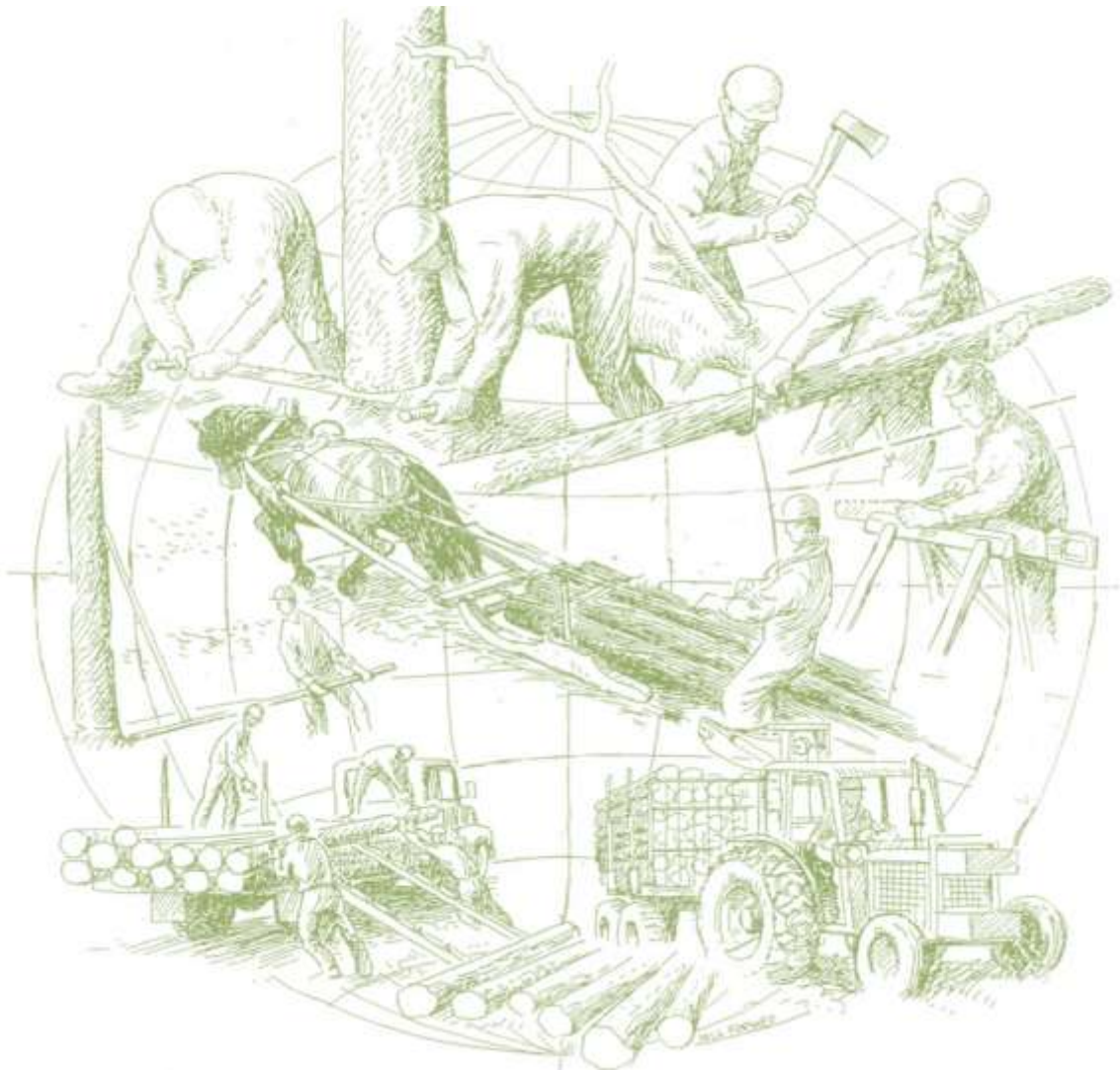




Appropriate small-scale forest harvesting technologies

a guidebook for Southeast Asia

Appropriate small-scale forest harvesting technologies: a guidebook for Southeast Asia



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Materials for this manual were gathered from field demonstrations and colleagues working in non-government, development, research and private forestry sectors all over the world, as well as from available reference documentation. The authors wish to acknowledge the cooperation and support received from individuals and organizations – the foresters, engineers and other personnel in the forestry sector of various agencies and organizations including CATIE, FAO, GIZ, ILO, KfW, METLA, the State Forest Service of Baden Wuerttemberg, the Universities of Freiburg and Dresden (Germany), Karelia (Finland), and the World Bank – for its invaluable cooperation and comments instrumental to the development of this guidebook.

FOREWORD

In the context of community and smallholder forestry, forest harvesting has been a grossly neglected field, particularly in Asia and the Pacific, where discouraging regulatory frameworks and limited market access for timber and bamboo become evident when harvesting activities increase beyond the subsistence level. The lack of appropriate harvesting and transport technologies available to local people prevents the realization of their greater share in the primary stages of timber- and bamboo-based value chains.

Poor access to transport facilities in remote forest areas can aggravate the problem and result in the under-utilization of forests, which also translates to missed opportunities in terms of poverty alleviation. Forest harvesting must be seen as the key income-enhancing element of sustainable forest management since it provides the only long-term, financially viable backbone for the large-scale maintenance of productive, multifunctional forest cover.

The Mekong Region has seen a considerable shift from labor surpluses to shortages in rural areas over the past two decades, where various forms of off-farm employment opportunities are offering local people a viable alternative. On the local level, lack of innovation and investment in the forestry sector has led to forest work being unable to compete with plantation agriculture, with the latter being driven by industrial-scale investments that have inherent improvements in labor efficiency. In addition, the inefficient extraction and transport of traditional forest products like fuelwood, when traded in scales beyond subsistence level, cannot in most cases compete even with imported forms of energy, such as liquefied petroleum gas (LPG). Development of appropriate technology and labor productivity for the forest sector is essential for improved sustainable forest management.

This guidebook does not deal with forest road or skid trail layout and construction since it was felt that at this stage, such investments are beyond the reach of local communities and smallholders even with the presence of donor support. The focus of this guidebook is thus appropriate harvesting technologies, while also exploring the role of primary processing using mobile sawmilling as an approach to facilitate extraction and transport. This guidebook covers aspects of enterprise development as long as they are directly related to the application of these technologies. This guidebook provides an initial reference, not only for local extension workers, entrepreneurs and the private sector, but also for governments and development agencies, to help them plan and introduce practical, affordable and sustainable solutions in the field of forest harvesting.

DISCLAIMER

Any person using information or recommendations contained in this guidebook should do so in accordance with local laws, regulations and with respect to local customs and traditions. Any equipment can be dangerous if not properly and safely operated. The safety of operators, workers and other personnel is of the utmost importance. Users should ensure that all necessary training, supervision and reasonable safety measures have been carried out prior to use of the machinery referred to in this guidebook. The authors take no responsibility for any inappropriate or unsafe use of equipment in pursuit of the concepts and principles described in this guidebook.

ACRONYMS

ACIAR	Australian Centre for International Agricultural Research
ASEAN	Association of Southeast Asian Nations
AUSTROFOMA	Austrian Forest Machinery Trade Fair
BEST	Biomass energy strategy
CATIE	Tropical Agricultural Research and Higher Education Center
CCP	Community-company partnership
CFE	Community forest enterprise
CL	Conventional logging
EEP	Energy and Environment Program Mekong Region
FAO	Food and Agriculture Organisation of the United Nations
FINNIDA	Finnish International Development Agency
FSC	Forest Stewardship Council
FOB	Free on Board
GERES	Groupe Energies Renouvelables, Environnement et Solidarités
GDP	Gross Domestic Product
GMS	Greater Mekong Sub-Region
GIZ	German Agency for International Cooperation
ILO	International Labor Organization
ITTO	International Tropical Timber Trade Organization
KWF	Kuratorium fuer Waldarbeit und Forsten (Organization for Forest Work and Forests)
LPG	Liquid petroleum gas
NORAD	Norwegian Agency for Development Cooperation
NTFP	Non-timber forest product
PPP	Public Private Partnership
REDD	Reduced (Carbon) Emissions from Deforestation and Forest Degradation
RIL	Reduced-impact logging
SIDA	Swedish International Development Cooperation
SME	Small and Medium Enterprise
TFT	Tropical Forest Trust
VALTIP	Value Adding to Plantation Timber Products (ACIAR funded project)
VC	Value chain
WWF	World Wide Fund for Nature

GLOSSARY

Bucking	Crosscutting of stems into logs and removal of top wastes.
Cut-to-length method	Logging method through which felled trees are processed into wood assortments in the stump area, which are then transported to roadside.
Delimbing	Removal of branches.
First landing	Location where trees are delimbed and bucked into shorter lengths and possibly stacked (can be identical with second landing).
Forwarding	Moving logs suspended from the ground to the (second) landing.
Full-tree method	Logging method through which the entire tree biomass above the felling cut (above the stump) is extracted to roadside intact.
Reduced-impact logging	The intensively planned and carefully controlled implementation of timber harvesting operations to minimize the environmental impact on forest stands and soils.
Second landing	Location from where the material is transported to processing site, which is the roadside in most cases, or riverbanks if rafting is applied. Trees are normally cut into logs according to grades, sorted into merchantable volumes and stacked for further transport.
Skidding	Moving logs to (first) landing by dragging on the ground.
Tree-length method	Logging method through which delimbed and topped stems are extracted intact, to at least the roadside.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	i
FOREWORD	ii
DISCLAIMER	iii
ACRONYMS	iv
GLOSSARY	v
1. Introduction	1
1.1 Outline of the guidebook	1
1.2 Harvesting – key cost factor in forest operations	2
1.3 Definition and scope of small-scale forest harvesting	3
1.4 Small-scale harvesting in the context of reduced impact logging	5
2. Small-scale forest harvesting in the community forestry context	7
2.1 Case: Fuelwood extraction – from subsistence to commercial operations in Nepal and Cambodia	7
2.2 Case: Community forest user group sawmills in central Nepal	10
2.3 Case: Smallholder teak harvesting and processing in Lao PDR	13
2.4 Case: Pacific islands and Indonesia	15
2.5 Case: Community forestry enterprises in Mexico	15
2.6 Case: Community forest management operations versus negotiated partnerships with private logging companies	17
2.7 Case: Comparative study of commercial community forestry initiatives in the Brazilian Amazon	19
2.8 Case: Small-scale timber extraction on formal and non-formal operations in the Amazon region	22
2.9 Summary findings of case studies	24
3. Overview of small-scale technologies	26
4. Assessing and selecting appropriate small-scale technologies	38
4.1 Legal environment	39
4.2 Product selection and product combinations	40
4.3 Assessment of terrain and transport infrastructure	42
4.4 Choice of technologies	44
4.5 Workers safety and labor aspects	45
4.6 Organizational aspects	48
4.7 Silviculture and ecology	49
4.8 Cost analysis in forest harvesting	51
4.9 Summary system analysis	56
5. Time and motion studies	58
5.1 Analysis of cycle time elements	58
5.2 Assessing work load and ergonomic issues	62
5.3 Assessing safety issues	63
5.4 Drudgery work of women and children	64
6. Outlook – knowledge dissemination and learning	65

7. References	66
8. Annex	75

Annex 1: Example of a Forest Operation Planning Map from FAO 1999

Annex 2. Factsheets

1. **Manual operations and hand tools**
 - 1.1 Hand tools
 - 1.2 Log chutes
 - 1.3 Sulkies
 - 1.4 River rafting
2. **Animal traction**
 - 2.1 Horse-mule-donkey
 - 2.2 Buffalo-oxen
 - 2.3 Elephant
3. **Mechanized harvesting and transport**
 - 3.1 Chainsaws
 - 3.2 Hand-held winches
 - 3.3 Self-powered/propelled winches
 - 3.4 Tractors and attachments
 - 3.6 Small cable logging system
 - 3.10 Rubber-tracked mini crawlers
4. **Mobile Processing**
 - 15.1 Chainsaw mills
 - 15.2 Mobile sawmills

1. Introduction

1.1 Outline of the guidebook

The guidebook consists of six main parts.

Part 1 provides a definition of ‘small-scale technologies’ and introduces criteria for the term’s appropriateness. Part 1 describes the concept within an international developmental context, specifically in view of the current debate on reduced-impact logging (RIL), which, since 1970, has been directed towards maintaining forest carbon stocks and other environmental services of forests.

Part 2 extracts information on the role of small-scale forest harvesting technologies from eight case studies on commercial community forestry. Part 2 also describes the application and possible contribution of small-scale forest harvesting technologies to income generation and poverty alleviation through the horizontal and vertical integration of communities into the wood-based value chain. The case studies’ findings are summarized with reference to the regional perspective of Southeast Asia.

Part 3 provides a comparative summary of various types of appropriate harvesting technologies. The section provides detailed descriptions of such technologies, which are presented in the Annex as a series of fact sheets. These fact sheets include an overview of the technology, review of literature and case studies on their application in situations comparable to the context of community forestry.

