site: Deforested areas/open areas is so degraded and there is only around 10% of forest in the total area. The forest regrowth has not occurred and which is mostly occupied by grasses and shrubs. Most of the area are waterlogged. Forest fire was observed almost every year.

Restoration Objectives. The main objective of reforestation in this area is to increase forest cover for soil conservation and for fire protection by introducing evergreen tree species.

Figure 3. Site condition for degraded/open area

Soil preparation: Site clearance and soil preparation was carried out in early rainy season to have minimal disturbance to land such as soil erosion. For high survival rate of planted seedlings, the pit holes measuring 40x40x40 cm were dug.

Figure 4. Planting activities in restoration block

Planting requirement: The activities involve backfilling of soil, application of fertilizer, planting of seedlings, weeding and maintenances of plantations. Seedlings with uniform sizes were kept for planting until they are at least one year old. Seedlings of each species were properly allocated and planted in designated sites. To boost growth performance of each seedling, 100 g of basal compound fertilizers were applied in each hole. Spacing for planting would be 2x3m, 3x3m or 3x4m depend on species.

Figure 5. Soil preparation and planting activities

Maintenance: The maintenance activities involve the following:

- Checking of survival after 1-2 moths was done and carried out enrichment planting was done to replace dead plants.
- Weeding and cultivation: Weeding was done for 1-3 years after planting and tended 2 to 3 times per year, once in the early, middle and late rainy season respectively. Tending was carried out and weeding once in September-October was done and tending and weeding once in April-May and October-November in the second and third year, respectively.
- Appropriate ground cover was kept during weeding to maintain ground temperature and humidity and promote tree growth. Noxious weeds were eliminated while benign weeds and shrubs were kept. During tending, tilling the soils around the plants to loosen the soil, ring

weeding and using the litters as mulch for the plants to reduce surface moisture evaporation, increase organic matters and inhibit growth of weeds. Care was taken not to hurt the stem, twig, leaves and root system of young trees during weeding, cultivation and ploughing, so as to avoid diseases of trees and keep the preserving rate.

- Fertilizer application: Compound fertilizer (15:15:15) 200g/tree at 25-40 cm were applied apart from seedling annually in the first 3 years in early May (before raining season).
- Pruning: Occasional pruning to trees with many low branches were done. Lower lateral branches were cut as well as diseased, weak and overcrowded branches. Pruning will enhance trunk with good shape.

Even survival of planted tree is recorded, restoring this type of degradation encountered many challenges including the following:

- Too much water during raining season and too little water during dry season which caused high mortality rate of planted seedlings
- Sandy soil which is less nutrient for tree growth which leads to poor growth performance.
- Free cattle browsing in the area which destroy the planted seedling.
- Forest fire cause by passerby through

To cope with the above mentioned challenges, the project team also introduced activities such as constructing drainage system to drain water out in rainy season and watering planted seedling during dry season, fertilizer application, fencing, forest fuel management and constructing fireline.

Responsible parties: Soil preparation, planting and maintenance were done by the community with technical guidance from the IRD staff. This is to ensure ownership of local community. However, some necessary working tools are handled by CF management team.

4.1.2.2 Restoration of severely degraded forest

Site condition: severely degraded forest areas are the area that used to have dense forest but was subjected to illegal logging destroying not only timber species. The illegal logging activities happened around 2000-2010. Most of tree species disappeared and the areas are invaded by weeds. Some part of this area are also waterlogged while forest cover occurs frequently.

Restoration Objectives. The main objective of reforestation in this area is to increase tree species for supplying fire wood in the community. Beside restoring for supplying fire wood, environmental protection and services is also expected from restoring this area.

Figure 6. Site condition of severely degraded area

Soil preparation: Restoration of severely degraded forest area was restored with firewood species. The dominant trees with good form were kept while small trees, shrub and weeds under the dominant trees were cleared. Site clearance and soil preparations were carried out in early rainy season. The pit holes with size of 40x40x30 cm were made for the planting of seedlings. The density of pit hole is 1x2m requiring 5,000 seedlings per hectare.

Planting requirement: The activities involve backfilling of soil, application of fertilizer, planting of seedlings, weeding and maintenances of plantations. It is good to keep in mind the followings:

- Seedling for planting should be in an even size and at least one year old
- Seedling are accurately allocated based their site requirement
- Applying 100 g basal compound fertilizer for each tree.

Figure 7. Soil preparation and planting activities

Maintenance: The maintenance followed the following:

- Checking the survival rate after 1-2 months and carried out enrichment planting immediately to dead plants.
- Weeding and cultivation: Weeding was conducted for 1-3 years after planting and tending was conducted for 2 to 3 times per year, once in the early, middle and late rainy season

respectively. Tending and weeding was conducted once in September-October and tending and weeding once in April-May and October-November in the second and third year, respectively.

