BMEL-ITTO Project:
"Enhancing Conservation and Sustainable Management of Teak Forests and Legal and Sustainable Wood Supply Chains in the Greater Mekong Sub-region"


**Contact more details at:**

**Dr. Hwan-ok Ma**
**ITTO, Yokohama, Japan (Email: ma@itto.int)**

**Professor Dr. Yongyut Trisurat**
**Kasetsart University, Thailand (Email: fforyyt@ku.ac.th)**

**Mr. Sapol Boonsermsuk**
**Royal Forest Department, Thailand (Email: sapolboonsermsuk@gmail.com)**

**Assist. Prof. Dr. Nopparat Kaakkurivaara**
**Kasetsart University, Thailand (Email: ffornrm@ku.ac.th)**


Federal Ministry of Food and Agriculture


BMEL-ITTO Project:
"Enhancing Conservation and Sustainable Management of Teak Forests and Legal and Sustainable Wood Supply Chains in the Greater Mekong Sub-region"


# Minimize Harvesting Loss, Efficient Transport and Processing of Teak Round-wood


Nopparat Kaakkurivaara


## Technical Report

Technical Report

# Minimize Harvesting Loss, Efficient Transport and Processing of Teak Round-wood

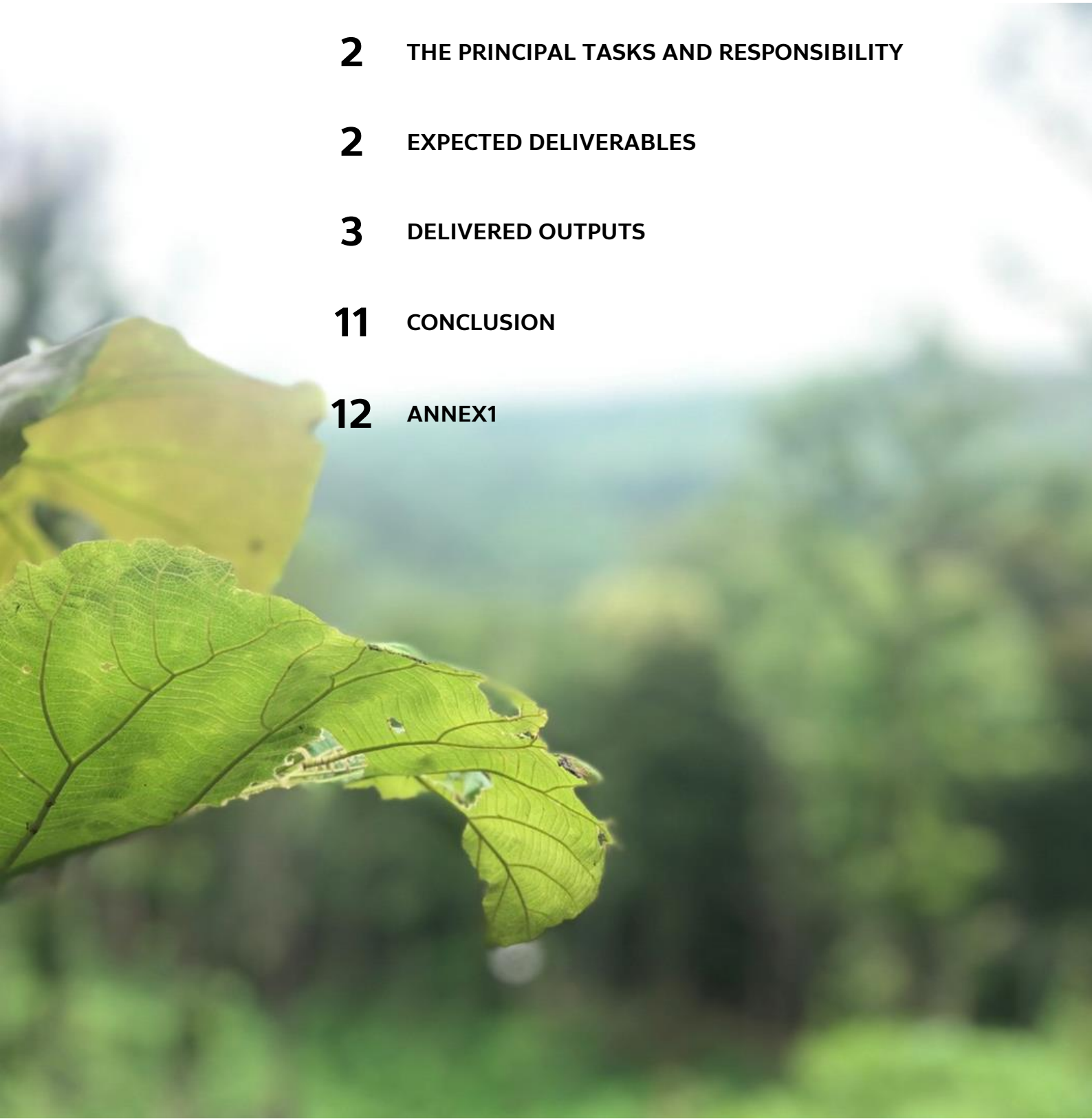
By

Nopparat Kaakkurivaara

BMEL-ITTO Project:
"Enhancing Conservation and Sustainable Management of Teak Forests and Legal and Sustainable Wood Supply Chains in the Greater Mekong Sub-region" (PP-A/54-331)

# CONTENTS





## BACKGROUND

The ITTO Teak project in Mekong, "Enhancing Conservation and Sustainable Management of Teak Forests and Legal and Sustainable Wood Supply Chains in the Greater Mekong Sub-region" (PP-A/54-331), was approved by the 53rd International Timber Council Meeting in Lima, Peru in November 2017 and the Global Landscapes Forum in Bonn, Germany, in December 2017. At ITTC 53, the Council approved ITTO's 2018-19 Biennial Work Program (BWP) with the ITTO Budget (Government of Germany) of USD 1,236,250. The duration of the project is 3 years from March 1, 2019 to September 30, 2022.

The objective of the Project is to demonstrate legal and sustainable teak supply chains with the engagement of local communities, smallholders and government actors in the Greater Mekong sub-region (GMS). The outputs of the project are 1) the conservation of teak genetic resources, sustainable management and use of natural teak forests and market accesses of teak from legal sources have been shown, 2) community-based and smallholders teak forest management and agroforestry systems have been strengthened with improved legal and sustainable supply chains, and 3) regional and international collaboration, information sharing and knowledge management, networking, policy development and outreach on the sustainable management of teak forests, including sustainable use of teak genetic resources have been strengthened.