Part 4 presents key criteria that users can apply and adapt to their situation – i.e. site-specific conditions and socioeconomic contexts – when assessing various small-scale harvesting systems. These criteria cover technical feasibility, including legal constraints, assessments on terrain and transport infrastructure, as well as the criteria’s relationship to the anticipated product types (e.g. fuelwood, other forms of biomass energy, poles, timber, bamboo products, etc.) The section also introduces the important link of product selection to the fundamental principle of piece-volume ratio and its effect on operational efficiency in forest harvesting. Product combinations consisting of main waste and by-products are also highlighted. In addition, part 4 also covers:

- Safety, ergonomic and labor aspects, particularly competition posed by off-farm labor and seasonality according to agricultural production cycles. The section also covers organizational aspects, which focus on the issues faced by providers of support services for training and maintenance and the need to form cooperative systems to scale-up operations with the goal of increasing harvest volumes and value by making sure that recommended technologies are, in the first place, financially viable.
- Silvicultural and ecological aspects of harvesting through comparisons between natural forest and plantation environments with both site types assessed for operations conducted on steep slopes. Also covered are the roles of harvesting in forest restoration, particularly in fuel load reduction, and the management of low commercial value pioneer or invasive species.

- Feasibility assessments, including time and motion studies, machine cost calculations and the analysis of harvest systems that combine various technologies.
- Carbon footprinting of harvesting technologies and provides some primary arguments on the current debate on climate change for labor-intensive, non-mechanized systems (e.g. animal based extraction).

Part 5 presents the tools of time and motion studies and explains the breakdown of harvesting systems in cycle time elements, assessment of workload and ergonomics, safety aspects and the issue of drudgery work for women and children in fuelwood harvesting.

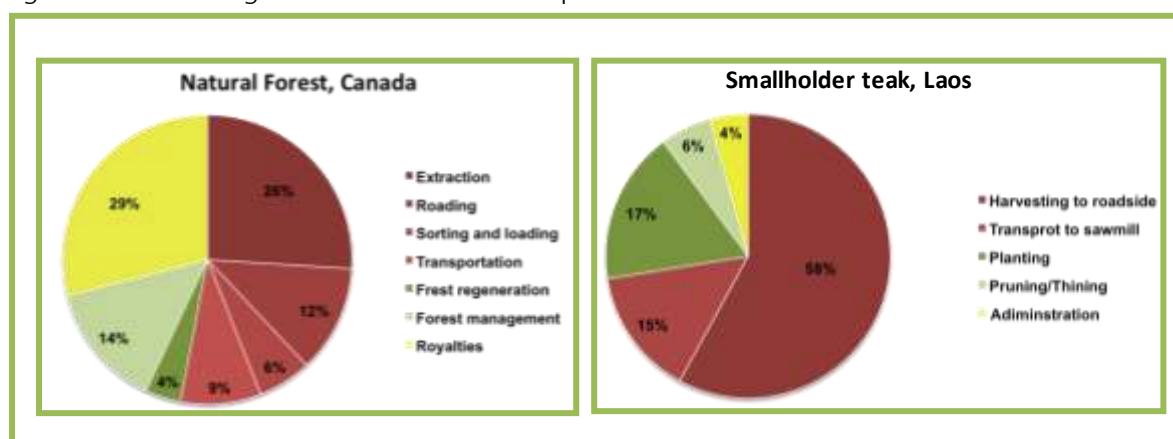
Part 6 provides a brief outlook on the future of small-scale appropriate harvesting technologies in Southeast Asian context and provides some guidelines on aspects of learning in this field.

1.2 Harvesting – the key cost factor in forest operations

The total **wood production process** in the context of this guidebook covers the stage from tree seedling either by planting or natural regeneration through various silvicultural treatments like fertilizing, weeding, thinning, pruning, etc. until the final harvesting, which covers in most cases the process from felling trees and forwarding them to road or riverside landings where grading and sorting takes place. These landings are in most cases also the handing over point between forest owner and trader/sawmillers. From there onwards transport takes place to primary processing sites in most cases sawmilling.

If the forest owner carries out the wood production process described above, harvesting costs typically cover **50 to 75 % of all operational costs** of forest enterprises as shown in Figure 1a. This percentage shares are different in plantations with – in most cases – existing road infrastructure and high costs for planting and stand maintenance and replanting. On the other hand natural forest type management with high rate of natural regeneration hardly requires any other operational (silvicultural) expenditure. Only administration and other costs directly related to the primary production process are considered in this comparison. They are typically in the range of 20 to 40 % of overall costs of the forest enterprise. The high share of costs related to harvesting in both illustrations show the importance of addressing efficiency issues and choice of technologies if forest enterprises are to be kept competitive.

Figure 1a: Percentage Cost Share in Forest Operation and Plantations

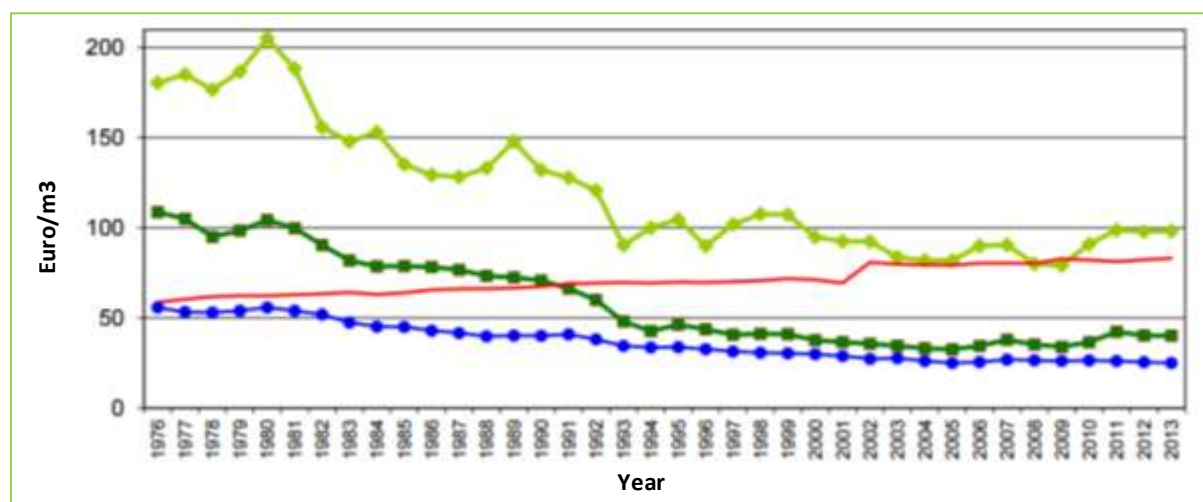


The *natural forest type* example from British Columbia, Canada shows that harvesting (extraction, sorting and loading) makes up **32 % of total** or **55 % of operational costs** which are 58 % of total costs with royalties (28%) and management (14 %) covering the rest. Costs for roads are kept separate in this assumption, but could also be added to harvesting costs as well and would thereby increase its share to 75 %.

Examples from smallholder teak plantations in Lao PDR and Indonesia indicate shares of harvesting costs of about 40 to 60 % assuming the production cycle from plantation establishment to timber sale at roadside landings (Kurniawan 2009, Mohns 2009). It becomes obvious that there is enormous potential for possibly doubling incomes to forest owners in both natural and plantation forestry operations if they can achieve a vertical integration of the timber production stages to roadside landings.

It has also to be realized that costs for harvesting operations need to decrease in situations where either log prices are dropping or labor costs are increasing or as shown in the following Figure 1b where both trends are occurring simultaneously. The graph shows the situation in Austria for harvesting small and medium sized logs and pulp/chip wood. For both categories prices have dramatically dropped over the last 30 years – if adjusted to inflation – while labor costs have gradually increased. Forest industry had to adjust to this situation by a marked decrease in harvesting costs in order to allow financially viable operations. Unfortunately such analyses are not available for any developing country – however as shown later examples on fuel wood harvesting costs in relation to LPG as similar trends in labor wages are emerging with similar consequences on the extraction of wood products.

Figure 1b: Development Labor and Harvesting Costs in Relation to Timber Prices from 1976 to 2013



Values adjusted to inflation (source: VPI Austria Statistics and personal communication - AUSTROFOMA 2015 Exhibition catalogue, personal communication. Nikolaus Nemestóthy Bundesforschungszentrum für Wald FAST Ort - Fachbereich Forsttechnik)

Legend:

Green diamond: Log prices (Euro/ m3) for Spruce 25 to 30 cm top diameter B-Quality
Green square: Prices for coniferous industrial wood (Euro / m3)
Red: Labor costs (Euro/m3) inflation free
Blue: Harvesting costs (Euro/m3) inflation free

1.3 Definition and scope of small-scale forest harvesting

The interchangeable terms 'small-scale forestry' or 'small-scale forest harvesting' have been used mainly in European and North American forestry circles. In general, they refer to forestry (harvesting) operations carried out by individual or collective owners of smaller-sized woodlots in contrast to larger scale government or industrial operations. Harvesting technologies in this context are within the financial reach and operational/managerial capacity of individual forest owners or cooperative producer groups. These technologies are also, in more cases, linked with farm machinery. Logging winches, grapple tongues and loading cranes mounted to agricultural tractors are the standard equipment of most farm-forestry operations in developed countries.

Forest research and extension, as well as training institutions and universities, still conduct extensive research on the economic and ergonomic performance of a wide range of small-scale forest harvesting systems. First-hand information on the respective equipment can be obtained in the following trade fairs. For the special conditions presented by small-scale harvesting in mountainous areas, the AUSTROFOMA exhibition held by Austrian manufacturers of forest-harvesting equipment, held only every four years, is an excellent source of information. The exhibition features actual demonstrations of equipment under real forest conditions and is documented in a well-prepared catalogue. A similar event takes place in Sweden with the Elmia Wood and the KWF Demonstration Week in Germany. In recent years, a clear focus on harvesting of energy biomass has emerged in Europe and North America within the context of small-scale operations, especially on whole-tree harvesting options and on-site wood chipping. On the high-end timber value chains, mobile sawmilling has dominated the interest of the industry for the past 15 to 20 years. Most information on these sources is very applicable to the rural development framework of Southeast Asia. Similar events with field demonstrations are unfortunately, however, not carried out in the region. Industrial trade fairs for the plantation industry (rubber oil palm) and the forestry sector do take place – in Malaysia and China, for example – but are less focused on small-scale forestry operations.

In terms of development, small-scale forestry reached its peak between 1970 and 1990 during a period when industrialization was seen as a key intervention, parallel in importance to the green revolution occurring in the agricultural sector. The Food and Agriculture Organisation (FAO) of the United Nations, the Swedish International Development Cooperation (SIDA), the Norwegian Agency for Development Cooperation (NORAD) and the Finnish International Development Agency (FINNIDA) published a series of technical reports on appropriate forest harvesting between 1970 and 1990. In retrospect, these papers offer good overviews on tools and machinery, but provide only limited information on approaches to assess the technologies under specific production systems and sites. This is mainly due to the fact that small-scale technology was seen as a way to create jobs in the forestry sector rather than as a way of looking at operational and cost efficiency. The proposed technologies assumed an overabundance of rural labor due to the perceived population explosion, thus not accounting for the labor shortage and increased income expectations now the standard in rural settings. The dollar symbol (\$) in Figure 2 – standing for the US\$ 1 per day income perception – reflects the thinking and subsequent intervention strategies at that time.

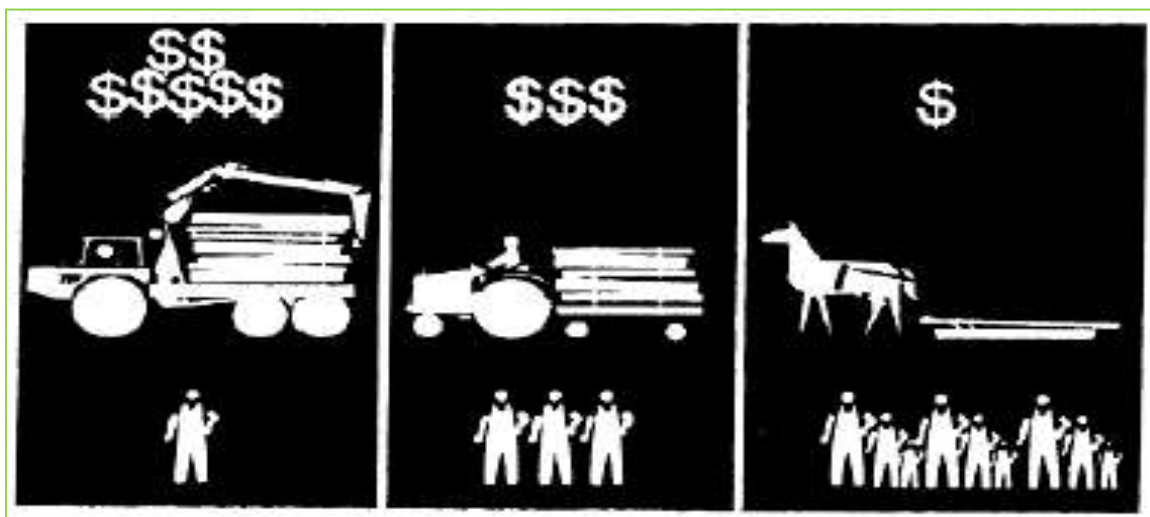


Figure 2. Implication of modern technology in the development country context (FAO 1982)

According to a recent FAO (2013) review, mechanization seems to have become, to a certain extent, neglected in agricultural and rural development contexts. As an essential input, mechanization can transform farm family economies by facilitating increased output and reducing the drudgery of hand-powered production. Agricultural mechanization, when carefully selected and proven to be appropriate to the task, is also capable of protecting natural capital and the environment while boosting food production. However, mechanization has been frequently neglected in recent years as a vital input.