- Appropriate ground cover was kept during weeding to maintain ground temperature and humidity and to promote tree growths. Noxious weeds are eliminated while benign weeds are shrubs are kept. During tending, tilling was made in the root zone and used the weed litters for mulching on the planting spots, to reduce surface moisture evaporation, increase organic matters and inhibit growth of weeds. Care was exercised not to damage the stems, twigs, leaves and root system of young trees during weeding, cultivation and ploughing, so as to avoid diseases of trees.
- Fertilizer application: Application of compound fertilizer (15:15:15) 200g/tree at 25-40 cm apart from seedling annually in the first 3 years in early May (before rainy season).

Survival of planted tree is recorded. Restoration of degraded areas encountered many challenges the include the following:

- Too much water during rainy season and too little water during dry season that cause high mortality of planted seedlings
- Sandy soils which holds less nutrient for tree growth resulted to poor growth performance.
- Loose cattle browsing in the area damaging the planted seedlings.
- Forest fire cause by passersby

To cope with the above mentioned challenges, the project team installed drainage system to drain water out in rainy season and watered the planted seedlings during dry season, applied fertilizers, constructed perimeter fence, conducted controlled burning, and constructed firelines.

Responsibility parties: Soil preparation, planting and maintenance was conducted by the community, with the technical guidance from project staff, and other preparations such as water tanks, water pipes, pumpers, a small simple tool house, and some working tools were handled by the CF management team with the assistances from village chief and other villagers.

4.1.2.3 Restoration of moderately degraded forest

Condition of the site: Moderately degraded forest areas are areas use to have dense forest before and illegal logging was happened. The illegal logging activities happened sometime in 2000-2010. Around 50% of forest remains in this area. Some part of this area are also waterlogged.

Restoration Objectives. The main objective of reforestation in this area is to increase high value timber tree species for supplying construction materials in the future. Aside from restoring the area to supply wood for construction material, environmental protection and services are also expected from the restoration.

Figure 8. Site condition of moderately degraded area

Soil preparation: Restoration of moderately degraded forest area is involved with multistory management, premium timber tree species. Vigorous high value trees with good form were maintained while untargeted trees were removed. The high value tree species were planted at 4x4m. Originally, the team tested planting black pepper in cluster under the forest with a density of 200-300 clusters per hectare and 3-5 seedlings per cluster. But this plant did not grow well and were not able to survive. Under this model, 650 seedlings of high value tree species are required per hectare.

Planting requirement: The activities involve backfilling of soil, application of fertilizer, planting of seedlings, weeding and maintenances of plantations. It is good to keep in mind the following:

- Seedling for planting should be in of even size and at least one year old
- Seedling are accurately allocated to their designated sites
- Application of 100 g basal compound fertilizer for each tree.

Figure 9. Soil preparation and planting activities

Maintenance:

- The survival rate was checked after 1-2 months, and carried out enrichment planting to the dead plants.
- Weeding and cultivation: Weeding was conducted for 1-3 years after planting and continued for 2 to 3 times per year, once in the early, middle and late rainy season respectively. Tending and weeding were carried out once in September-October in the afforestation year and tending and weeding once in April-May and October-November in the second and third year, respectively.
- Appropriate ground cover was kept during weeding to maintain ground temperature and humidity and promote tree growth. Noxious weeds were eliminated while benign weeds and shrubs were kept. During tending, the soils around the root zone were loosened, and use the weed litters for mulching the plants, to keep the moisture, increase organic matters and inhibit growth of weeds. Care was exercised not to damage the stem, twig, leaves and root system of young trees during weeding, cultivation and ploughing, to avoid diseases of planted seedlings.
- Fertilizer application: Compound fertilizer (15:15:15) 200g/tree at 25-40 cm were applied apart from seedling annually in the first 3 years in early May (before raining season).

The survival of planted tree is recorded, restoring this type of degradation encountered many challenges including the following:

- Too much water during raining season and too little water during dry season which caused high mortality rate of planted seedlings
- Sandy soil which is less nutrient for tree growth which leads to poor growth performance.
- Free cattle browsing in the area which destroy the planted seedling.

- Forest fire cause by passerby through

To cope with the above mentioned challenges, the project team have constructed the drainage system to drain water out in rainy season and watering planted seedling during dry season, applied fertilizers, construct fence, conduct controlled burning, and constructed firelines.

Responsible parties: Soil preparation, planting and maintenance were conducted by the CF members, with the technical guidance from project staffs. Other infrastructures such as water tanks, water pipes, pumpers, a small simple tool house, and some working tools were provided by the CF management team with the assistances from village chief and other villagers.