Natural teak forests covering an area of about 29 million hectares occur in central and southern India, Lao PDR, Myanmar and Thailand. Myanmar has the largest area of natural teak forests (almost 16 million ha) and is the number one producer of teak logs in the world. Thailand has the second largest area of natural teak forests (after Myanmar) at an estimated 8.7 million ha, all of which are located in protected areas. The participating countries in the GMS include Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam are located in the GMS. These five participating countries are home to more than 300 million people. It is a very dynamic and fast-changing region that has made significant socio-economic progress from 1990 resulting in significant impacts on natural and forest resources.

The Project Activity is aimed at assisting governments, local communities and smallholders to enhance natural teak forest management, production and marketing to facilitate the establishment of legal and sustainable wood supply chains while improving national economy and local communities 'livelihood in the Greater Mekong Sub-region. The Activity provides an opportunity for the recipient countries to build-up sustainable forest management capacities and to further pursue their strategic objectives and policies on the sustainable development of teak forest resources, which are of particular livelihood improvement and ecological significance in all countries of the Greater Mekong Sub-region.

In order to implement the ITTO Teak Project in Mekong effective, the **Consultant#6: Minimize Harvesting Loss, Efficient Transport and Processing of Teak Round-wood** is recruited to take responsibility to enhance capacity local communities and relevant agencies on efficient teak round-wood harvesting through a series of training sessions and field works.

## THE PRINCIPAL TASKS AND RESPONSIBILITIES

The principal tasks of the **Consultant#6: Minimize Harvesting Loss, Efficient Transport and Processing of Teak Round-wood** is to strengthen capacity of local communities and relevant agencies to effectively harvest round-wood both from plantations and natural forests as indicated in Activity 2.1 of Output 2. Participants in the training sessions are from the participating countries, namely Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam.

The specific functions and responsibilities include:

- Prepare a program for a five-days group training, including classroom presentations/discussions and field demonstrations, that is tailored to the needs of rural communities and has the objective to improve efficiency, product quality and productivity
- Include in the training program the following subjects: 1) minimizing harvesting loss, efficient transport and processing of teak round-wood, 2) equipment maintenance, waste disposal and storage of forest products, and 3) supply chains and marketing (work with Cons#7).
- Implement the training program once every year during the activity period (in total three times).
- Present activity outcomes, results and findings to the Project Technical Committee (PTC)
- Incorporate comments provided by the PTC members and stakeholders in the final report.
- Compile all results and findings of each training event, incl. recommendations for follow-up actions, in a technical activity report in the English language to be submitted to the Regional Activity Manager.
- Available to provide recommendations and advises to National Coordinators, PTC members (if any).
- Undertake national and international travels, as and when required

## EXPECTED DELIVERABLES

The consultant should submit the following outputs to the Regional Activity Manager:

- Conception report and a general training program on the assigned topics, target audiences for each training session.
- Training material on minimizing harvesting loss, efficient transport and processing of teak round-wood, equipment maintenance, waste disposal and storage of forest products, supply chains and marketing
- Training reports (by 1 month after completion of each session)
- Final report
- Technical note for publishing via TEAKNET

## DELIVERED OUTPUTS

Summary of delivered outputs of consultant#6 during the reporting time (April 2019 – June 2021) include:

| Year | Tasks |
|---|---|
| 2019 | 1. Attended Regional Workshop on Sustaining Teak Forests in Mekong Basin, 24-27 September 2019, Yangon, Myanmar. And presented the presentation entitled **"The selection of sustainable logging systems, case study Teak plantations in Thailand".** |
| 2020 | 1. Prepared and **conducted "Joint Training Workshop on New Management System and Minimize Harvesting Loss"**, 5-7 February 2020, Phrae Province |
| | 2. Attended **The 2nd Project Steering Committee Meeting and the National Teak Forum in Lao PDR**, 18-20 February 2020, Vientiance and Luang Prabang, Lao PDR |
| | 3. Prepared and conducted **"Training workshop on Certified Teak Wood from Smallholder Plantations using C&I Approach"**, 26-28 August 2020, Nan Province |
| | 4. Provided recommendations and advises for smallholders in order to implementing the sustainable forest management according to National Criteria & Indicator |
| | 5. Published Policy Brief on **"Teak Harvesting Efficiency and safety issues in Thailand"** in Teak Mekong Newsletter June 2020 - Volume 2(3) |
| | 6. Submitted abstract entitled **"Minimizing Timber Harvesting Loss: from Theory to Practice"**, to the XV World Forestry Congress (WFC 2021) |
| 2021 | 1. Attended the1st Monthly Webinar Meeting and gave presentation entitled "**Teak Harvesting and Minimize Loss from Forest Plantations"**, on 28 January 2021 |
| | 2. Published **Good Practices of Teak Timber Harvesting.** This guideline is for Demonstration plot: Harvesting demonstration plot, Khunmae Kummae Teak Plantation, Phrae Province |
| | 3. Preparing two book chapters related to timber harvesting for book entitled **"Sustainable Management of Teak *(Tectona grandis)* in the Mekong Region".** |

The delivered outputs can be categorized to 3 groups:

1) Training Workshops 2) Presentations and 3) Publications.

**1) Training Workshops**

### 1.1) Joint Training Workshop on New Management System and Minimize Harvesting Loss

A joint training workshop on New Management System and Minimize Harvesting Loss was conducted during 5-7 February 2020 in Phrae Province. The objectives of joint workshop are 1) to introduce participants to basic new management system, 2) to introduce sustainable forest management standards that will be applied to the new system management, 3) to introduce participants basic principle of harvesting loss and reduction of harvesting loss, 4) to introduce the bucking optimization that maximize profit and minimize waste, and 5) to demonstrate the given techniques on the ground. Joint training workshop approaches included lecture, brainstorm, exercise, discussion, and field demonstration. Thirty participants attended the workshop. They were dominated by field staffs of Forest Industry Organization (15 persons), followed by private and smallholder teak plantations (10 persons), and relevant staffs from RFD (5 persons).

Lectures on overview sustainable forest management, national wood demand and supply, the trend of forest certification and Thailand's Criteria & Indicator for sustainable forest management were provided on the first day, followed by harvesting loss, bucking optimization to ensure that participants understand the types and causes of harvesting loss on the second day. Field practices were conducted on data acquisition (log measurement, harvesting loss collection and calculation) on the last day.


**Photo 1.** Joint Training Workshop on New Management System and Minimize Harvesting Loss 5-7 February 2020, Phrae province, Thailand.