Agricultural and forest engineering departments in the CGIAR international research centers have been wound-down or closed and world class undergraduate training in this field is also in serious decline. Why this should be the case is not understandable when careful studies have made it abundantly clear just how crucial an input mechanization is in the pursuit of sustainable global agriculture or forestry production to meet the challenges posed by global food security, declining wood supplies and the need to improve rural livelihoods. Within FAO itself, the resources invested in the selection of appropriate mechanization options have been declining, although the vital role of rural mechanization is recognized in the agricultural sector as a vehicle for raising rural incomes through high quality service provision on farms, for road transport and forestry and in the development of entrepreneurship in the primary stages of rural product value chains.

However, following recent food scarcity, price hikes and the subsequent global financial crisis with spiking prices for food stocks, the global focus has returned to the importance of agricultural production and productivity. Current mechanization trends, such as the rapid spread of 4-wheel agricultural tractors throughout the Mekong region, is evidence of this, and it offers opportunities to link with mechanization development for the forestry sector. A recent publication on intermediate equipment for road development by Petts (2012) illustrates this essential link to agricultural machinery. Petts' work has, to some extent, guided the approach of this publication with a strong focus on economical viability for the proposed technology.

1.4 Small-scale harvesting in the context of reduced-impact logging

Since around 1995, the subject of forest harvesting in the tropical regions has been dominated by the term reduced-impact logging (RIL), which has gained prominence specifically within the context of the REDD+ debate. RIL refers to forest harvesting with improved methods of pre-harvest tree inventories, directional felling and extraction methods aimed at reducing the damage to the mainly natural residual forest stands. However, an FAO review on the subject in 2004, which studied forest operations under RIL, apparently considered equipment, mainly in large-scale industrial forest operations, more or less a given and did not even consider any equipment parameters as a possible criteria.

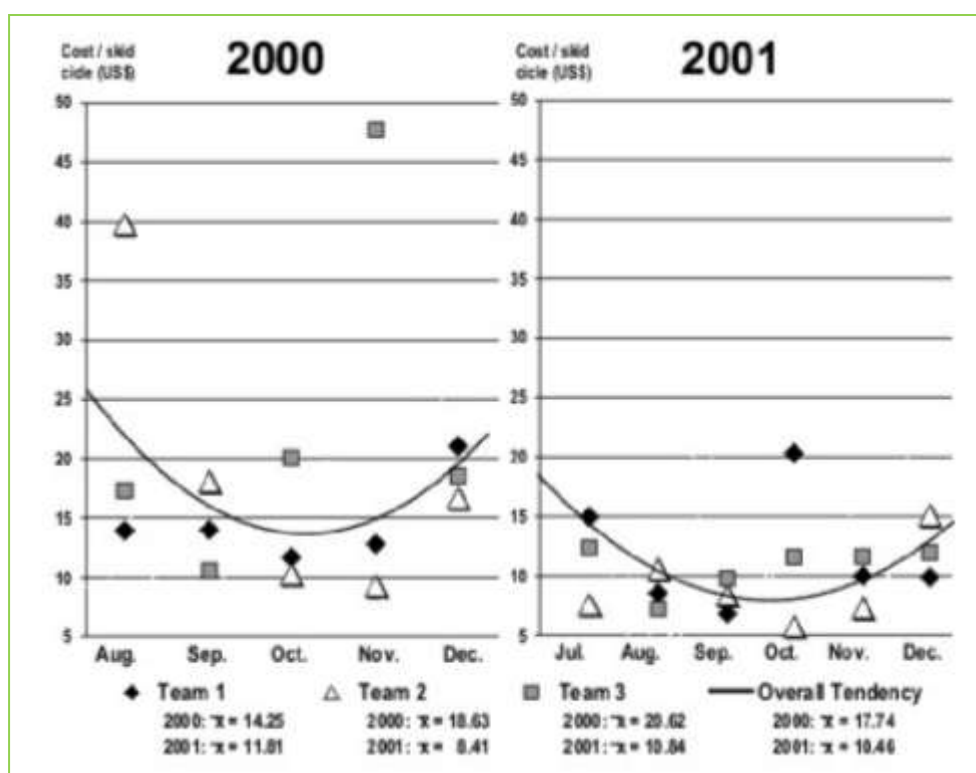


Figure 3. Cost of skidding logs (US\$/m³) during two harvest periods affected by implementation of planned skidding as part of RIL strategy in the Amazon (Pokorny, B 2005)

There is ample evidence from Central and South America, however, on the potentially positive role of small-scale technology (animal logging and agricultural tractors) in the RIL context (Rockwell 2006), though some studies have pointed out that RIL has apparently led to increases in production costs (Figure 3). In Southeast Asia, local communities or small-sized forest operators were completely left out of the RIL approach because these actors play a minor role in commercial-scale operations in wood extraction. Thus, information on the application of technologies appropriate for forest harvesting for levels below state-owned or concession forest enterprises basically do not exist for the region.

Other studies, as shown in Table 1, found a reduction of costs in RIL operations where mainly improved planning appears to have impacted efficiency of skidding and landing operations, where stumpage costs could considerably offset higher preparatory planning costs.

Table 1. Costs and returns of conventional logging (CL) versus reduced-impact logging (RIL) operations, Holmes, et al. (2000)

Activity	CL (US\$/m ³)	RIL (US\$/m ³)	Increase or (Decrease) RIL – CL
Pre-harvest	0.00	1.18	1.18
Harvest Planning	0.14	0.16	0.00
Infrastructure	0.57	0.59	0.02
Felling & bucking	0.49	0.62	0.13
Skidding	1.99	1.24	(0.75)
Log deck operations	2.01	1.28	(0.73)
Waste adjustment	0.40	0.09	(0.31)
Stumpage cost ¹	9.09	7.61	(1.48)
Training ²	--	0.21	0.21
Overhead/support	0.97	0.86	(0.11)
Total cost	15.66	13.84	(1.84)
Gross returns	25.50	25.50	0.00
Net revenues	9.84	11.66	1.84

¹ Stumpage costs are higher on typical CL operations because more wood is wasted and, therefore, per hectare price of harvesting rights is spread over fewer units of volume recovered.

² Costs were not computed for on-the-job-training (OJT) for CL operations, nor were increased equipment costs due to rough treatment.

2. Small-scale forest harvesting in the community forestry context

Forest harvesting is almost always a controversial topic. Small-scale approaches are no exception and can be seen from various, often extreme, angles. For example, some ecologists might argue that the extraction of tops and branches and dead material by local people – even for subsistence purposes – decreases the recycling of nutrients. Others, still taking an environmental perspective, might justify such work by local people by noting that the removal of combustible material helps reduce the threat of forest fires. From the viewpoint of government foresters, arguments have been brought forward that efficient monitoring of many small operations would be nearly impossible. On the other hand, non-government organizations (NGOs) involved in forest management have argued that, with help, local communities and user groups can develop their own monitoring skills and the ability to protect forests, including the provision of environmental services.

Opponents of primary processing by local people often refer to the lower conversion efficiencies compared to the more efficient outcomes produced by a well-run sawmill. But a key question is: is it justifiable to accept a lower conversion efficiency to create additional employment and spend less foreign exchange on heavy equipment? This comparison highlights the decision-making trade-offs central to considerations involving small-scale harvesting. Given the variability of forest conditions, socio-economic situations and purposes for harvesting forest products, there is no single answer to these questions. When applied in a manner consistent with sound management practices, small-scale harvesting and conventional logging are both important components of forestry. Indeed, combinations of conventional logging and small-scale harvesting may well be the appropriate way forward, assuming a regulatory environment that supports community–company partnerships in the forestry sector.

All pros and cons considered, the potential of small-scale harvesting to increase employment and help reduce poverty cannot be denied. It is in view of these benefits that small-scale harvesting deserves increased attention, particularly in the areas of policy, research, training, organization of communities, linkage to markets and opportunities for linking with conventional logging.

There are numerous articles on timber-based community forest enterprises (CFEs). However, only few studies in Asia provide detailed data assessing the importance of the technology applied, effects of labor utilization, subsequent costing and viability of logging and processing operations. The following case studies are an attempt to give an initial overview that highlights key arguments on the subject.

2.1 Case No. 1: Fuelwood extraction from subsistence to commercial operations in Nepal and Cambodia

The so called ‘fuelwood crisis’ of the 1980s – a perceived mismatch between fuelwood demand by an ever increasing population in relation to decreasing forest resources – was at that time – the driving element of community forestry in Asia and the Pacific, particularly in the Himalayan region. A recent baseline study for a biomass energy strategy (BEST) in Nepal (Mohns 2013) attempted to analyze this situation. The study revealed a constant price increase of fuelwood traded to urban centers with a spread of prices ranging from US\$ 0.03/kilogram (kg) for low quality softwood (Pine) in remote areas to up to US\$ 0.20/kg for Sal hardwood (Shorea) in the Terai cities and the urban areas of Kathmandu and Pokhara. The trend of fuelwood prices is

illustrated in Figure 4. The graph depicts the original data from a 10-year study on fuelwood pricing in Pokhara in the 1990s. It is important to note that there is an increase from 1 600 Nepali Rupees (NRs)/ton in 1990 to 8 000 NRs/ton in 2013, an annual increase in price of 5.9 percent. According to interviews in 15 pilot sites of the baseline study, this increase is a reflection of high harvesting costs related to increased labor wages, road transport costs, rent seeking along the supply chain and possibly regional shortages.

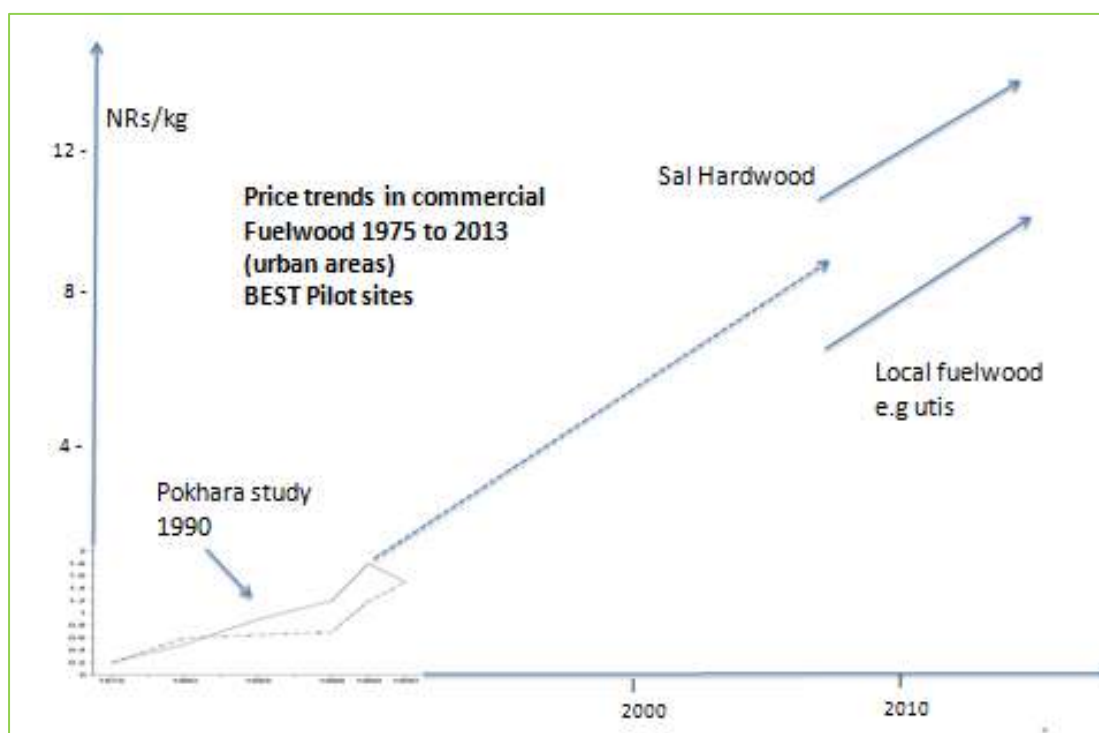


Figure 4. Price trend for fuel food in Nepal from 1980 to 2013 (100 NRs = US\$ 1.00)

In spite of the scientific interest in community forestry in Nepal, there is extremely limited information on operational aspects. The review found only one detailed study on harvesting cost of fuelwood in combination with timber, which is summarized in Figure 5. There is a marked difference between the samples in the mid-hill areas (US\$ 33/ton) vs. the Terai samples (US\$ 21/ton), which most likely reflects the effect of slope and road access/harvesting distance. These results match the interview findings of the pilot sites in the hill districts, where manual extraction rates of fuelwood are in the range of around 150 kg/day. If multiplied by average wage rates of around US\$ 3.5/day to 5/day, we arrive at US\$ 23/ton to 33/ton.

Traded fuelwood is highly linked to the trade of timber. Records on fuelwood/timber trade in the Kathmandu Valley for 2006/2007 indicated prices of US\$ 75/meter (m)³ (stacked dry) or US\$ 62/ton (wet). The price range matched well with the observations of the BEST study. It is interesting to note that this price is identical to the sawn timber prices in the Nepal pine timber case study which will be discussed below.