4.2 Establishing the cluster-Miyawaki plot

During the establishment phase, the project suffered heavy mortality. The seedlings died after reaching 1 meter in height. It was suspected that the species introduced, as provide in the restoration design, are not suitable to the site. Thus, a small experiment of alternate restoration method was conducted using the Miyawaki method. The Miyawaki method required dense planting using a mix of several species (climax, pioneer and some fruit bearing trees) over an area at close spacing. The general steps of the Miyawaki method follows the following:

4.2.1 Soil survey

Detailed soil analysis was done to assess the following soil parameters:

- Soil texture
- Soil organic carbon
- Nitrogen
- Soil pH
- Visible evidence of micro or macro fauna and the soil

The above listed soil parameter is very important in determining and quantifying the materials that will be used for soil nourishment. Followings are nourishment materials used:

- Agricultural crop husk
- Coco peat or sugarcane bagasse
- Farm yard manure
- Rice straw
- Liquid soil microbiology enhancer
- Solid soil microbiology enhancer

4.2.2 Native species and biomass survey

Native species survey focuses on the following activities:

- Visiting local forests and conducting potential native vegetation survey
- Collecting and validating primary and secondary data
- Gathering quantitative and qualitative data which are important in creation of species combination.
- Allocate each species to a different layer in the forest

- Find suppliers of healthy seedlings of species required
- Ensure genetic authenticity of seedling and genetic diversity among trees of same species
- Final quantification and order list is created to balance the layers and ensure best combination of major, supporting and minor species.

4.2.3 Soil preparation

- Uniform and consistent biomass mixture preparation
- Enrichment biomass mixture using soil microbiology enhancers
- Uniform mixing of biomass into soil up to a depth of 1 meter
- Mound securing and finishing
- Soil nourishment at different levels during excavation using soil microbiology enhancers.

4.2.4 Planting

- The species are distributed as per layers in accordance with Miyawaki method. The Miyawaki method require dense planting using a mix of several species (climax, pioneer and some fruit bearing trees) over an area at close spacing.
- Plantation instructions given and followed as per requirement of the method. The area proposed for the Miyawaki technique is within severely degraded areas.
- Rood zones secured during plantation using soil microbiology enhancers
- Each sapling staked using appropriate materials
- Forest floor mulched as per standards set by the method.

4.2.5 Maintenance and monitoring

- Maintenance training given with pre-defined standards
- Site specific maintenance needs to be evaluated
- Project monitoring to assess overall results
- Regular site evaluation to ensure that the forest progresses towards becoming self-sustainable within 2-3 year

In this project, the Miyawaki technique was applied in severely degraded areas with a size of 30 m X 100 m. The luxury species (hard wood) like Dipterocarpus, *Pterocarpus macrocarpus* and Dalbergia were mixed with the fast-growing species such as acacia and *Acacia siamensis* using seedling and direct seeds planted at 1 m x 1 m apart. This method was tried again after encountering some low survival using conventional planting method. As a result of the above-mentioned method, the survival of seedling have increased which was more than 80% of planted seedlings one year after planting.

4.3 Plant Sampling Using K-Tree Method

K-Tree sampling is one of the distance sampling methods based on point-to-tree distance measurements. It is also known as the fixed count or plotless method. This sampling method is a practical field method for forest inventories and ecological surveys (Sohrabi. 2018). The work begin by locating a random point to be used as the center of the plot. For laying out these points as a sampling unit, one can use one of the sampling designs, like simple random or systematic sampling. After this, the sampling proceeds as follows:

1. Select at least 10 permanent monitoring spots in each area to be monitored
2. Each spot should at least have been planted with at least 50 trees.
3. Take note of the coordinates of the monitoring spot and install a painted stake with label.
4. Locate one planted tree and take note of the species, height (in meters) and root collar diameter (if less than 1.5 meter in height) or DBH if the plant already reaches sapling stage.
5. Locate the next planted tree and measure its distance from the first tree. Repeat the measurement until the last 10 trees has been measured. The distance of the 10th tree will be the radius of the plot.
6. Determine the area of the plot using the radius of the plot.
7. Compute the tree density and survival of the plot by dividing the tree with the area of the plot. Compute the other parameters such as survival and growth. Revisit the same spot the following year and repeat the measurements.
8. The tree density and survival will be computed by dividing the tree with the area of the plot

4.4 Monitoring Using Geotagged Photos

Geotagging is the process of adding geographical information to various media in the form of metadata. The metadata usually consists of coordinates like latitude and longitude, but may even include altitude, distance and place names (Forest Management Bureau, 2013). There are numerous applications of geotagging for both human and physical geography as a method of data collection. Katharine *et al* (2012) reported some suggestions for practical applications include taking geotagged photographs of:

- Shops in clone towns to identify distribution of national chain stores versus independent retailers;
- Trees and plants in different areas during tree identification activities. This is particularly useful if we are struggling to identify a plant/tree as they can take the photograph and location information back and investigate further when they have access to the Internet;
- Gully systems to show distribution and scale at different locations;
- Vegetation successions along a transect;
- Signatures of crime such as graffiti, derelict buildings, etc. to identify areas of crime within a larger region;
- Coastal erosion along a beach transect to identify spatial patterns of coastal erosion;
- A hazardous region over time to investigate temporal density of crowds in different areas with a view to using these data to better deploy resources for hazard management and
- The human or physical landscape and using the annotation space as a reflective tool.