### 1.2) Training workshop on Certified Teak Wood from Smallholder Plantations using C&I Approach

A training workshop on "Certified Teak Wood from Smallholder Plantations Using C&I Approach" during 26-28 August 2020 in Nan province, northern Thailand aimed to adopt the guidelines into implementation. Thirty participants attended the workshop. They were dominated by smallholder

teak farmers (20 persons), followed by field staffs of Forest Industry Organization (5 persons) and the relevant staffs from RFD (5 persons). Besides, Teak Smallholder Enterprise in Nan Province was selected as a pilot site.

Lectures on overview sustainable forest management, national wood demand and supply, the trend of forest certification and Thailand's Criteria & Indicator for sustainable forest management were provided on the first day, followed by field practices on data acquisition (tree measurement, soil sample collection and physical & chemical analysis and water quality using field tool kits). Documentation and statistical analysis (lumber volume) and record keeping as well as CoC of lumber delivered from a local sawmill were conducted on the last day. Certificate of Teak Smallholder Enterprise in Nan Province jointly adopting the certificate by the RFD and Kasetsart University was awarded to the community.


**Photo 2.** Certified Teak Wood from Smallholder Plantations Using C&I Approach 26-28 August 2020, Nan province, Thailand

## 2) Presentations

### 2.1) The selection of sustainable logging systems, case study Teak plantations in Thailand

Presentation entitled "The selection of sustainable logging systems, case study Teak plantations in Thailand" was given in the regional workshop on sustaining Teak forests in Mekong Basin, during 24-27 September 2019, Yangon, Myanmar. There were 40 researchers and experts from 14 countries representing universities, policy makers, teak plantation managers, wood industry, international organizations, and NGOs. The regional workshop was designed with six thematic technical sessions in focus. This presentation was in session 4: Promoting of smallholders and

communities in natural Teak forests management and establishment of planted Teak. The summary of presentation is presented as following.

The selection of proper forest harvesting system is an important in order to balance environmental, social and economic interests. This study applied the Delphi method to identify the weight balance between environmental, social and economic aspects. The panel of experts consisted of a number of scientists in the field. The data was collected using a questionnaire distributed in two rounds. The results demonstrated that the job positions (manager assistant, forest manager, and administrator) do not have significant impact on the result. The results from both round illustrated the same direction that economic is the most concern for forest plantation, while environment and social aspects are less anxiety. Not many of responder changed their opinion in the second round. Afterwards, the weight score which received from Delphi method is used for ranking the logging systems. This study included ten different logging systems to be evaluated. There are several factors to be taken into account, such as, productivity, harvesting cost, heart rate, soil compaction, soil erosion, etc. All factors were reclassified into five classes, graded as 1, 2, 3, 4, and 5 (critical, fair, moderate, good, and excellence) according to expert's opinion. The logging system which got the highest score is felling by chainsaw, extraction by elephant together with farm tractor and transported by truck with loader. The findings could assist forest managers in selecting the right harvesting system, while taking into account the environment, economic and social aspects. This kind of a calculation model was used to facilitate an ease in comparing the logging systems, it is relatively simple tool for forest manager to help in making decision. However, the study shall apply the GIS into the implementation in the future in order to visualize the precise area with specific logging system.


**Photo 3.** Presentation in Regional Workshop on Sustaining Teak Forests in Mekong Basin

### 2.2) Teak harvesting and minimize loss from forest plantations

The first virtual monthly webinar meeting was held on 28 January 2021, there were 31 participants attend the meeting. The key messages of presentation can be classified into two main topics: Teak harvesting technique in Thailand, and harvesting loss.

Logging method that commonly apply is so called “Tree Length” method. This method, trees are felled, delimbed and topped in the stump area by chainsaw, then trees are skidded to roadside by elephant, farm tractor, or skidder depending on slop limitation and available resources. After that primary transportation is taking part from roadside to log landing. At log landing, trees are crossed cut into certain length, 3, 4, 6 m and stacked into a pile for auction process. During harvesting, the damage or loss cannot be avoided. The severity of harvesting loss that may occur depending on the intensive of planning and implementation. Harvesting loss can occurred during felling, bucking, skidding, and transportation. Damage was considered to be physical wounds that detracted value from the harvested log or standing tree. Loss during felling the top of the tree often get damage from fallen tree stem and damage to residual trees in the stand as well, broken top, broken branches. Loss during bucking mainly deals with improper bucking skill of chainsaw operator. This might be due to lack of incentives, lack of training, and lack of decision aids. These can be caused the poor bucking decision. Loss during skidding or extraction, since trees are commonly dragging on ground can contribute to log breakage in certain situations. In order to reduce the harvesting loss, the workers must be trained to ensure that he/she made the right decision when felling, skidding and cross cutting. Also, incentives are important to motivate worker to work with care.


**Photo 4.** The first Virtual Monthly Webinar Meeting

### 2.3) Minimizing Timber Harvesting Loss: from Theory to Practice (Abstract submitted)

Presentation entitled “Minimizing Timber Harvesting Loss: from Theory to Practice” has been accepted as poster session in The XV World Forestry Congress (WFC 2021), sub-theme 3: The green pathway to growth and sustainability. Due to the continued and unprecedented challenges of the global health pandemic, it is increasingly clear that it will not be possible to hold a safe, inclusive World Forestry Congress on the originally scheduled dates of 24 to 28 May 2021 in Seoul. The Congress will therefore be postponed to 2 to 6 May 2022.

The abstract of Minimizing Timber Harvesting Loss: from Theory to Practice is presented as following. Reduced impact logging (RIL) is the intensively planned and carefully controlled implementation of timber harvesting operations to minimize environmental impacts on forest stands and soils. It involves a number of practical measures, such as the pre-harvest planning of skid trails to minimize soil disturbance and remaining trees. The aim of this study is to plan the skidding trail via aerial photography technique to extract marked trees from the cutting area to logs landing and evaluate the effectiveness of the skidding trails. The Unmanned Aerial Vehicle (UAV) survey was applied to capture the areas that needs to be harvested. Multi-Criteria decision analysis—the analytic hierarchy process (AHP) was used to estimate important value of each

criterion to weight the factors on creating the land stability map. The network analysis technique was applied to plan and design the skidding trail according to land stability. The result showed that, the skidding trails design facilitated efficient logging, reduce operational costs, lead time and the impact on the remaining trees. There were 93 and 94 trees thinning from unplanned and planned harvesting compartment. In unplanned harvesting compartment, there were 153 trees left from total of 1,165 with 193 cut damaged remain which is equivalent to 36,420.88 square centimeters of cut damage area. However, in planned harvesting compartment, there were 83 trees left from total of 787 and 143 cut damaged remain which is equivalent to 32,215.33 square centimeters of cut damage area. Comparing the two compartments, residue tree damage from unplanned compartment was 13.13% higher than planned compartment of 10.55%, and there was no statistical difference (p-value > 0.01) cut area in each compartment. Nevertheless, the Spatial Decision Support System (SDSS) provides the best route to access marked trees and avoid disturbances on standing trees. It can be applied to other harvesting areas, especially for thinning operation.