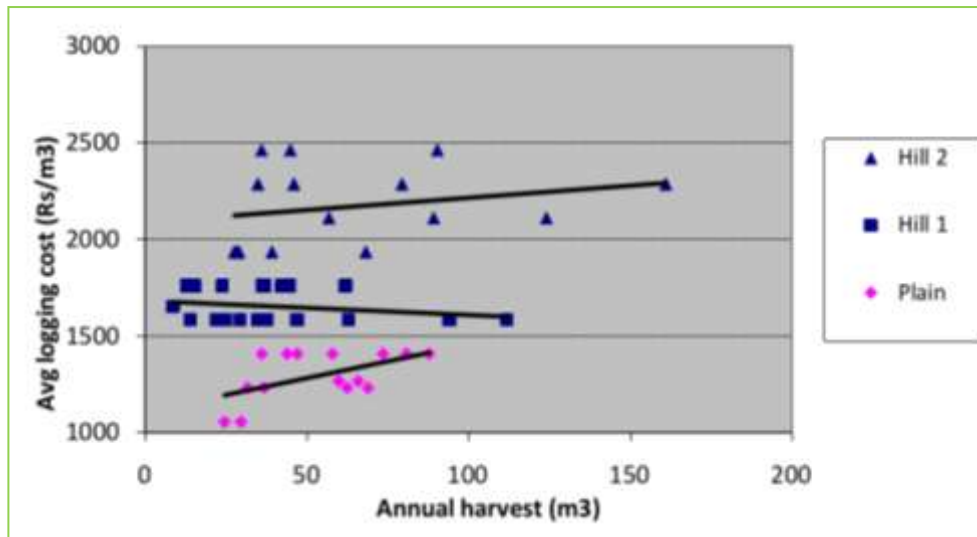


Figure 5. Harvesting costs in community forest operations and effect of total annual harvest volume (Rai 2010)

A comparison of fuelwood pricing and trends was carried out as part of the BEST study in Nepal. The 2013 price for liquid petroleum gas (LPG) was US\$ 14.6 per 14.2-kg cylinder. The price trend since 1997, which is shown in Figure 3, indicates a price increase of 7.4 percent. The price trend of LPG is compared with the energy equivalent for fuelwood in high (Terai and Kathmandu) and low price (other urban areas) scenarios. The analysis shows that the high price fuelwood is in fact far more expensive than LPG if the energetic value is taken into consideration. Even the lower priced fuelwood appears hardly competitive with LPG within the last 15 years.



Figure 6: Comparison of LPG price vs. fuelwood replacement cost: 1997-2013

Energetic value (adjusted to stove efficiency of open fires) of 11 kg of dry (15 percent moisture) fuelwood = 1.0 kg LPG (2013 data is derived from the BEST in Nepal case study site findings).

Though not the only component of commercially traded fuelwood in Nepal, harvesting costs, in addition to road transport, are an important component. Harvesting costs are around 25 to 30 percent of total production costs in the hill areas and 15 to 20 percent in the Terai. It is clear

that efforts will be needed to keep traded fuelwood in a price range that is competitive with imported LPG if Nepal wants to follow a course of energy self-sufficiency and reduced emissions for non-renewable fuels. However, analysis of the operational capacities of local communities in Nepal shows various constraints. As shown in many studies on the subject, internal resources (entrepreneurial skills and access to finance) ranked highest, followed by restrictions on operations and market access.

Similar findings were recently made in Cambodia under a component of the Environment and Energy Program (EEP), a project implemented by RECOFTC – The Center for People and Forests and Groupe Energies Renouvelables, Environnement et Solidarités (GERES), in the assessment of charcoal value chains. Harvesting costs were found to be between US\$ 25/ton to 45/ton for split and stacked air-dry fuelwood at roadsides. Neither the fuelwood nor the charcoal subsequently produced was found to be competitive to imported LPG in energetic terms, which carries prices between US\$ 15 and 18 per 15-kg cylinder. However, it must be noted that charcoal is not only used for direct heating in food preparation, but very often for barbecuing, whereas LPG has found limited entry acceptance in urban areas.

In the assessment of the complete value chains, it was found that the wood used to produce fuelwood originated mostly from land clearings, which basically do not carry any forest management or production costs. Clearing leftover trees very often carry a negative value in order to allow cultivation.

First attempts to improve efficiency by applying chainsaws, hand sulkies and small tractors have so far not delivered convincing results on the financial viability of commercial-scale fuelwood production, in often sparsely-stocked community forests.

2.2 Case No. 2: Community forest user group sawmills in central Nepal

Between 1975 and 1990, about 22 000 hectares (ha) of Chir pine plantations were established by local communities supported by Australian Aid in the central hill districts of Sindhupalchok and Kabre. Most plantations reached the thinning stage by 1985 and thinning material was sold as standing trees at a stumpage value of US\$ 12/m³ to 18/m³. In 1996 and 2001, two small band sawmills managed by community forest user groups were established with project support under the assumption that the value addition on pine thinning would be considerable and could encourage further thinning operations and other elements of better management.

Harvesting methods were based on motor manual operations with chainsaws and 2-man crosscut saws. Hand sulkies, as depicted in Figure 7, were introduced around 1990 and were locally produced in small numbers for several years. Unfortunately, this technology was later abandoned for unknown reasons. Transport to main roads or sawmills were done either by 2-wheel hand tractors or 4-wheel tractors with small trailers.



Figure 7. Locally manufactured hand sulky in Sindhupalchok district (Photo courtesy of Don Gilmour)

Table 2 shows the cost structure of the sawmill operations as assessed by a study by URS Sustainable Development Project Management Consultants in 2003 under the Nepal-Australia Community resource management and livelihoods project.

Felling and forwarding operations to roadside landings appear reasonable with costs between US\$ 8/m³ and 11/m³ of round wood. However, the further processing stages seem to be financially nonviable given the very low prices of around US\$ 70/m³ for sawn wood and low conversion rates of 40 to 50 percent from round wood to sawn wood. The overall returns to the forest user groups between US\$ 3/m³ and 6/m³ for round wood is only one-third of the stumpage value when selling standing timber. The study concluded that the intended additional value on material from pine thinning operations was poorly assessed in the design phase in terms of technical feasibility and market potential of sawn pine timber. The operations of both sawmills were also hampered by poorly selected sites that were too far away from major roads and urban markets. The sawmill operations have since been discontinued by the original user group management model.

Table 2: Summary cost structure and returns from two community forest user group-operated sawmills based on pinus plantations in central Nepal (Data extracted from URS, 2003)

Component	Details	Shree Chhap sawmill	Chaubas sawmill
Commencement of operation	Small village level circular sawmills	2001	1996
Price for sawn timber sale at roadside outlet	Pinus roxburgii timber Log length on average 3 m US\$/m ³ sawn wood	70	70
Value added tax	US\$/m ³ sawn wood	4.5	4.5
Transport of timber from mill to roadside sales outlet	Both sawmill at considerable distance to roadside	3.5	7.0
Price of timber ex sawmill	US\$/m ³ sawn wood	62	58.5
Cost of timber processing	Both sawmills use band saws with a capacity of about 300 to 400 m ³ /year Maintenance costs are high due to remoteness of mill location US\$/m ³ sawn wood	14	21
Residual from cost of sawn timber and transport	US\$/m ³ sawn wood	48	37.5
Conversion of residual from sawn wood to round wood	39% for Shree Chhap 48% for Chaubas US\$/m ³ round wood	19	18
Transport of logs from forest to sawmill	US\$/m ³ round wood	5.25	3.50
Felling and sectioning of logs forwarding to roadside	US\$/m ³ round wood	10.50	8.75
Residual for return to community forest user groups	US\$/m ³ round wood	3.25	5.75

2.3 Case No. 3: Smallholder teak harvesting and processing in Lao PDR

Smallholder teak plantations have been established in central and northern Lao PDR over the past two decades, driven by the fact that smallholders can gain land ownership – or at least long term user rights – and can create a financial asset that can be immediately accessed in times of financial need. Teak covers currently approximately 40 000 ha with a regional focus in Luang Prabang province. Several donors and NGOs – the Australian Center for International Agricultural Research (ACIAR), Tropical Forest Trust (TFT), Japan International Cooperation Agency (JICA) and German Agency for International Cooperation (GIZ) – have been supporting the sector with various projects ranging from stand management to value addition. Issues of harvesting systems have so far largely been left out from this support in the past and have only recently been recognized by RECOFTC's Livelihood Improvement through Generation and Ownership of Forest Information by Local People in Product and Services Markets (ForInfo) project and the ACIAR-funded Value Addition to Plantation Timber (VALTIP) project. This development has mainly taken place in view of the fact that farmers lose interest in reestablishing teak plantations in accessible locations due to emerging competition with rubber (since around 2004) and banana (since 2007) plantations, which has been driven by Chinese industrial-scale investments in the area. Besides the issue of competing with these crops, the project implementers realized that if teak were to survive as a smallholder crop, it should be planted farther away from roadsides. Thus, solutions for transporting teak timber over great distances to roadsides or processing on-site with mobile mills, must be developed.

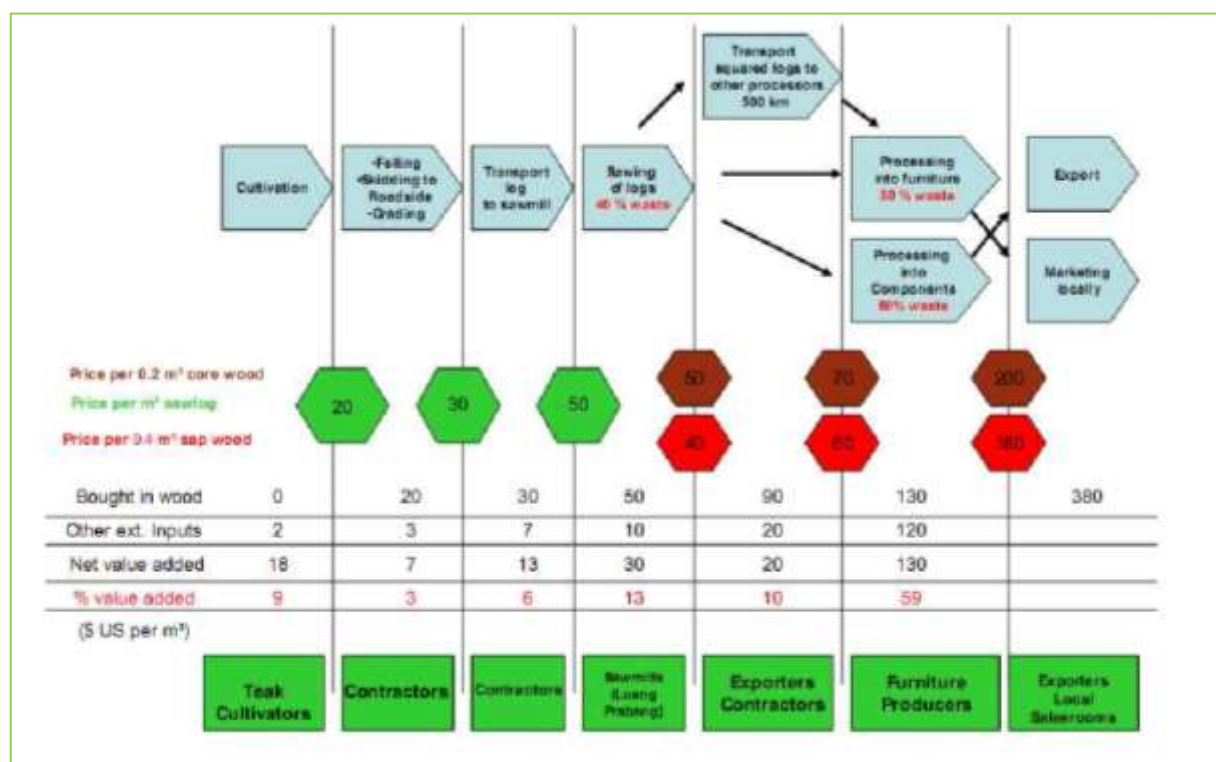


Figure 8. Smallholder teak timber value chain aimed at producing outdoor furniture (Mohns 2009)

A study carried out by Mohns (2009) on smallholder timber-based value chains, in cooperation with the Vientiane Wood Industry Cluster, the analysis of the primary production stages revealed that plantation management until the harvesting stage carried a cost of about US\$

20/m³ for round wood, which corresponds to nine percent of the outdoor furniture value chain studied. Further costs for felling and skidding made up three percent, road transport six percent and local sawmilling 13 percent. The price of a saw log increased from US\$ 20/m³ at the plantation to US\$ 50/m³ at the sawmills (in Luang Prabang province). When a log is transported to Vientiane, the price increases by another US\$ 50, due to long distance. About 40 percent waste wood would be transported for round logs. Thus, there is potential to create a win-win situation if sawmills in Vientiane would cooperate with teak farmers in at least squaring teak logs as close as possible to the plantation sites, thereby reducing transport costs considerably.

These findings are consistent with other case studies on logging and primary processing in community forests. Such studies are unfortunately quite rare in the international forestry context. Antinori and Bray (2005) found that Mexican community forestry groups increased total village employment from 15 percent for stumpage sale systems to 19 percent for logging and 26 percent for simple secondary processing (sawmilling) situations. Auzel, et al. (2001) found 12 times higher log prices for community-based operations versus the traditional concession logging system in Cameroon.