There are 4 steps in taking geotagged photos for data collection:

1. Field visit: Identify location and specific site to visit
2. Establishing stable GPS signal: There are two steps have to be taken into account for establishing stable GPS signal. First is to enable GPS on device and second is to run GPS status and adjusting GPS satellite error which is less than 10m.
3. Taking geotagged photos: After establishing stable GPS, we have to take geotagged photos. Taking geotagged photo involves with opening camara, setting camara for geotagged photo, and taking the photo. Before taking photo, we have to make sure that a fixed GPS signal is acquired and a GPS enable icon is present and not blinking on the camara screen.
4. Consolidate geotagged photos in computers: Copy and pass all geotagged photos into the folder where we want to store it for other uses.

4.5 Agroforestry and home garden

Aside from forest restoration, the project also tested several methods that will boost agricultural production. Two technologies were used: the Agroforestry, Home Garden and Woodlot Development.

4.5.1 Agroforestry

4.5.1.1 Identifying appropriate agroforestry system

Agroforestry systems are more complex than monocultures and may need considerable effort, time and expertise for their successful uptake. It is important, therefore, to consider the costs and benefits of agroforestry. The suitability of an agroforestry system for a particular site depends on the needs of the family or community and the potential benefits of the system.

Reasons for agroforestry adoption include: increasing farm production or income; diversifying production, such as food, fiber, fodder, fruit, construction materials, medicine, honey, dyes, resins and gums; and providing environmental services that help increase food security and improve household livelihoods.

If agroforestry is considered as useful system in helping people to meet the needs of land users, the next step is to determine which agroforestry system is most suitable in the prevailing economic, social and environmental conditions. Three key elements to be considered in this decision-making process are:

- Land characteristics, such as topography and landform.
- Soil fertility and drainage, and
- Water resources, and climate and other environmental conditions, such as precipitation, temperature and seasonal variations.

4.5.1.2 Improving, adapting and designing agroforestry system

In many areas, agroforestry has been a traditional land use for a long time. Surveys of local knowledge and practices, including the agroforestry species (both native and exotic) used in an area, are highly recommended and will help decision-making on the adoption of agroforestry. Information can be gathered through field observations, questionnaires and consultations with local residents. Survey results can be used to evaluate existing practices, explore possible improvements, and help design agroforestry systems. Where an agroforestry system already exists, it may be most appropriate to look to improve that system rather than to introduce an entirely new system. Traditional systems will be well-adapted to local circumstances, although it may be possible to make them more efficient, and local farmers are likely to be more willing to modify an existing system than to introduce an unfamiliar one.

The adaptation or design of an agroforestry system is the process of choosing and arranging components spatially and temporally. Common components of an agroforestry system are:

- Trees or other woody perennials – trees can provide fruit, fodder, wood fuel, timber and other products, as well as environmental services such as soil fertility replenishment, erosion control and carbon sequestration. Trees normally remain in a landscape for many years, with rotation lengths depending on species and desired end-products.
- Crops or forage such as grains, tubers, roots, vegetables and even flowers - the rotation for crops is generally much shorter than for trees.
- Animals – animals for dairy, meat and egg production, as well as fish, snails and other edible organisms.

The size of plots available for agroforestry can vary significantly, from less than one hectare to many hectares. Some agroforestry systems may not be practical (or economically feasible) below a certain size; for example, very small plots may be unable to sustain livestock. The location of a plot – in terms of access, slope, and possibilities for future land-use change – can also affect agroforestry design. Environmental factors such as climate, soil, drainage, sunlight and precipitation will help determine the trees, agricultural crops and livestock that can be grown or raised in a given area.

4.5.1.3 Establishing and managing an agroforestry system

The establishment of an agroforestry system involves, among other things, site preparation, plant and animal material selection, planting, and marketing. The availability of suitable materials and adequate financial and technical inputs is crucial. The nature of site preparation varies according to the land type and agroforestry system. It may be minimal (e.g. preparing holes for planting seedlings, or weeding around and protecting naturally regenerated seedlings), or it may involve extensive works, such as land clearing, terracing, fencing, irrigation and fertilization. Such works require appropriate machinery and tools, which can be shared among farmers and communities as a way of reducing (and sharing) costs. The selection of plant and animal material is an important element in the success of agroforestry establishment.