## 3) Publications

### 3.1) Policy Brief "Teak harvesting efficiency and safety issues in Thailand"

This policy brief published on Teak Mekong Newsletter June 2020 - Volume 2(3). The contents of this policy brief are overview of Teak timber harvesting in Thailand, used logging systems, used machines, harvesting productivity, harvesting cost, and lastly pinpoint about work safety issue. The current system that applying in Thailand is motor manual system, trees are felled by chainsaw, extracted by tractor or skidding to roadside, and processed into short logs by chainsaw. This system is rather labor-intensive system, and requires many workers to carry out the harvesting activity. Sometimes, this system so called "appropriate technology" which suits the local circumstances, easy to obtain, easy to maintenance, and best fit with socio-economics. However, the key problem of timber harvesting in Thailand is labor shortage. Since forest work is consider as "3D" job which means, Dirty, Difficult, and Dangerous together with unstable income. Causing young generation transfer from agriculture to industrial or service sectors, for a better livelihood. In the future, there are high possibility to hire migrant workers from neighbor countries or introduce new technology or machinery to replace manual work.


**Photo 5.** Policy briefs on entitled Teak harvesting efficiency and safety issues in Thailand

### 3.2) Good Harvesting Practices in Teak Forests

This Good Harvesting Practices in Teak Forests is part of demonstration plot, which named Khunmae Kummae Teak Plantation, activities that focusing on timber harvesting. The aims of this document are to 1) provide clear direction when planning and conducting harvesting operations, and 2) improve timber harvesting, particularly Teak in Mekong sub-region, with consistent with the SFM approaches and work safety perspective.

Recently, several countries have committed to achieving sustainable forest management (SFM), which balances production goals with environmental and social aspects. In the field of timber harvesting, it can generate many economic and social benefits. However, the poor practices can lead to serious environmental degradation and negative impacts on local communities.

The document is divided into five chapters. Chapters one provides a general introduction. Chapter two provides an overview of sustainable forest management and sustainable forest operations. Chapter three explains specific harvesting processes includes felling, extraction, crosscut, and an introduction into strategic, tactical and operational harvesting planning. Chapter four focuses on Reduced Impact Logging approach: pre-harvest, during harvesting, and post-harvest evaluation. Finally, chapter five describes health and safety in general, and personal protective equipment (PPE).

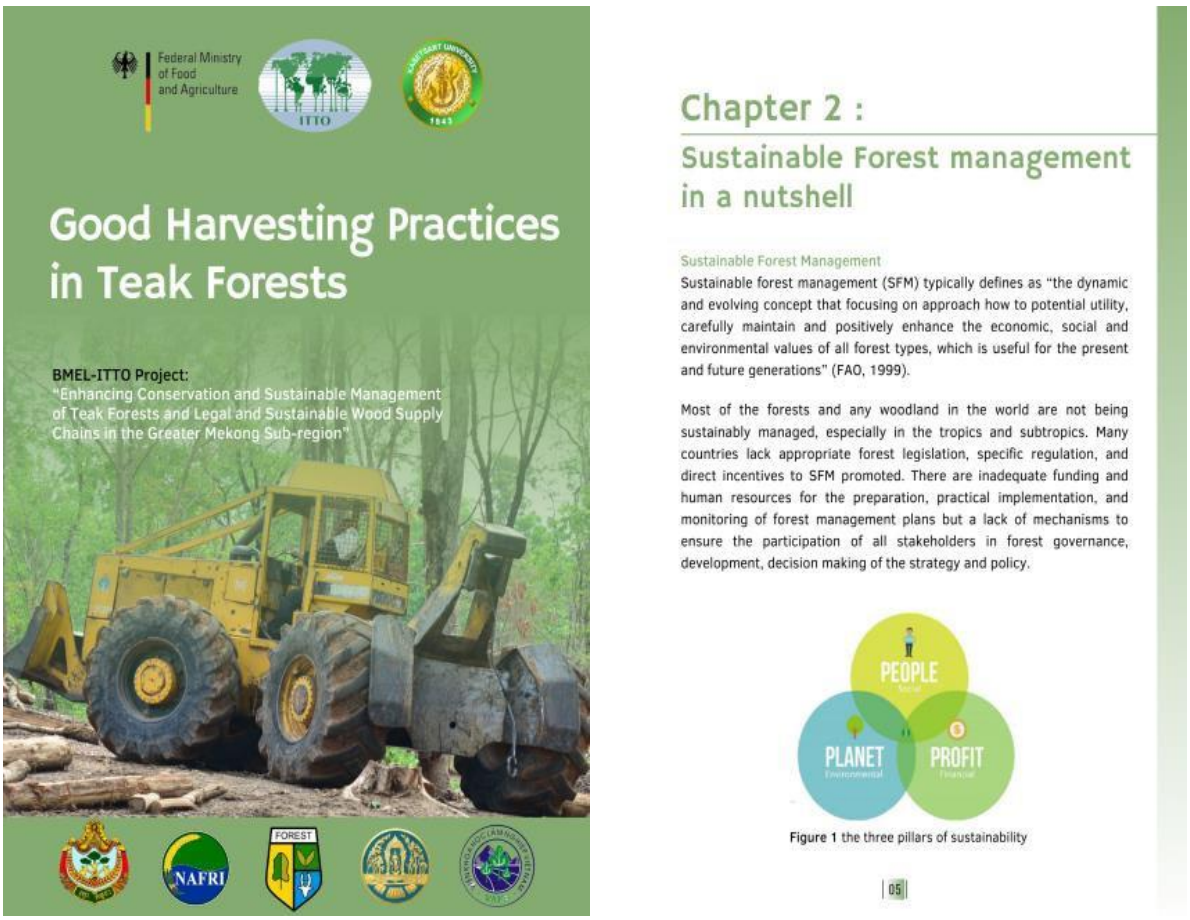



**Photo 6.** Good Harvesting Practices in Teak Forests

### 3.3) Book entitled "TEAK IN MEKONG FOR A SUSTAINABLE FUTURE"

This book aims at presenting a comprehensive assessment of natural forest management and plantation in the Mekong Region where natural teak forests exist through original articles as well as edited parts of project outputs including research and review papers that have been produced during the course of this project. This book will also provide a window on the recent developments in theory and practices of sustainable teak management in the Mekong region and beyond. The target readers of this edited book include graduate students, scientists, practitioners, private sectors, smallholders and policy makers who are interested in and involved in natural teak forests and teak plantations, wood industry, legality and its related supply chains and environmental management.