Figure 9. Trials on long distance extraction of teak timber with rubber-tracked crawler systems

Currently, most timber is sold standing while middlemen or sawmillers harvest and transport the timber to sawmills. Simple harvesting solutions are needed to allow plantation owners to at least bring the logs to roadsides and sell in accordance with simple grading rules. For short distance harvesting, sulkies are currently applied in the Bokeo province in northern Lao PDR under the ForInfo project. Tests have also been carried out to develop rubber crawlers converted from agriculture machines to address the issue of long distance harvesting without roads. The project team also anticipates that mobile sawmilling in cooperation with local sawmills will facilitate transportation from the more remote areas.

2.4 Case No. 4: Pacific islands and Indonesia

A recent review by the United States Agency for International Development (USAID) (Lawler 2004) on six country cases (Pacific Islands, Indonesia, Papua New Guinea, Cameroon,

Madagascar and Bolivia) of small-scale timber harvesting in community forestry projects with a strong orientation towards wood processing and marketing, indicates that none of the projects could show conclusive evidence that communities were in full control over all stages of the value chain from standing trees to sawn timber. A major obstacle for these communities was a lack of technical and managerial competence, particularly in controlling the extraction and transportation processes. The USAID review makes it apparent that rural communities can only benefit considerably from wood-based value chains if technologies are available to them, which allow their control over the initial stages of tree felling and transporting to the sites of selling, processing or, loading for road or river transport.

Table 3. Estimated logging costs of 300 to 1 000 ha community forest management units in the Pacific Islands (Lawler 2004)

Estimated costs per cubic meter of logs extracted	
Item	Cost US\$ /m ³
Royalty for standing timber	6
Labor	20
Fuel/oil	8
Maintenance of spare parts	11
Loans on machinery	25
Transport external	12
Cost subtotal	83
Revenue on timber sales	132
Net revenue	50

The case study findings on the relatively high portion of loan and other costs for machinery (highlighted in red in Table 3) totalling US\$ 44/m³ or 53 percent of the subtotal (83) corresponds well with the findings and critical conclusions presented in the research on the Amazon done by Pokorny (2010). To be sure, a reader may seriously doubt that the choice of machinery in this case was appropriate given the fact that machine costs are twice as high as labor costs. Unfortunately, the study does not provide further details on the type of equipment used.

2.5 Case No. 5: Community forestry enterprises (CFEs) in Mexico

Mexico is rich in indigenous forms of communal organization. These institutions were overlaid and imitated by the agrarian reforms arising from the Mexican Revolution (1910-20) and enshrined in Article 27 of the country's Constitution of 1917. The resulting agrarian law led to the implementation of two forms of common property, *ejidos* and *comunidades*, which now cover about half of the national territory.

Both governance systems were derived from more ancient indigenous institutions and thus do not have classically capitalist roots. The agrarian sector was reformed in 1992, giving local community members the opportunity to privatize individual land use. However, privatization of common property forests is still prohibited by the law. Both governance systems and

subsequent reforms provide the social matrix for the emergence of community forest enterprise (CFE) management institutions. Logging communities in Mexico range from traditional indigenous communities with pre-colonial agrarian claims, typically *comunidades*, to much more recently organized non-indigenous *ejidos* bearing few communal traditions.

Antinori, C. and Bray D.B. (2005) analyzed capital assets and investment forms for key forest machinery tracks, cranes and sawmills, operated by four CFE types of vertical integration: 1) stumpage sale based, 2) delivery of roundwood, 3) operation of own sawmills, and 4) production of secondary products.

Table 4. Capital asset ownership in Mexican community forest enterprises (Antinori 2005)

	Trucks				Cranes				Sawmills	
	Stumpage	Roundwood	Sawnwood	Secondary products	Stumpage	Roundwood	Sawnwood	Secondary products	Sawnwood	Secondary products
	n = 15	n = 13	n = 8	n = 7	n = 15	n = 11	n = 7	n = 7	n = 8	n = 7
Average number used for harvest	10	10	13	14	1.75	1.7	1.5	2.9		
<i>Distribution of ownership (number of communities)</i>										
Community owned	1	8	6	7	0	6	7	7		
Total individually owned, comuneros	4	7	7	4	1	3	0	0		
Total individually owned, noncomuneros	11	9	2	4	0	0	0	1		
Buyer owned	7	1	1	0	14	4	1	0		
Average year first bought, if community owns	1993	1991	1989	1980	1994	1995	1991	1986	1993	1986
<i>How bought first, if community or comunero owned^a</i>										
Community funds	1	7	5	4	1 ^b	4	5	6	6	6
Government assistance	0	0	0	1	0	0	0	2	1	0
Bank credit	0	1	1	0	0	0	0	1	1	1
Agreement with private company	0	0	0	2	1 ^b	4	1	1	1	4

In Table 4, most communities have made such investments, although more vertically integrated CFEs did so at higher rates. Logging was in most cases profitable enough to generate the funds to acquire more productive assets for the CFEs as shown by the use of the CFEs' own funds rather loans or government assistance. Table 4 highlights the degree of asset ownership in CFEs at the four levels of integration: who owns the equipment and when and how it was acquired. The community forestry industry covers a sizeable amount of capital assets in Mexico. Individuals often own trucks used for transporting logs. The incidence of collective truck ownership increases with integration level. Cranes require more specialized skills and fewer are needed compared to trucks in meeting production goals. Of particular note here is that in the great majority of cases, assets were purchased with community funds with little reliance on outside debt, suggesting barriers to credit, a bias against debt or a lack of need for debt financing at that point. Profits in some cases even went to asset maintenance such as constructing or maintaining logging roads for equipment that permits vertical integration.

2.6 Case No. 6: Community forest management operations versus negotiated partnerships with private logging companies in the Amazon region

A recent study in the Amazon region compared community forest management (CFM) groups and partnerships with logging companies based on prior negotiations (Humphries 2010). The study revealed that the most common approach to forest management by communities in the study areas, representing 96 percent of the sample, was done through informal negotiation of timber rights with logging companies. CFM initiatives for timber extraction were found as

isolated pilot cases, restricted to less than two percent of the sample, and were externally supported and not adopted by neighboring communities. In none of the study areas were communities found to be harvesting and selling timber on their own through self-governed systems. Loggers generally depleted stocks of species with commercial value in as quickly as one to three years. Due to the intensity of logging operations, future possibilities depend on new market demand for species other than those currently harvested. The CFM initiatives did, however, intend to implement sustainable forest management (SFM) based on RIL principles. The available forest area was divided into annual units for management cycles. However, such schemes were abandoned by the communities once external support ceased. In some cases, communities subsequently started informal negotiations of their timber rights with loggers.

Table 5. Comparison of income derived by communities from timber rights negotiations with logging companies and CFM initiatives supported by development organizations (Humphries, S 2010)

	Negotiation with loggers					CFM				
	Vaca Diez	Xapuri	Porto de Moz	Masisea	Average	Vaca Diez	Xapuri	Porto de Moz	Masisea	Average
Total cash income received (US\$)	1 392	14 280	9 520	720	6 478	2 750	7 416	8 977	120	4 815
Volume exploited (m ³)	950	6 300	43 000	3 600	13 462	1 500	618	450	25	648
Volume sold (m ³)*	693	6 300	42 000	3 300	13 073	550	618	450	9	406
Income actually received per m ³ (US\$)	2.01	2.27	0.23	0.22	1.18	5.00	12.00	19.95	13.33	12.57
Number of persons participating	20	15	20	76	33	36	10	10	5	15
Working days per person per year	4	25	10	1	10	35	30	135	20	55
Income per working day per person (US\$)	17.40	38.08	47.60	9.47	28.14	2.18	24.72	6.65	1.2	8.69
Local wage per day	2	5	5.2	1.5	3.43	2	5	5.2	1.5	3.43

* Part of the exploited timber was lost in the forest and not sold; therefore the exploited volume does not correspond necessarily to the sold volume

As shown in Table 5, partnerships with loggers and community forestry initiatives generated only limited financial benefits for communities. From partnerships with loggers, communities received only a relatively small payment for each cubic meter of timber harvested. The negotiation was attractive mainly because communities had limited input of time invested, and consequently, a high reward per working day. Financial inputs for harvesting or processing equipment were not necessary in this case, which contributed significantly to the better overall economic performance of this model.

In CFM initiatives, communities received a higher reward per cubic meter of timber than the prices paid by loggers. However, the relatively high input in field activities resulted in a lower income per working day. Under both conceptual models, communities benefited indirectly through improved transport infrastructure and jobs offered by the presence of loggers, NGOs and government agencies. Unfortunately, the study did not include an impact assessment on the resource in both models, and thus does not answer whether or not the models are sustainable in the long term.

Table 6. Indirect benefits derived from communities negotiating with logging companies and involved in CFM initiatives supported by development organizations (Humphries 2010)

Study areas	Negotiation with loggers				CFM			
	Vaca Diez	Xapuri	Porto de Moz.	Masissea	Vaca Diez	Xapuri	Porto de Moz.	Masissea
Transport	Roads maintained	Bridges maintained	Boat with motor	Rides	Road build	Roads build & maintained	Boat & house	Small adapted vehicle
Jobs	10 people identifying trees	5 people processing timber	20 people opening roads	2 people identifying trees	Per diem for leaders	5 people working in a co-operative	Per diem for leaders	Per diem for leaders
Further possibilities	Families sell timber individually	Market for cattle	Credits in the local market	Building a meeting room	Land tenure and legal status	Legal status, support by other projects	Legal status	Local acknowledgment
Others	Documents for land tenure	Opportunity for selling land	Opportunity for renting chainsaw	Left felled trees	Training on management & tree felling	Training on administration	Training on furniture-making	Credit and training on timber processing

The results of this study contrast with the general belief that communities can benefit significantly from the management of their timber resources under the current institutional framework found in the Amazon region. Neither the community-company partnerships (CCPs) nor the models of CFM supported by development organizations analyzed in this study allowed communities to derive meaningful benefits from the use of their forests. The studied CCPs were based on a poor balance of power and left limited possibilities for communities to bargain on the prices paid and the management practices adopted. The studied CFM concepts were based on developing the capacities of the communities in managing their forests according to externally defined models without taking into consideration local interests and current capacities. The study indicates that the ideal concepts of CCP, as well as CFM, are quite distant from the actual reality in the Amazon.

Before further promoting the implementation of either conceptual model, a critical debate on how to promote them based on their potentials and limitations needs to take place. With regard to CCPs, communities in the Amazon frontier are not empowered to negotiate better deals with loggers. Under CFM, communities miss out on support programs to help support their specific interests and develop their capacities. Instead of training communities to manage their forests according to previously established concepts, it is necessary to build on their already existing practices. If forest use by communities is to have a future in the Amazon region, it is essential to allow communities to make use of their comparative advantages.

It is thus necessary to explore possibilities for a third conceptual model through which communities can develop self-governed management concepts based on their own interests and capacities. The conception and implementation of these self-governed concepts must then be supported by external development agencies.

2.7 Case No. 7: Comparative study of commercial community forest initiatives in the Brazilian Amazon

Medina and Pokorny (2008) studied the financial performance of 12 commercial community forest initiatives in the Amazon basin. Their estimates were based on field data, interviews and secondary data about the applied management models, including aspects such as productivity, technologies, equipment and machinery, area of annual coup and harvested volume, private

investments and investments of the supporting organizations and product prices obtained. Labor costs reflect local daily wage rates including conversions from family labor. Yearly machinery costs included costs for capital calculated with an interest rate of five percent. Depreciation was calculated linearly for a period of 10 years. Maintenance costs were defined as 60 percent of the depreciation costs. Costs for consumables were based whenever possible on data about real consumption.

Figure 10. Initial investments in community forestry initiatives. Estimates are based on interviews and secondary data considering (Pokorny 2010)

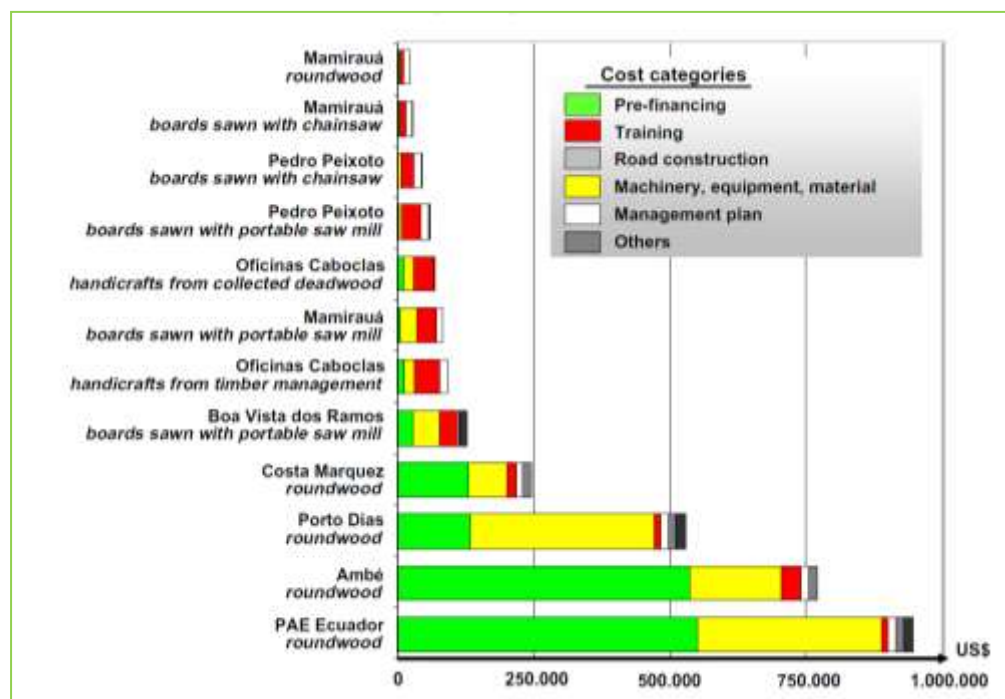


Figure 10 shows the cost structure of the enterprises studied. The financial analysis identified high production costs ranging from 15-50 US\$/m³ for round wood to 350-420 US\$/m³ for boards processed with chainsaws and 190-600 US\$/m³ for boards produced using portable sawmills in the forests. While extraction costs appear to be realistic and fall well within the range of a similar study in the region (see Table 7 below), costs for both chainsaw and mobile sawmilling appear to be beyond the range of financial viability.