1. Tree seedlings can be purchased from commercial nurseries or produced by the land owners/managers themselves, depending on needs and situations. Smallholders may be able to purchase tree seedlings at competitive rates from local nurseries. In some cases, it may be possible to transplant seedlings from nearby natural forests (where this is legal), although survival rates may be relatively low because of the stresses imposed on the seedlings by the transplanting process.
2. Crop seeds may be purchased in local markets or obtained from self-production. High-quality crop seeds should be chosen. Experienced local farmers are likely to be good sources of information. Trials should be conducted to test the quality and survival rate of seeds.
3. Animals can be bought in markets or from neighbors; only healthy animals should be purchased, and they should be provided with adequate shelter and food to ensure their continued growth and good health. In any given agroforestry system, it should be clear who has primary responsibility for the care and security of the animals and for obtaining animal products.

Beside above-mentioned elements, marketing is another essential element of agroforestry in which the products generated by the system are converted into actual income. It involves the following steps:

- Selecting target markets;
- Adding value to products;
- Getting products to prospective buyers;
- Setting the price; and
- Promoting the products.

4.5.1.4 Maintaining and monitoring an agroforestry system

Maintenance is needed to ensure that an agroforestry system functions effectively. Common maintenance practices include:

- Seedling protection

- Weed control
- Pest control
- Animal browsing
- Fertilization irrigation
- Thinning and pruning
- Coppicing
- Harvesting

Agroforestry systems are dynamic. Their performance, and the impacts of outside factors, should be monitored. The management plan should be adapted to changing circumstances and in achieving production goals. Management changes may be required when trees start competing with crops for space, sunlight and nutrients; markets for products change; and there are changes in labor requirements or availability.

4.5.2 Home garden

Food security has been an issue and hounding the rural areas. Acknowledging this perennial problem, the project considered establishing a model home garden and agroforestry farms to encourage the farmers to improve their farms. The technology addresses periodic problems of food security among the farmers especially during dry season and increasing farm production and income of a small piece of land. The technology also aims to minimize the impacts of agriculture to the soil. This handbook intends to share the experience of IRD in developing the home garden using multistorey cropping technique and provide a guide on how the home garden will be implemented. Simplified illustrations how the home garden will be conducted was provided for ease in understanding.

The home gardens were implemented in Krang Serei village, Kirivoan commune, Phnom Srouch district, Kampong Speu province. The site is a farming community and adjacent to a community forest. While the main occupation is farming, most of the farmers use the traditional farming methods. During dry season, farms are generally unproductive due to lack of water. The combination of annuals and perennials can address the unproductive state of the farms during dry season. Two farmer cooperators participated in the project to develop portion of their lot for home garden: Mr. Long Him, chief of Krang Serei CF, and Mrs. Prak Khoeun, Krang Serei village deputy chief. Mr. Long Him, has 3,815 sq.m. and Mrs. Prak Khoeun, has 2,337 sq.m. for home gardens. Before the project, the farmers grow only vegetables planting only one kind of crops in their lots and there is no definite pattern of planting. They only change the crops when there is a change of the demand in the market.

4.5.2.1 Technical Design and Purpose of the Home Garden

The project helped the farmers to developed a farm plan where the land is divided into rows for planting fruit trees and vegetables, after they cooperate with the project. The home garden of the farmer was subdivided into compartments with the rows of bananas, the rows spaced at 10 meters apart along the east-west direction. The bananas that occupy the upper story canopy were planted at 3-meter x 10-meter distance. The vegetables were planted In between the rows of the bananas.

Crop Rotation. The subdivision of farms to rows allows the rotation of crops (See Figure 10). The rotation planting of crops is intended to disrupt the life cycle of soil borne-pathogen and to prevent the depletion of soil nutrients. The farmers were advised to make an alternate planting of the compartment with leguminous and a non-leguminous plant to continuously supply the soil with nitrogen. The continuous planting of single crop over the same piece of land will have the tendency to deplete a specific nutrient of the soil. The rotation of different plants will replenish some nutrients to the soil through the litters that the plants will deposit to the soil.