This book includes 6 sections.

Section 1: Introduction

Section 2: Teak Distribution Across the Greater Mekong Sub-Region

Section 3: Silvicultural Practices and Teak Improvement

Section 4: Sustainable Teak Forest Management and Certification

Section 5: Research in Teak Genetics

Section 6: Policy and Regional/International Collaboration

Consultant#6 prepared and submitted of one chapter under Session 4 (Sustainable Teak Forest Management and Certification) entitled "*Teak Timber Harvesting*". The full chapter is attached as Annex 1.

## CONCLUSION

The **Consultant#6: Minimize Harvesting Loss, Efficient Transport and Processing of Teak Round-wood** jointly conducted two training: 1) Training Workshop on "New Management System and Minimize Harvesting Loss" during 5-7 February 2020 in Phrae Province. and 2) Training Workshop on "Certified Teak Wood from Smallholder Plantations Using C&I Approach" during 26-28 August 2020 in Nan province, Thailand.

Meanwhile, The Consultant#6 also contributed in three events: 1) presentation entitled "The selection of sustainable logging systems, case study Teak plantations in Thailand" was given in the regional workshop on sustaining Teak forests in Mekong Basin, during 24-27 September 2019, Yangon, Myanmar 2) presentation entitled "Teak harvesting and minimize loss from forest plantations" was given in the first virtual monthly webinar meeting was held on 28 January 2021 and 3) presentation entitled "Minimizing Timber Harvesting Loss: from Theory to Practice" has been accepted as poster session in The XV World Forestry Congress (WFC 2021). And three published: 1) published policy brief on **Policy Brief "Teak harvesting efficiency and safety issues in Thailand"** this policy brief published on Teak Mekong Newsletter June 2020 - Volume 2(3) 2) published document on **"Good Harvesting Practices in Teak Forests"** and 3) an article in the Book entitled "TEAK IN MEKONG FOR A SUSTAINABLE FUTURE" under session 4 (Sustainable Teak Forest Management and Certification) entitled "*Teak Timber Harvesting*" (Annex 1.)

# Chapter 16: Teak Timber Harvesting

**Nopparat Kaakkurivaara**

## Abstract

Timber harvesting is an essential and cost-intensive activity in forest management. It involves cutting trees and moving them to a landing, processing, sorting and loading, and transporting materials. The felling and extraction of timber is potentially a very dangerous operation and harvesting crews are required to be highly skilled and well trained. Poor planning and/or poor implementation can be costly, result in environmental degradation as well as excessive harvesting waste, ineffective utilization of wood, and injury to personnel. A carefully managed, sustainable timber harvest is not just about cutting down trees and earning their commercial value. It is about implementing a plan that encourages regeneration and the long-term well-being of the woods.

The resources, equipment, and machines that can be used in timber harvesting are diverse and can be composed in complex systems. Many countries are facing a lack of financial resources for using their forests in a competitive and sustainable way. Logging companies with better financial background are able to mechanize harvesting processes and increase productivity and working safety. While, smallholders are still relying on simple tools and equipment, animal skidding, and manual or motor-manual work in harvesting operations. The present chapter gives an overview on the existing methods, equipment, and machines that are available for Teak harvesting operations in Makong region.

## Introduction

Sustainable Forest Management (SFM) is the process of managing forest to achieve clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction in the forest's inherent values and future productivity and without undue undesirable effects on the physical and social environment (ITTO, n.d.). This definition implies the critical importance of safeguarding the environment and the livelihood needs of forest-dependent communities. One of the reasons for the slow implementation of SFM is related to how to effectively protect the environment and the people who depend on forests. Timber harvesting, when not carried out properly, can lead to serious environmental degradation and negative impacts on local communities. But if timber harvesting is well planned and implemented, it can generate many economic and social benefits with only marginal impacts on the environment. In tropical forests designed for timber production, selective logging can be considered as a silviculture technique to ensure minimum impacts on the environment.

Forest harvesting can be defined as *"The aggregation of all operations, including pre-harvest planning and post-harvest assessment, related to the felling of trees and the extraction of their stems or other usable parts from the forest for subsequent processing into industrial products"* (Dyksta & Heinrich, 1992, 1996). Thus, harvesting is not only felling and extraction of the trees but also includes the planning beforehand and impact assessment after the operations in order to take all concerns into considerations for the next harvesting.

### Harvest Planning

Harvest planning provides a balanced and comprehensive foundation for sustainable harvesting practices to enable good technical control during harvesting reconciled with the need for reducing harvesting costs. Harvest plans are of two types, strategic and tactical (Klassen, 2011)

A strategic harvest plan explains why, where, when and what type of harvesting is proposed. Strategic harvest planning cannot be undertaken

without considering the issues which affect the management of the forests more widely. It is a basic part of forest management plan, prepared by the planning team, and should never be a separate planning statement.

A tactical harvest plan is a short-term plan, prepared by a team directly responsible for supervision of harvesting operations, that explains how and who will carry out the operations and when cutting will be undertaken in each cutting area. A Tactical Harvest Plan can apply to a single felling area or to a group of separate felling areas and is linked to the approved forest management plan through the Annual Plan of Operations.

The following basic steps are involved in tactical harvest planning (Applegate *et al.*, 2004):

- A pre-harvest inventory should be conducted to identify tree species, to estimate the size and volume of trees present and their position throughout a felling area. The inventory should extend over the whole area where harvesting is proposed. In the case of selection harvesting, trees to be cut should be identified, marked, and numbered.
- A topographic survey, either on the ground or using remote sensing imagery, should be conducted during a pre-harvest forest inventory to provide information for mapping.
- A detailed topographic map should be drawn, showing all topographic features that will influence logging, and the boundaries of the harvest area. Set aside area, buffer zone, conservation areas, watercourses, wildlife habitat, and any other special reservations specified in a management plan should be mapped. Contour mapping can be prepared either by manual drafting methods or using GIS technology. It is the experience of many companies who are managing tropical forests that an investment in good quality mapping can lead to reduced impacts and lowered infrastructure costs.
- A skid trail network from the chosen landing needs to be laid out and mapped taking into account all concerns regarding environmental impact, economic viability, skidding distance, and terrain features. This map is used to guide field reconnaissance and actual skid trail places.