Table 7. Harvest and transport costs (US\$/m³) in study sites (Pokorny 2005)

Study	Year	Type of logging	Stumpage Fee	Invent-ory	Infra-str.	Fell-ing	Skidd-ing	Land-ing	Ot-her	Subto-tal Logg-ing	Trans-port	TOTAL ^b
		CL Tapajós	n.r.	0.65	0.42	0.46	1.48	n.r.	1.30	4.31	3.37	7.68
Costa Filho & Ferreira	1991	CL Jari	n.r.	0.65	2.94	0.41	1.96	n.r.	2.50	8.46	3.89	12.35
		CL Curuá Una	n.r.	0.65	2.09	0.56	1.77	n.r.	2.18	7.25	2.86	10.11
Verissimo et al.	1992	CL small scale	1.90	n.r. ^a						11.11	8.42	21.43
Verissimo et. al.	1995	Mahogany	40.00	4.60			23.80		7.60	36.00	75.90	151.90
		CL small scale	5.00	n.r. ^a						12.60	20.09	37.69
Stone ^a	1998	CL large scale	5.00	n.r. ^a						10.34	18.09	33.43
		CL small for '92	2.21	n.r. ^a						13.93	13.39	29.53
Baretto et al.	1998	RIL	5.00	1.87	0.28	0.25	1.31	2.59	4.18	10.48	11.00	26.48
		CL	5.00	0.00	0.40	0.40	1.37	2.53	4.18	8.88	11.00	24.88
Muehlsiegl & Pokorny	1998	RIL	5.00	4.04	3.03	2.72	3.78	2.83	15.- 25	36.65	3.22	39.87
Pokorny & Sousa	2000	CL	4.95	n.r.						10.69	6.27	21.91
		RIL	7.61	1.18	0.32	0.62	1.51	1.28	1.07	5.98	10.00	23.59
Holmes et al.	2000	CL	9.09	0.00	0.57	0.65	1.99	2.01	0.97	6.19	10.00	25.28
		RIL	n.r.	2.50	n.r.	5.00	12.00	n.r.	n.r.	19.50	4.50 ^c	24.00
Pokorny & Steinbrenner	2004	RIL Implement-ation	4.81	0.84	0.69	0.97	2.75	2.06	0.68	7.37	4.23	17.28

RIL = Reduced Impact Logging; CL = Conventional Logging.

n.r. = not reported

^a Both Verissimo (1992) and Stone (1998a, b) calculate costs per item rather than by activity: i. e. salaries and benefits, fuel, maintenance, depreciation, capital costs, forest tax, and estimated management costs.

^b The total costs correspond to value in US\$ given by the authors for the period of each study. They have not been adjusted to the present because of the difficulty of addressing the effects caused by the change of currency (Cruzeiro to Real, 1994) and the devaluation of the Real against the US dollar since then. It is quite probable that the effect of inflation is partly offset by the effect of devaluation. That said, it is important that the relative costs be examined with the caveat that the values are not fully comparable.

^c For an estimated distance of 30 km

In smaller initiatives, the proportion of technical support provided by projects and administrative costs were exorbitant in relation to benefits generated. For initiatives processing round wood with chainsaws or portable sawmills, machinery costs were most significant. Taxes on processed wood also constituted a major cost item. In larger initiatives with mechanized extraction operations, heavy machinery used for road construction, skidding and landing operations constituted the majority of total costs, including loan repayments. Initiatives attempting to commercialize their products directly to external markets suffered from elevated administration and management costs.

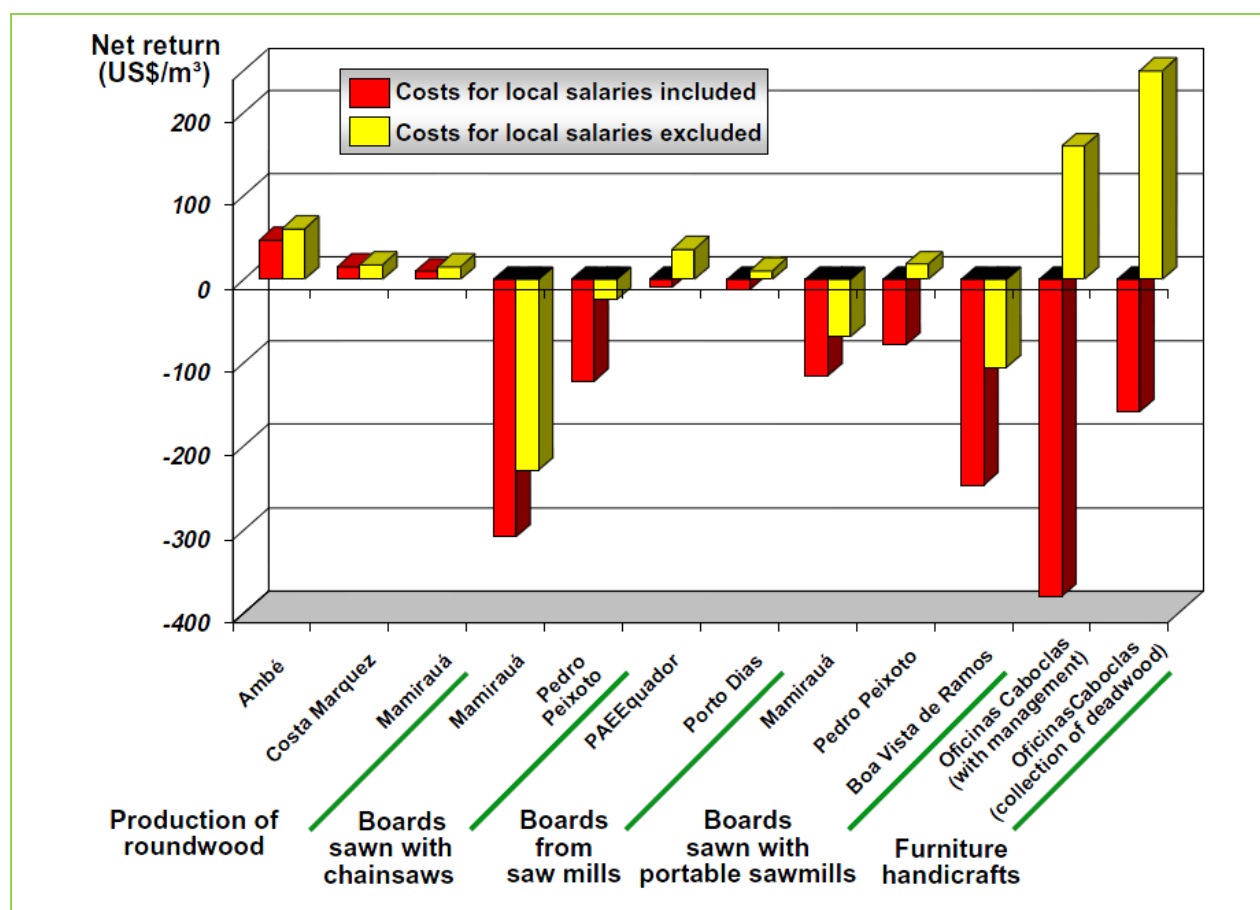


Figure 11. Annual net returns of commercial community forestry initiatives in the Brazilian Amazon with and without considering costs for local labor (Pokorny 2010)

As a consequence of the high costs of production, profits were at best modest (Figure 11), although all initiatives received relatively attractive prices for their timber from non-local buyers due to negotiations facilitated by the supporting development organizations. Despite the generally low level of local salaries, only the larger initiatives with a low level of vertical integration managed to cover labor costs and, in a few cases, generate low profits. All other initiatives were unable even to cover the operational costs of logging, though some cases did manage to pay a portion of the local labor costs. Furthermore, the expectation of enhancing income by adding value from further processing timber or production of manufactured products was not fulfilled though attractive prices for the products were paid. This was mainly because the production costs increased disproportionately as a consequence of more complex administration and the need for essential investments in machinery and equipment. While Forest Stewardship Council (FSC) certification has permitted access to a wider range of markets, the costs associated with FSC certification were found to be disproportionate in relation to the benefits generated – unless of course – the costs are met by external sources of financing. Initiatives seeking to add value also suffered from a higher proportion of fixed costs and the urgent need for capital to pre-finance operations, which seriously affected the flexibility and increased pressure on production.

Families criticized the high degree of risk resulting from the need for significant investments, the need to cover the running costs and most importantly, the significant time lag before obtaining a return on the investment.

To summarize this discussion, the report questions the concept of vertical integration of timber production in the context of commercial community forestry. It supports the argument favoring attempts for horizontal integration, enlarging the supply base and forming cooperative arrangements in the extraction process where appropriate harvesting technologies (AHTs) can be applied. One of the more interesting parts of the report to note in the context of this guidebook is that only enterprises that restricted themselves to logging operations, as well as the case of mobile sawmilling, achieved positive returns when all local salaries were included.

2.8 Case No. 8: Small-scale timber extraction in formal and non-formal operations in the Amazon region

Mejia, et al. (2015) studied eight cases of formal and non-formal timber extraction by smallholders through a mix of both quantitative and qualitative methods. The overall analysis relied on information from household surveys, analysis of selected cases of timber extraction and interviews with key informants. The paper is based on three sources of information: 1) household survey data indicates the importance of small-scale timber extractions for the livelihoods of smallholders, both new settlers and indigenous people; 2) analysis of selected cases of timber operations, whether undertaken following the implementation of the national forestry regulations or not, help estimate the costs and benefits of various operators in the timber value chain as well as the distribution of benefits; and 3) semi-structured interviews highlight market interactions and links between supply and end-market demand.

A total of 243 household surveys were conducted in 21 communities. The selection of households was made in two stages with stratification according to ethnic origin, size and location of communities.

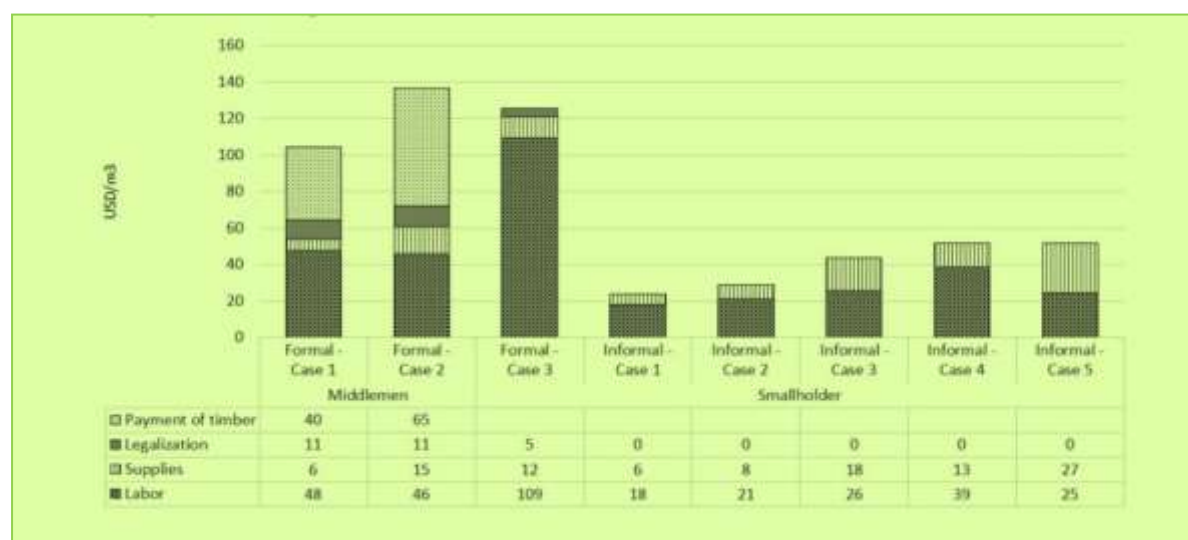


Figure 12. Distribution of costs (in US\$/m³) for eight selected small-scale timber extraction operations, with and without formal permits and according to different types of smallholder and middleman participation (Mejia, et al. 2015)

The authors concluded from the study that smallholder benefits from timber extraction depend on the way in which timber operations are organized, the inputs to harvesting operations (e.g. machinery, management, etc.), the species of tree harvested and on connections to the market

intermediation networks, rather than on whether the operations comply or not with existing forestry regulations.

Evidence suggests that larger timber extraction operations, which are often conducted by middlemen, are undertaken with approved plans and payments of royalties and other fees. Total costs of these operations are nearly twice as expensive as the non-formal systems. Even if royalty payments are deducted, these operations appear considerably more expensive, while smaller scale ones, which are undertaken by smallholders, remain outside of the law and focus on soft wood species. In turn, middlemen adopt flexible strategies by sourcing hard and semi-hard timber species from legal operations, often financed from their own funds, while also buying timber, mainly softwood from informal small-scale operations, in order to meet the demand from buyers in the cities. This is due to the fact that middlemen have to respond quickly to purchase orders from final buyers that specify volumes and species under relatively rigid time frames.