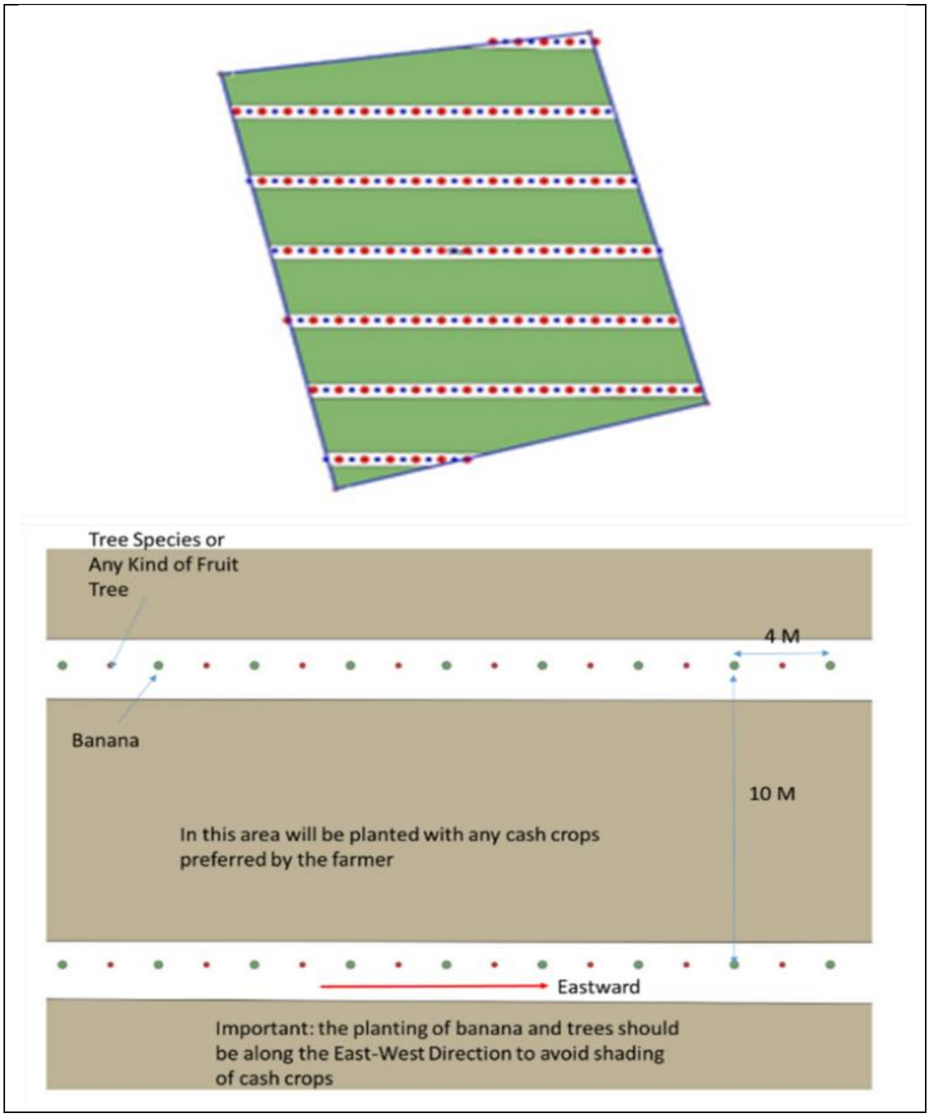

Figure 10. Spatial arrangements of the crops in the home garden.

Multistorey Design. The planting design was developed in such a way that the space of farmlot is optimized both spatially and vertically. The vertical space is optimally utilized by arranging the upper story and the understory plants with minimal obstruction of sunlight reaching the understory plants (Figure 11). The wide space between rows of bananas is oriented along the east-west direction where the cash crops were planted in between. The purpose of planting along the east west direction is to allow maximum sunlight reaching to the ground.

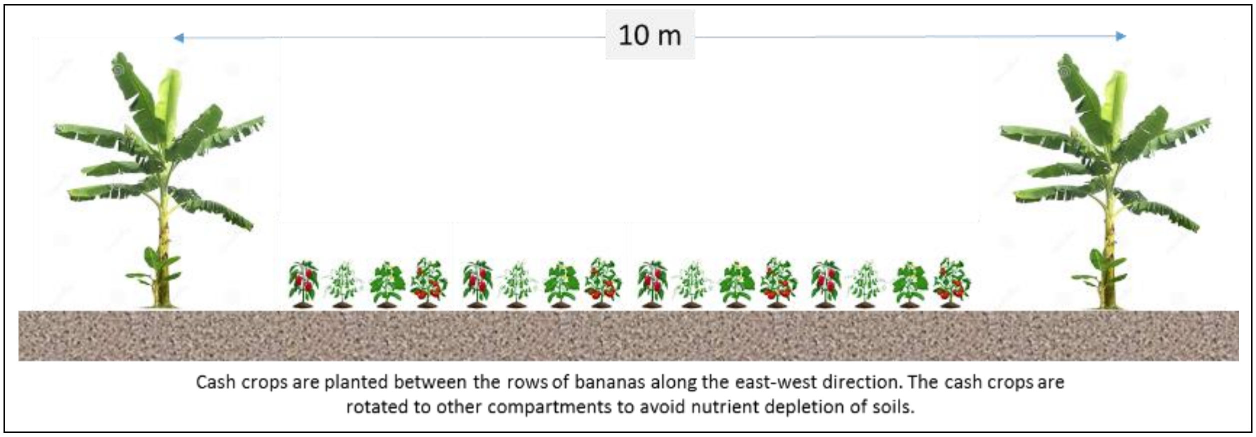

Figure 11. Arrangement of the vertical canopy of planted crops in the home garden lot.