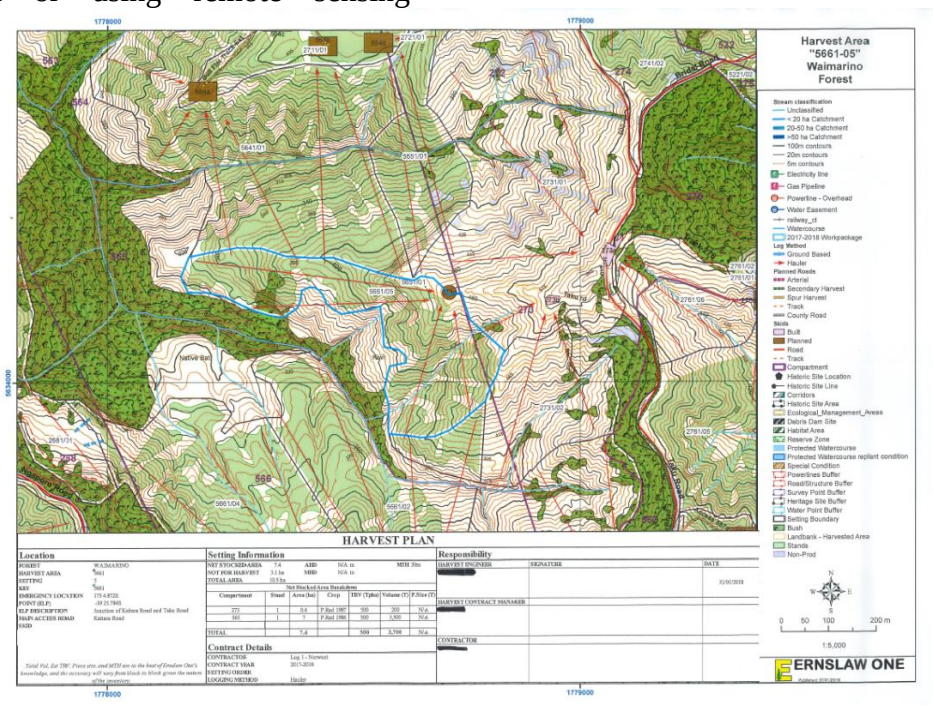



**Figure 16-1** Example of harvesting plan

Specific planning requirements are:

- Tactical harvest planning should be based on harvesting prescriptions set out in a forest management plan. The volume and/or number of trees per hectare to be extracted and the number of seed trees per hectare that are to be retained should be specified.
- A cutting and log extraction plan should comprise a part of the harvest plan and should be undertaken using the topographical and tree position map. It can also be generated using vertical and oblique GIS imagery. The plan should be prepared jointly by forest planners and loggers and must be practical and realistic. The location of landings, skid trails (if ground skidding is to be used), cableways (if cable extraction systems are to be used), and haul roads should be shown. Where possible, directional felling should be indicated.
    - Harvesting equipment should be specified and a general operations schedule formulated, using actual or estimated production rates. Work studies may be necessary to determine appropriate production rates.
    - A harvesting schedule should be prepared setting out the estimated timing of harvesting in different felling areas. It should be flexible and able to be quickly modified, when necessary.
    - Preparation of a harvesting schedule should, where applicable, be prepared in consultation with local communities who might be affected by harvesting. The harvest of NTFPs and the dependency of local communities upon these for subsistence, employment and income generation should be considered. Examples are collection of rattan, mushrooms, bamboo shoots, and medicinal plants.
    - Any legal requirements, should be listed, for example, harvesting and transport permissions, chainsaw use permission, and obtained.

**Teak Timber Harvesting**

Since logging in natural forests is banned, timber production in Thailand has shifted from natural forests to planted forests, particularly in the case of Teak. The Tree Length (TL) method is mostly used for Teak harvesting in which trees are felled, delimbed and topped using chainsaws within the compartment itself and only the bole is extracted to roadside by animal power (elephant), tractor, or skidders. Theis is then followed by short distance transportation between roadside landing to main log landing for further processes such as log measuring, cross cutting, and stacking (Figure 16-2).

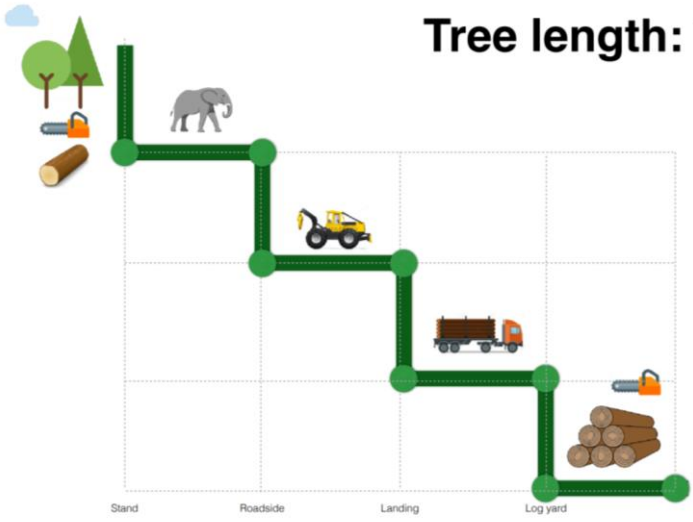



**Figure 16-2** Harvesting process of Teak harvesting in Thailand

*Felling*

The general rotation of Teak from plantation is about 30 years preceded by two thinnings at 15 and 25 years. Trees to be cut are marked with paint beforehand by local forest manager. Felling crew consists of 2-3 men, one chainsaw operator together with two assistants for felling direction control. Crew normally work for about six hours a day. After trees are felled the branches are removed right away. The average effective productivity of felling is 29.81 $m^3$/h, where average stump diameter, log length, and log volume are 32.39 cm, 13.04 m, and 0.86 $m^3$, respectively (Rianthakool et al., 2018).

**Photo 16-1** Tree felling with chainsaw

*Extraction*

Timber extraction from stump area to roadside is either by animal power or mechanized method i.e. tractor or skidder (Photo 16-2). The most common animal power is elephant. Elephant logging is common in many parts of Asia like Thailand and Myanmar. The advantages of using elephant lies in their ability to access steep terrains and forests without road network, and no consumption of fossil fuels. However, the limitations of using elephants are low productivity compared to other methods, short skidding distances, working hours limited to mornings, and the time taken for healing if elephant gets sick. The average productivity of extraction by elephant is 11.11 $m^3$/h for skidding distances shorter than 100 m. with an average of 2.75 logs or 0.68 $m^3$ per work cycle (Rianthakool et al., 2018). In places, where mechanized skidding is available, mechanized skidding is preferred since it provides higher productivity compared to animal power. The average productivity of mechanized skidding varies between 10-25 $m^3$/h depending upon the type of machine but impact on soil and water is a big concern if timber extraction is in steep terrain.