For smallholders, there is an important gap between what they can produce on their own outside of the law and what they can produce formally with the help of a middleman. This suggests that, in order to achieve legality, it is also important to meet the needs of capital, technological know-how and market access with final buyers. The role of middlemen as capital providers for timber harvesting indicates that smallholders lack access to finance and technologies, which hinders them from undertaking large volume harvesting operations under legally approved plans. The case study suggests that smallholders tend to earn more money by engaging in legal operations as long as they participate in the sawing and harvesting of hardwood species, but that also may likely result in the rapid exhaustion of their forests. Unfortunately, the ecological impacts of small-scale logging are not able to be addressed in this guidebook and do deserve more research. Indeed evidence does suggest that hardwood species are logged more intensively, which may lead to forest degradation.

The Mejia, et al. (2015) study argues that the right species and participation in harvesting are far more important than legality to smallholders' income levels. Regulatory frameworks should have the flexibility to support the various smallholder strategies in using their own forests to gradually adapt their practices and strategies in ways that will allow them to obtain income from timber extraction while at the same time preserving and restoring their forests. However, policies must look beyond the supply side of the issue and give greater attention to improving the transparency of market networks that shape smallholders' decisions and propose more collaborative solutions involving end-market buyers.

2.9 Summary findings of case studies

The case studies have pointed out difficulties in most commercially-oriented community forestry operations in which vertical integration was attempted along wood-based value chains. As pointed out by most researchers, there are no sound examples with the exception of mature community operations in Mexico (Bray 2002) where sustainable enterprises could be established.

A key recommendation should therefore be that horizontal integration – looking initially at scale within the same business field (e.g. log sales) – rather than vertical integration should be attempted with industry support if possible. Table 8 below highlights some key advantages and issues in different forms of enterprise integration.

Beyond the issue of up scaling in the correct direction, the following conclusions may also be drawn for the CFE context:

- Land tenure is important but not an absolute prerequisite for the initial stages of CFE development. Regulatory barriers and the legality of forest harvesting appear to be the key obstacles.
- Laws and policies that adequately address the realities and needs of CFEs are often non-existent.
- The lengthy duration needed for CFEs to reach maturity (about 20–40 years) compromises the viability and impact of any support. Thus, long term support is critical to CFE development.
- Managerial and operational capacity has often been overestimated.
- Most sampled CFEs are highly undercapitalized, irrespective of size and scale.
- There are numerous examples indicating that donor support has facilitated unsustainable investments in oversized, inappropriate and thus, unsustainable technologies.
- The cultural context and the perception of local people in terms of cooperative enterprises has been too often neglected or misunderstood. Forestry development experts have, on many occasions, failed to adequately understand these local realities and have not adjusted their mode of operation (*modus operandi*) according to these local realities.
- CFEs should be modeled on existing labor and distributive solidarity groups and should adopt discussions and a decision-making mechanism that coincides with existing practices and spaces.
- Lack of knowledge about markets and their mechanisms have been a repeated shortcoming.
- Remoteness, lack of road networks and subsequent long extraction distances to processing sites appear as issues throughout the case studies.
- The service environment for CFE development is rarely conducive.
- Certification, basically always driven by NGOs, often advocated as addressing some of the issues listed above, has not delivered convincing results.
- Even when market distances are short and commercial timber stocks are abundant, local forestry producers rarely obtained annual per hectare incomes of more than US\$ 20/ha.
- Benefit distribution should represent the individual contributions of each member. Adequate amounts of surplus benefits should be invested in social projects (asset building) and in the enterprise capitalization.

These findings are in line with similar assessments by several authors in the CFE context also beyond the wood sector (Donovan 2008, Macqueen, D 2008 and Wunder 2001).

Table 8. Advantages and disadvantages of vertical and horizontal integration of indigenous community forestry in the value-added chain of timber production (Nebel 2003).


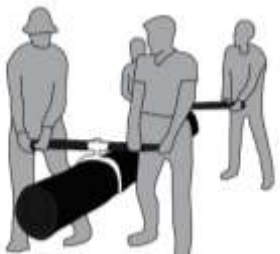

Vertical integration within business system – organisational scope in the value-added chain of production			
Advantages		Disadvantages	
<ul style="list-style-type: none">• increased bargaining power• economics of scale• operational coordination• avoidance of contracting costs• implementation of system-wide changes		<ul style="list-style-type: none">• high capital investment• broad demands for relations and competences• reduced flexibility• dulled incentives• high governance costs	
Horizontal direct integration			
Scale (size within business)		Scope (array of businesses to include)	
Advantages	Disadvantages	Advantages	Disadvantages
<ul style="list-style-type: none">• cost savings• leveraging resources• bargaining power• industry leader/definer	<ul style="list-style-type: none">• coordination costs• bureaucracy• lagging innovation	<ul style="list-style-type: none">• leveraging competences• activity sharing• financial synergies	<ul style="list-style-type: none">• coordination costs• slow decision-making• lack of know-how in corporate centre




3. Overview of small-scale technologies




The following summary table presented below attempts to provide an overview of possible small-scale technologies that may be appropriate in the community and smallholder forestry context of the Mekong region in Southeast Asia. The table is based on an intensive literature study, which contains comparative studies covering multiple technologies, which were carried out in Europe: Kantola (1988), LOBF (2002) and Skogsarbeten (1986); The United States and Canada: Nova Scotia Natural Resources (2006), Updegraff (2000), Windell (1999), Webster (2005), Kirk (1994), Halbrook (2005) and McCormack (2000); Costa Rica: CATIER (1997); Philippines: Laarman (1981); and also by international development organizations: FAO (1982, 1985 and 1986) and ILO (1970 and 1989).



This selection may not be complete and may in some cases not find agreement from the reader in the selection and inclusion of certain systems. However, the attempt was made to choose equipment, which is within the financial range of local communities and smallholders, at least on a cooperative basis. The equipment aims largely at horizontal integration and focuses less on processing with the exception of mobile sawmilling and chipping, if these technologies are part of the extraction process. Further criteria considered were the socio-cultural context and the possibility for local adaptation, maintenance and service provision. Focus was also placed on possible integration of the machinery with agricultural mechanization in order to maximize utilization in non-forest applications.



Comparison chart for small-scale harvesting technologies




Technology	Price (US\$)	Productivity and advantages	Limitations
Manual systems			
Crosscut saw 	50-120	<p>6 minutes (min) for 10 centimeter (cm) DBH softwood 15 min for 25 cm DBH softwood 15-20 min for 25 cm DBH hardwood</p> <ul style="list-style-type: none"> ➤ Low costs ➤ Reliable tool ➤ Safe operation ➤ Relatively low skill level required for operating ➤ Available in most situations and sites 	<ul style="list-style-type: none"> ➤ Strenuous work ➤ High performance only with quality saws ➤ Skills needed for sharpening
Hand tools 	50-150	<ul style="list-style-type: none"> ➤ Can increase productivity considerably ➤ Can ensure safe handling ➤ Wide range of tools that can all be manufactured locally according to standard designs by local blacksmith's workshops. Gas welding preferred for joints ➤ Inexpensive ➤ Based on local materials and skills 	
Downhill skidding 	100 (per sappie)	<p>30 m extraction distance: 8 m³/hr 500 m extraction distance: 2 m³/hr</p> <ul style="list-style-type: none"> ➤ Team size three to four ➤ Relatively high performance in comparison with mechanized methods ➤ Entirely manual with use of sappies and turning hooks ➤ Relatively low skill level required 	<ul style="list-style-type: none"> ➤ Minimum slope required 40% ➤ Requires minimum extraction volumes of about 20 m³/ha ➤ Causes severe soil erosion ➤ Unsafe if crews are not trained well




Log chute 	40-50/m (30 cm diameter)	100 m extraction: 2m³/hr (DBH 12 cm) to 3.5 m³/hr (DBH 25cm) <ul style="list-style-type: none"> • Team size three to four • Can be locally manufactured from PVC pipes • Causes no soil damage, one of the most eco-friendly extraction methods for sloping terrain • Speed can be controlled with breaks inserted in chute 	<ul style="list-style-type: none"> ➤ Minimum slope required 30% ➤ Requires minimum extraction volumes of about 20 m³/ha ➤ Training requirements lower than ➤ Downhill skidding
Hand sully 	200-300 (Locally manufactured with scrap wheels)	Downhill or level extraction 50 m extraction distance: 3 m³/hr 300 m extraction distance: 1 m³/hr <ul style="list-style-type: none"> • Can be locally manufactured with scrap wheels • Modifications possible with clamp banks for small logs or bamboo • Combinations possible with animal logging • Uphill extraction only in pairs with pulleys 	<ul style="list-style-type: none"> ➤ Limited suitability for uphill extraction (below 10%)
Animal-based systems			
Horse/donkey/mule 	1 500-2 000 (adult and trained)	Possibilities for short and long distance forwarding 100 m extraction distance: 3-4 m³/hr 1 000 m extraction distance: 0.3 m³/hr <ul style="list-style-type: none"> • Two horse teams needed for logs over 0.5 m³ • Extractions from slopes up to 30 %possible • Can be more cost efficient than tractor extraction • Less damage to soils and remaining stands • Use of logging troughs to reduce friction • Combination with horse riding and trekking 	<ul style="list-style-type: none"> ➤ Only found in some upland communities and specific locations (e.g. Lampang) ➤ Large mule breeding by Thai army for transport application in mountainous areas



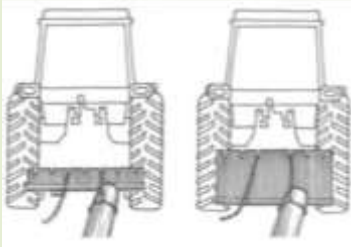
Oxen/buffalo 	600-1 000 (adult and trained)	Possibilities for short and long distance forwarding 100 m extraction distance: 2-3 m³/hr 1 000 m extraction distance: 0.1 m³/hr <ul style="list-style-type: none"> • Lower performance than horses • Less suitable for sloping terrain • Two horse teams needed for logs over 0.5 m³ • Can be more cost efficient than tractor extraction • Less damage to soils and remaining stands • Use of logging troughs to reduce friction 	<ul style="list-style-type: none"> ➤ Normally operation only possible in pairs ➤ Buffalo population is vanishing with introduction of tractor ➤ Breeding and training of oxen for work is also receding in the region
Elephant 	25 000-30 000 (adult and trained)	Extraction of valuable timber over large distances 100 m extraction distance: 3-8 m³/hr 1 500 m extraction distance: 1 m³/hr <ul style="list-style-type: none"> • Can also be applied for log loading on trucks • Daily performance below 5 hrs animals need rest and cool down in water • Can be linked to eco/agro-tourism • Important animal in socio-cultural context in Asia 	<ul style="list-style-type: none"> ➤ Controversial aspects of animal wellbeing ➤ Probably not possible to introduce to new sites ➤ Application mainly possible if animals are found in the specific sites already
Water-based extraction			
Rafting of timber 	Minimal equipment cost: rafting hooks and ropes (below USD 20/operator)	Panel construction: 5-10 tons/m³/hr/person Floating: 0.4 m³/hr over 5-10 kilometers (km) 15-20 ton rafts: 25 to 30 km /day / person <ul style="list-style-type: none"> • Traditional system with local skills • Ideal for small streams, lakes or reservoirs • High potential in areas with hydropower development (Lao PDR) • Low skill level on slow flowing rivers 	<ul style="list-style-type: none"> ➤ Dangerous on fast-flowing streams ➤ Require expert teams in such situations




Rafting of bamboo 	Minimal equipment cost: rafting hooks and ropes (below USD 20/operator)	Panel construction: 1.5-2 tons/hr (2-3 persons) 20-30 ton rafts: 25-30 km/day (2 persons) <ul style="list-style-type: none"> • Seasonal operation can be adjusted to labor situation • Can be scaled-up through ecotourism • Skill level can be achieved in reasonable time • High potential in areas with hydropower development (Lao PDR) 	<ul style="list-style-type: none"> ➤ Highly depended on river flows and obstruction in rivers ➤ Safety aspects not known
Motorized rafting 	Outboard motors 30 horsepower (hp): 4 000-5 000 Tug boats 150 hp: 15 000-20 000	<ul style="list-style-type: none"> • Individual raft panels of volumes of 20-50 tons can be constructed and joined together to carry volumes of several hundred tons • Transport speed up to 100 km/day on slow flowing rivers or lakes • Skills for operating boats required • High potential in areas with hydropower development (Lao PDR) and the lower Mekong 	<ul style="list-style-type: none"> ➤ Only possible on slow flowing rivers or natural lakes, reservoirs




Mechanized hand-operated systems			
Bush cutter 	Light: 500 Medium: 800 Heavy: 1 400	3 min for 10 cm DBH softwood 6-7 min for 25 cm DBH softwood <ul style="list-style-type: none"> Upright work posture is less strenuous than kneeling position with chainsaws Can be used to clear brushwood prior to felling more efficiently than chainsaws Safety training and equipment requirement similar to chainsaw 	<ul style="list-style-type: none"> Limited to small diameters below 25 cm Safety issues if work is performed in Teams operator needs to permanently observe crew members when swinging bush cutter
Chainsaw 	Light: 400 Medium: 800 Heavy: 1500	2-3 min for 10 cm DBH softwood 5-6 min for 25 cm DBH softwood 6-7 min for 25 cm DBH hardwood 12-15 min for 50 cm DBH hardwood <ul style="list-style-type: none"> In general, the performance is 200-300% more to that of handsaws Requires trained personnel Safety equipment needed 	<ul style="list-style-type: none"> Some safety equipment not really suited for tropical countries and will slow down work performance