Use of Fertilizers. The design of the home garden (spatial and temporal) aims to improve the nutrient condition of the soil by utilizing the plant debris and chicken dung during soil preparation. Some of the plant debris are also not burned but allowed to decompose to add nutrients to the home garden. The use of organic fertilizers encourages rejuvenation of the soil.

Outcome. The introduction of home garden technology aims to increase the yield and income of farmers. The home garden technology maximizes the utilization of the vertical canopy and prevents the depletion of soils through crop rotation.

Yield and Income. Previously, the farmers harvested about 150 – 200 kg per month of vegetables which were sold at around $0.3-$0.75 per kg. This makes the farmers earn approximately $50 - $100 per month. Since the farmers applied the technique recommended by the project, their vegetable yield has increased. The farmers now harvest vegetables about 450-700 kg per month and earn an income of $300-$500 per month. There are no wastes for the vegetables produced since those that were not sold were used by the farmers as feeds for chicken and pigs. So, the farmers also make extra income from poultry and pig raising.

Figure 12. The farmer tending her home garden.

Soil Condition. In addition to increasing yields and income, the farmers also gained technical knowledge on land preparation, cultivation, and crop rotation. The rotation of the different crops over the compartments of the home garden helped in rejuvenating the soil and result to increase of yield.

Challenges, Lessons Learned and Improvement Needs. The home garden technology is also challenging due to the need of high value vegetables to be closely monitored and taken cared. There is also limited information on the condition of the soil, making it difficult to determine the exact fertilizer requirement of the vegetables. The project is planning to submit the soil sample to the soil laboratory in Phnom Penh for analysis. There is also difficulty in documenting all the detailed expenses and income of the produce, especially in valuing those that consumed by the family. This is because the farmers are sometimes preoccupied of their day to day activities in the farm and sometimes forgot to properly record the details of their farm operation.

4.5.2.4 Use of Fertilizers

The design of the home garden (spatial and temporal) aims to improve the nutrient condition of the soil by utilizing the plant debris and chicken dung during soil preparation. Some of the plant debris were not burned but allowed to decompose to add nutrients to the home garden. The use of organic fertilizers encourages soil rejuvenation of the soil.

4.6 Establishment and maintenance of woodlot

The forests in Prek Thnot watershed are constantly under pressure and subjected to illegal cutting, encroachment, forest fire and land conversion. One of the drivers of deforestation is the inability of the forests to provide incomes and food to the communities. The forests are viewed by the community as competitor to agricultural development, the latter of which, is considered a boon to rural development and helps in improving the lives of the communities. With the mindset that the forests are incompatible to production of cash crops, the forests often ended up being cleared to pave way for farm development. This belief, however, is not entirely correct considering that there are several high value crops that can be commercially produced under the forests. The project "*Landscape approach to forest restoration*" was implemented by the Institute of Forest and Wildlife Research and Development (IRD) in developing a woodlot to test the production of cash crops underneath the canopy of the woodlot. There is still a dearth of information on the techniques of producing cash crops under the woodlots. The establishment of demonstration sites to test some of the crops that are compatible with the forests are needed to develop this technology.

4.6.1 What is woodlot?

A woodlot is a section of a woodland or forest capable of small-scale production of forest products such as saw logs, pulpwood, firewood, and other specialty products. Woodlots also have recreational uses such as bird and animal watching, hiking, wildflower appreciation, hunting, fishing, or other outside activities used for enjoyment. Vegetables or crops are often intercropped in the woodlot in the early stages of establishment, but with time, wood production is the most important use. In small-scale farming areas woodlots are often very small, 0.1 hectare or less. Large-scale farms may have woodlots covering several hectares.

4.6.2 Tree and Crops Suitable for Intercropping

There are two main options when it comes to what type of trees to plant, either short-term commercial exotic trees or long-term native trees. Soils, topography, altitude and climate also dictate what tree species will thrive in the selected site. There are a number of selected cultivars designed to match requirements. Native trees are a good option for a long-term plan, especially in challenging locations. Native trees can provide a food source for bees, enhance water supplies and be selectively logged for high value timbers.

After selecting tree species to plant, the next is to finding an appropriate shade-tolerant crops that can be grown underneath the canopy of the forest trees can provide intermediate income or foods for the communities is one of the challenges in intercropping in the woodlot. Among the common products that are produced from the forests include NTFPs (bamboos and rattans), mushrooms, spices, ornamentals and to some extent, raising of wild pigs for bush meats. Shiitake and other mushrooms that can be grown in logs are already becoming common in forest farming in other countries. Vanilla orchids, one of the most expensive spices, next to saffron, are also successfully grown as intercrop in the woodlots. Finding the right technology of growing shade-tolerant crops in the woodlots is crucial for the successful intercropping in the woodlots. In the tropics, ear mushrooms (Auricularia species) grow in hot humid environment which can be grown in logs under the forest.