**Photo 16-2** Timber extraction

*Short distance transportation*

The short distance transportation between roadside of harvesting site to permanent log landing is sometimes known as primary transportation. It is an internal timber transport inside the plantation itself. There are various types of vehicles for this sort of transportation, for example, crane truck, trailer together with front end grapple loader, or self-loading truck (Photo 16-3). The average productivity of short distance transportation is 9.23 $m^3$/h, with average 1 . 7 7 kilometers of transporting distance (Rianthakool et al., 2018).

**Photo 16-4** Examples of short distance transportation vehicles

*Processing*

Once timbers are transported to log landing the next step is log measuring, cross cutting, log identifying (hammer branding), and finally stacking for sale (Photo 16-4). Log measurement is conducted manually for log length and diameter in order to decide where to cross cut. Average productivity of this process was 330 logs/h (Rianthakool et al., 2018). Afterwards the chainsaw operator team takes over for cross cutting as marked by the log measuring crew. The average productivity of cross cutting by using chainsaw is 170 logs/h with averaging 20.94 cm of log diameter (Rianthakool et al., 2018). After logs are cut the log serial number is stamped on log surface with hammer branding. The serial number represents traceability system to reflect where the logs come from and when it has been harvested. The average productivity of hammer branding for log identity is 207 logs/h (Rianthakool et al., 2018). Eventually, the logs which have similar characteristics (diameter and length) will be stacked together in one pile (approx. 6-7 $m^3$) for bidding. Forest owner usually set minimum price according to log diameter, log volume, and quality.

**Photo 16-4** Log processing

Generally teak logging operation is time-consuming because teak normally grows on mountainous area that are very steep in some places, and the harvesting is more or less labor intensive operation. It is seen that there is high productivity in felling stage but lower productivity in extraction and primary transportation leading to bottleneck problem in work flow. This problem can be tackled by increased resources, i.e. number of workers or machines. There are two methods to increase productivity in the extraction process, namely, the introduction of higher efficiency machines and reorganizing work processes.

## Work Safety

Forestry is one of the most dangerous of occupations; it is sometimes called a “3D” job – dirty, difficult and dangerous. Forest harvesting on steep terrain is always a challenge in terms of safety, operating costs, and environmental impact. Kaakkurivaara & Stampfer (2018) have indicated an extremely high fatality rate in Thailand compared to the

average in other countries. Possible reasons for this may include ineffective safety regulations, seasonal forestry workers, inadequate worker training programs, and a lack of personal protective equipment. A safe harvesting operation is an efficient harvesting operation, not only because it reduces the potential for loss, but also because it increases production, improves the working environment and overall improvement in attitude and morale of workers. Occupational health and safety in forestry can be greatly improved through adequate worker training and supervision and the use of safety equipment, among other things.

The most common causes of accidents is the workers' lacks of knowledges or skills. Training is one of the most effective tools in controlling risk. Employees should be trained to work along with the systems and work safely. The employer should ensure all employees have been adequately trained and instructed to perform their employment safely before allowing them to work in harvesting operations. Workers should be made aware of relevant dangers involved with their work and of any safety precautions that should be taken to avoid accidents or injury. Additionally, wearing suitable PPE can provide protection for workers when all other control measures cannot adequately eliminate or minimize risks to a worker's health and safety. A wide range of PPE is available to help minimize the risk of injury to forest workers and the employer is expected to evaluate the risks involved in each job and select suitable PPE for specific tasks.

**Personal Protective Equipment (PPE)**

PPE provides a protective barrier between the hazard and the employee. If the PPE device fails or is improperly used, the employee will be directly exposed to the hazard. PPE remains the "last line of defense" and needs to be used properly and in accordance with established standards (Langin *et al.,* 2010). To manage PPE correctly it is critical to ensure the following: use the most suitable PPE for each hazard, supply PPE to employees, provide training on how to correctly use PPE, and monitor PPE use. PPE consist of the following lists (Photo 16-5):

Head protection: wear approved safety hard hat or helmet of a color that contrasts with the work environment. Secure the chin strap when working.


**Photo 16-5** Personal Protective Equipment. (PPE)

Eye and face protection: wear safety eyewear with a face shield to protect eyes from floating debris. When using chainsaws, wear safety eyewear with a face shield which easily flips up if not required.

Hearing protection: wear earmuffs or earplugs when exposed to high noise levels, for example, when using a chainsaw or around noisy equipment.

Clothing: dress appropriately for anticipated weather conditions. Remove any dangling jewelry to avoid getting snagged on equipment or branches. Wear comfortable close-fitting clothing that does not restrict the ability to move freely.

High visibility apparel: wear high visibility clothing in a color that contrasts with the environment so it can be seen at a distance. Make sure that high-visibility clothing is not covered by other clothes. It must be worn

when working around any moving vehicles, equipment or lines, working alone or in isolation, harvesting trees at night, performing traffic control in work areas where there is vehicle traffic moving through a work zone or for falling operations. Loose-fitting high-visibility outer clothing must be "tear-away" if worn for work where it could get caught on moving equipment or objects like branches.

Hand protection: wear gloves that fit and grip well to protect against cuts, abrasions, splinters, vibrations, wet, damaging vegetation, and when filling and handling the chainsaw, and when handling wire, rope, or other steel objects.

Leg protection: when operating a chainsaw, leg protection must be worn like pants, chaps, or an apron made of cut-resistant material. Check that the leg protection has a label indicating it meets work safety standards. Check that the cut-resistant material protects the front and sides of legs. Make sure that clothes stay in position while working so the cut-resistant material provides protection. Leg protection should be comfortable enough and fit with each person to avoid a safety risk.

Foot protection: wear approved safety footwear to protect ankles, soles, and toes. Wear chainsaw protective footwear when working with a chainsaw. Wear caulked or other equally effective safety footwear when walking on logs, poles, pilling, or other round timbers.