4.6.3 Woodlot establishment and maintenance.

The woodlot established by the project is located in Damrey Chakthlork CF, Krang Deivay, Kampong Speu. A farmer cooperator of the project has a woodlot composed of naturally growing and mostly less valuable species. The trees are mostly young and very dense as these are not being tended. The IRD team helped the farmer to conduct strip thinning (about 5 meters) to allow lights to penetrate to the ground. Less valuable and deformed trees were cut in the thinned strips, and planted with galangal and turmeric as test species. Prior to the planting of galangal, black pepper was planted as intercrop (using dispersed planting).

4.6.4 Outcome and Challenges Encountered

The initial interplanting of black pepper was not successful. The black pepper did not grow very well and became stunted. The farmer cooperator interplanted black pepper in his woodlot due to the demand of black pepper in Cambodia. After the initial failure, galangal (*Alpinia galanga*) and turmeric (Curcuma longa) that both thrives in shaded condition, were recommended to the farmer. Out of the crops tested, galangal shows better performance (Figure 3). However, the farmer lacks the enthusiasm to commercially raise the spice due to lack of market or buyers in the locality. The value chain of the species is not well established and mostly these are utilized for household use. Online, however, shows that there are buyers of this species.

4.7 Assessing the applicability of forest watcher system compared with other techniques

State-owned forests account for a much bigger proportion of Cambodian forests. These forests, however, are threatened by forest fires, land encroachment, illegal cutting and hunting, etc. The technology of forest watcher provides a continuous monitoring and surveillance of the surroundings

In Khum Ream, forests to be monitored consists of 1,888 ha of seed source areas, 180 ha of newly planted area, and 15 ha of seed orchard. Forest to be watched in Tamao Zoo Forest covers a total area of 2,285 ha and this area is playing an important role in rescuing and rehabilitating the wildlife of Cambodia. Based on the experience from installing forest watcher system that was installed within the above mentioned sites, below would be some criteria for site selection to install forest watcher system:

- The tower to constructed must be higher than highest tree in the forest area. Therefore, highest elevation spot in the area would be very important criteria in contributing to minimizing course from construction the tower.
- Safety for tower and for maintenance: The safety for equipment/instrument installed is very important so that sustainability of watching system can be achieved.
- Electricity: since camera and the system required power to run, continuous electricity supply would be a must for site selection. In the current project, the system is not working properly because the electricity in this area is not continuously.
- Accessibility: The site for installation would be the area where staff can easily access for maintenance or repairing if needed, otherwise the maintenance cost would be high.
- Forest watcher system would be applicable for natural forests where road access is limited unlike in forest plantation where the area is divided into block and each block may be separated by road access.

4.8 Fuel management

The selection and application of fire management options depend upon the conditions and circumstances found at the national, provincial, and local levels which may include, inter alia:

- Forest types and management activities
- Risk and sources of fire
- Access and terrain
- Fire management capabilities
- Climatic conditions
- Adjoining land uses, and
- Socio-economic factors.

Based on experiences in Cambodia, forest fire in the project site occurred mainly during dry season between December to April of the year and fire happens mainly on deciduous forest in which tree leaf have shaded and dried out, thus, susceptible to forest fire. Different methods have been carried in the project site to manage fuel for reducing forest fire. These methods include the following:

1. Introduction of ever-green tree species: This introduction would help in minimizing fuel from deciduous tree species.
2. Fire line: the construction of fire line was carried out by removing grasses and dry leaves. Tractor can be used to clear fire line with the wide of 5m and 12km long around the restoration area. The activities are implemented in early dry season. This fireline serve not only for firebreak but also reducing dried fuel from forest floor.
3. Controlled burning or prescribe burning: This method is used to reduce forest litters and grass from forest floor so as to eliminate or reduce fire risk. The burning is scheduled for the time when fire will not pose a threat to the public or to fire managers. Forest condition in this area should call for controlled burning and whether condition should be right to allow burning but prevent from spreading. Fuels include dead grass, fallen tree branches, dead tree, and thick undergrowths.

Figure 13. Controlled burning ad establishment of firebreak

4.9 Using geotagged photos for monitoring

Geo-tagged photos have its special contribution to forest management including monitoring of reforestation, land encroachment, illegal logging, illegal hunting activities. This novel technology shall pave the way for greater appreciation of reforestation efforts as it serves as a means to monitor the development of reforestation and other activities that happened in the forest.

Based on this technology, the project team has set up the following steps for forest monitoring:

1. Form up patrolling team which led by local community member
2. This patrol team use digital camara or other devices that can take photo with GPS. The patrol team take photos if they observed unusual features in the field during their patrol activities such as forest fire, illegal logging, etc.
3. After taking photos, the project team has checked the coordinates of the photo and uploaded to the computer.
4. By using Map Utility, the photos will be exported for google earth file. These files can then be opened in google earth where we can see the activities such as illegal logging or forest fire happened so that the project team can have a better plan for coping with those activities.

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