**Selecting an Appropriate Forest Harvesting System**

An appropriate harvesting system for a forest seeks to balance environmental, social and economic interests in undertaking harvesting in that forest. In recent years some studies have been published to estimate best suitable harvesting systems for specific forest districts or compartments using GIS that take ecological and social criteria into account for a comprehensive analysis of the impacts of harvesting operations (Kuhmaier & Stampfer, 2010). However, the selection of suitable logging systems via GIS application requires skilled operators and can be rather complicated for adoption by local farmers or foresters who do not have basic knowledge of GIS. A study conducted to devise a simpler method for selecting the appropriate logging system as a part of Sustainable Forest Operations (SFO) is presented here.

The study, which was carried out in Teak plantations in Phrae province of northern Thailand, applied the Delphi method to identify the balance between environmental, social and economic aspects (Table 16-1). A total of 22 forest plantation staffs were asked to give weightage to these aspects among the choices placed before them. The grading score from each factor is combined with weight score for each tools/machine and summed up for each logging system. The logging system that obtained the highest score is considered the best logging system in the given circumstances.

**Table 16-1** Reclassification of grading score for each relevant factors

| Aspect | Grading score | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| | Critical | Unacceptable | Fair | Good | Excellent |
| Productivity | <5.99 $m^3$/h | 6-10.99 $m^3$/h | 11-15.99 $m^3$/h | 16-20.99 $m^3$/h | >20.99 $m^3$/h |
| Logging cost | >900 BTH/$m^3$ | 650-900 BTH/$m^3$ | 450-649 BTH/$m^3$ | 150-449 BTH/$m^3$ | <150 BTH/$m^3$ |
| Heart rate | >80 bpm | 76-80 bpm | 72-75 bpm | 69-71 bpm | <69 bpm |
| Working posture | >= 11 | 8.0-10.9 | 4.0-7.9 | 2.0-3.9 | <2 |
| Soil compaction | >1.8 g/$cm^3$ | 1.6-1.8 g/$cm^3$ | 1.4-1.6 g/$cm^3$ | 1.2-1.4 g/$cm^3$ | <1.2 g/$cm^3$ |
| Soil erosion | > 9.6 mm/y | 7.21-9.60 mm/y | 2.41-7.20 mm/y | 0.96-2.40 mm/y | <0.96 mm/y |

The recommended logging system which got the highest score was felling by chainsaw, extraction by elephant together with farm tractor, and transport by truck with loader. The findings can assist forest managers in selecting the right harvesting system taking into account the environmental, economic and social aspects. It is a relatively simple tool for forest manager to help in making decision.

**Appropriate Harvesting Technology**

Appropriate technology for teak harvesting in Thailand would be one that suits small-scale operations, affordable by locals, decentralized, labor-intensive, energy-efficient, environmentally sound, and locally autonomous. When a machine or a combination of machines is selected, care must be taken to introduce harvesting systems and techniques which are appropriate under the given circumstances. A system can be considered appropriate if all the various needs, possibilities and limitations have been taken into consideration. The level of technology adopted should take into account availability of both funds and skills with the project (Heinrich, 1987).

In developing countries manual and semi-mechanized logging operations still persist in most instances on account of 1) plentiful availability of cheap labor, 2) difficulties in importing high tech equipment, 3) limited availability of funds for forestry activities, 4) difficulties in access to spare parts, 5) shortage of skilled machine operators and technicians, and 6) lack of maintenance and repair facilities for equipment and advanced machinery.

**Lessons Learned and Recommendations**

Forest harvesting carries not only physical risks to the harvesting workers but can also cause severe environmental impacts if implemented without forethought and proper planning. Hence carefully plan and supervision during implementation is very crucial part of harvesting operation. Improvement of existing labor-intensive methods through better organization of work, use of more efficient hand tools, equipment and working methods, and training of personnel in the planning and application of appropriate logging technology may help improve logging operations in the short and medium term while in the long term greater reliance on modern technologies should be aimed at.

## Conclusion

Harvesting and extraction operations are the activities that generally cause the most significant impacts on forest and environments in forestry. The impact of harvesting and extraction can be reduced through proper planning and control of harvesting operations using sound principles, systems, and techniques that have stood the test of time. Successful harvesting should be 1) technically feasible considering physical limitations, engineering knowledge, and environmental relationship of the forest, 2) economically viable considering the costs and benefit of short- and long-range consequences, 3) environmentally sound considering impacts on the natural and social environment, and 4) institutionally feasible considering laws and regulations, landowner objectives, and social values.

## References

Applegate, G., Putz, F. E. & Snook, L. K. (2004). *Who Pays for and Who Benefits from Improved Timber Harvesting Practices in the Tropics? Lessons Learned and Information Gaps*. Center for International Forestry Research, Bogor, Indonesia.

Dykstra, D. P. & Heinrich, R. (1992). Sustaining tropical forests through environmentally sound harvesting practices. *Unasylva*, 169, 9-15.

Dykstra D. P. & Heinrich, R. (1996). *FAO model code of forest harvesting practice*.

Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO (Food and Agriculture Organization) (1999). *Code of Practice for Forest Harvesting in Asia-Pacific*. RAP Publication: 1999/12, Bangkok, Thailand.

Heinrich, R. (1987). Appropriate forest operations. In: *Proceedings of FAO/Finlan Training Course Philippines*. FTP publications: forest harvesting no.24.

ITTO (The International Tropical Timber Organization) (n.d.). *Reduced Impact Logging*. https://www.itto.int/sustainable_forest_management/logging/. (accessed 29 August 2021).

Kaakkurivaara, N. & Stampfer, K. (2018). Assessment for Improvement: Harvesting Operations in Small-Scale Forest on Thai Steep Terrain. *Small-scale Forestry*, 17, 259-27.

Klassen, A. (2011). *Planning considerations for Reduced Impact Logging*. Technical Procedures Manual under project: ITTO PD 110/01 REV.4 (I): "Program to facilitate and promote adoption of reduced impact logging (RIL) in Indonesia and the Asia Pacific region"

Kuhmaier, M. & Stampfer, K. (2010). Development of a Multi-Attribute Spatial Decision Support System in Selecting Timber Harvesting Systems. *Croatian Journal of Forest Engineering*, 32(2), 75-88.

Langin, D., Ackerman, P., Krieg, B., Immelmann, A., Potgieter, C., Rooyen, J. et al. (2010). *South African Ground Based Harvesting Handbook*. Institute for Commercial Forestry Research, Pietermaritzburg, South Africa.

Rianthakool, L., Kaakkurivaara, N., Diloksumpun, P. & Arunpraparut, W. (2018). Supply Chain Operations in Teak Plantation. In: *Proceedings of 6th International Forest Engineering Conference (FEC2018)*, Rotorua, New Zealand.