Portable winch 	1 000-1 500	Max 30 m extraction distance: 2 m³/hr for 0.1 m³ logs Bamboo: 0.4 tons/hr over 20 m <ul style="list-style-type: none"> Up and downhill operation possible Ideal combination with chainsaws in short distance skidding Simple operation low skill level required Other applications outside forest harvesting 	<ul style="list-style-type: none"> ➤ Small extraction range even with spill winches (max 50 m) ➤ Pulling power below 2 tons ➤ Only for small-sized material
Self-propelled winch 	2 000-3 000 (local conversion from non-forest winches)	30-70 m extraction distance: 2 m³/hr for 0.1 m³ logs to 7 m³ for 0.8 m³ logs Bamboo: 0.6 tons/hr for 40 m to 0.5 tons/hr for 100 m <ul style="list-style-type: none"> Very high performance possible over extraction distances up to 100-150 m Skidding direction changeable with pulleys Skilled operators required for long distance extraction Up and downhill operation possible 	<ul style="list-style-type: none"> ➤ Limited application outside forest harvesting ➤ Downhill extraction can be dangerous
Rubber-tracked mini skidder 	2 500-3 000 to convert from agricultural machines 15 000	100 m extraction distance: 1 m³/hr for 0.2 m³ logs to 2.5 for 0.8 m³ logs 300 m extraction distance: 1.5 m³/hr mixed logs 100 m extraction distance: 0.5 ton/hr bamboo <ul style="list-style-type: none"> Highly specialized machine for difficult terrain that cannot be reached by tractor Can operate up and downhill on slopes up to 40% Local conversions form a variety of agriculture and construction machinery 	<ul style="list-style-type: none"> ➤ Original machines from Europe are too expensive for the local context ➤ So far limited use outside harvesting season; therefore, high fixed costs
Two-wheel tractor			




	<p>to convert from commercial suppliers</p>	<p>1 000 m extraction distance: 3-6 m³/hr 5 000 m extraction distance: 1- 2 m³/hr</p> <ul style="list-style-type: none"> • Numerous suppliers and service points • Further modifications to trailers possible to increase efficiency • Load capacity 1.5 to 2.5 m³ • Locally widespread and adapted 	<p>➤ Limited off-road capability with loaded trailers</p>
	<p>1 500-1 800</p>		
<p>Systems based on 4-wheel agricultural tractor</p>			
<p>Agricultural tractor</p> 	<p>35 hp; 12 000-15 000 50 hp: 18 000-20 000</p>	<ul style="list-style-type: none"> • Numerous suppliers and service points • Affordable at least in cooperatives • Base machine not dedicated to specific task • Adaptable to forest use at reasonable costs • Numerous forestry attachments available • Hydraulic system for specific applications • Excellent utilization rates outside forestry application 	<p>➤ Two-wheel drive models have restricted terrain capabilities ➤ Additional machine protection required for forestry use ➤ Operation restricted to skidding trails on slopes</p>
<p>Logging winch</p> 	<p>3-ton: 1 100-1 400 5-ton: 1 400-1 800 7-ton: 1 600-2 000</p>	<p>100 m skidding plus forwarding distance: 4 m³/hr for 0.1 m³/piece to 6 m³/hr for 1 m³/piece 1 000 m skidding plus forwarding distance: 1.5 m³/hr for 0.1 m³/piece to 3 m³/hr for 1 m³/piece</p> <ul style="list-style-type: none"> • Up and downhill operation possible • Proven extraction system over 50 years with high safety standards in manufacturing 	<p>➤ Maximum skidding distance 60-100 m ➤ Can cause damage to soil and residual stands</p>

<p>High lead double drum winch</p> 	<p>~1 500-2 000 If locally manufactured In combination with double drum logging winch</p>	<p>100 m skidding distance: 4 m³/hr for 0.1 m³/piece to 6 m³/hr for 1 m³/piece</p> <ul style="list-style-type: none"> Up and downhill operation possible Ideal for uphill extraction with less damage to soil due to reduced friction 	<ul style="list-style-type: none"> ➤ Maximum skidding distance 60-100 m ➤ Forwarding with high lead frame difficult ➤ Systems are technically outdated and have been largely replaced by skyline yarders ➤ Requires expensive double drum winch
<p>Mini skyline</p> 	<p>Uphill only: 5 000-6 000 Up and downhill 400 m distance: 10 000-12 000</p>	<p>250 m extraction distance Extraction per ha: 25 m³: 0.8 m³/hr for 0.3 m³ to 3.0 m³/hr for 0.8 m³ loads Extraction per ha: 50 m³: 2.5 m³/hr for 0.3 m³ to 5.0 m³/hr for 0.8 m³ loads</p> <ul style="list-style-type: none"> Can be used with 50-hp tractors Downhill extraction possible with double drum Only reasonable system for long distance uphill extraction 	<ul style="list-style-type: none"> ➤ Productivity highly dependent on extraction rates per ha (min 50 m³/ha) ➤ Key criteria for selecting this equipment ➤ Highly skilled labor required
<p>Skidding bar or butt plate</p> 	<p>300-600 Locally manufactured for attachment to hydraulic arms</p>	<p>100 m forwarding distance: 4 m³/hr for 0.1 m³/piece to 6 m³/hr for 1 m³/piece 1 000 m forwarding distance: 1.5 m³/hr for 0.1 m³/piece to 3 m³/hr for 1 m³/piece</p> <ul style="list-style-type: none"> Cheap and easy start-up harvesting system Safe operation Limited skills required 	<ul style="list-style-type: none"> ➤ Can only be applied for situations where logs can be reached by tractor

Back fork 	300-400 Locally manufactured for attachment to hydraulic arms	100 m forwarding distance: 2 m³/hr for 0.1 m³/piece 1 000 m forwarding distance: 0.5 m³/hr for 0.1 m³/pc <ul style="list-style-type: none"> • Cheap and easy start up harvesting system for firewood short logs • Safe operation • No skills required 	<ul style="list-style-type: none"> ➤ Can only be applied for situations where logs can be reached by tractor ➤ Only for short logs (firewood)
Rear grapple 	1 500-2 000	100 m forwarding distance: 8 m³/hr for 0.1 m³/piece to 12 m³/hr for 1 m³/piece 1 000 m forwarding distance: 2 m³/hr for 0.1 m³/piece to 5 m³/hr for 1 m³/piece <ul style="list-style-type: none"> • Very efficient loading time if logs are pre-stacked 	<ul style="list-style-type: none"> ➤ Can only be applied for situations where logs can be reached by tractor
Front grapple 	4 000-5 000	Below 0.1 m³/piece logs: 5-10 m³/hr 0.1 to 0.2 m³/piece logs: 10-15 m³/hr <ul style="list-style-type: none"> • Mainly used for very small logs or brushwood and bamboo • Many on-farm uses • High annual utilization rate 	Can only be applied for situations where logs can be reached by tractor

Log trailer 	3-ton: 5 000 5-ton: 8 000	1 000 m extraction distance: 10-20 m ³ /hr 5 000 m extraction distance: 5-10 m ³ /hr <ul style="list-style-type: none"> • Can be supplied with own loading crane • Limited for non-forest use 	<ul style="list-style-type: none"> ➤ Restricted to dirt roads and flat terrain ➤ Needs high utilization rate
Loading crane 	0.5 ton: 5 000-6 000	Loading only: 0.2 m ³ /piece logs: 15-20 m ³ /hr 0.5 m ³ /piece logs: 20-30 m ³ /hr <ul style="list-style-type: none"> • Can be used for efficient feeding of chippers and shredders • Very high productivity 	<ul style="list-style-type: none"> ➤ Needs skilled operators ➤ Needs careful consideration due to limited non-forest use
Hydraulic front dozer shield 	1 000-1 500	Earth movements : 10-11 m ³ /hr in road surfacing Log pushing and piling: 20-30 m ³ /hr <ul style="list-style-type: none"> • Blade angle towards driving direction and tilt should be adjustable to allow dozer work • Versatile attachment for both small road improvements and skid trail constructions • Can be used in piling up logs at landing sites • Serves also as additional front weight • Can be used for non forestry work 	Can only be applied for situations where logs can be reached by tractor

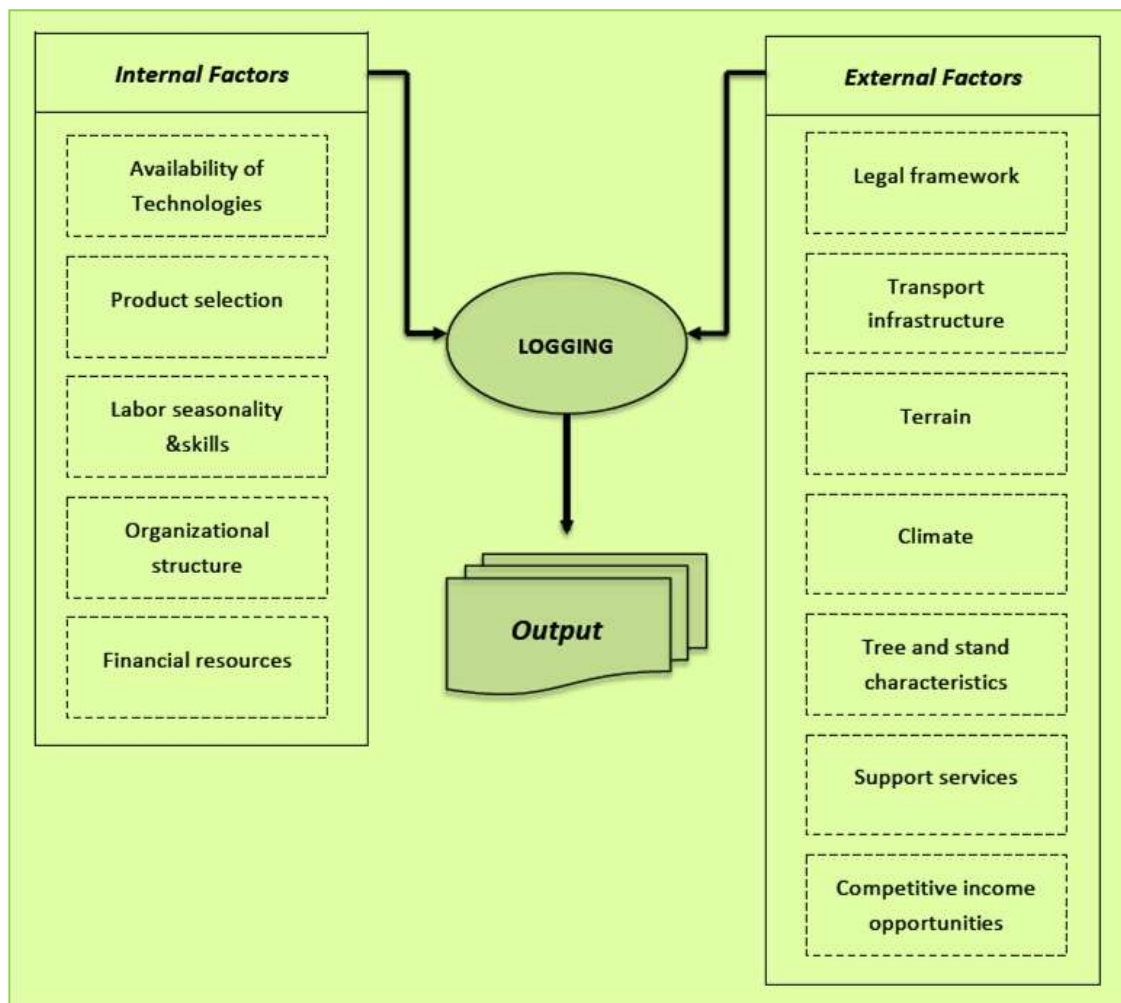
Mobile sawmilling			
Chainsaw mill 	Locally manufactured : 100-400	Productivity: 0.5-1.5 m³/day <ul style="list-style-type: none"> • May allow extraction in very difficult and remote locations • Low skill level required • Can be locally manufactured 	Legal restrictions for use as mobile unit Low recovery rates (below 40%) Issue of illegal logging
Mobile sawmill 	15 hp: 8 000-10 000 30 hp: 10 000-15 000	Productivity: 1-1.5 m³/hr 300-500 m³/year 15 hp: max 30 cm hardwood 30 hp: max 50 cm hardwood <ul style="list-style-type: none"> • Electric or petrol/diesel engines available for fully mobile operation • High quality of sawn product 	Legal restrictions for use as mobile unit Only regional backup service (Singapore) available High skill levels required
Mini skidders 	30 000-40 000	100 m skidding plus forwarding distance: 5-6 for 0.1 m³/piece to 6-7 m³/hr for 1 m³/piece <ul style="list-style-type: none"> • Slightly higher skidding performance than agricultural tractors • Can be used on difficult sites • Only application possible as conversion from construction machinery 	-Uneconomic for long distance forwarding -Only possible as used machine in the CFE context since too expensive -Possibly no service network -Local appropriateness still needs to be assessed

All-terrain vehicle (ATV) 	6 000-8 000	20-40 m extraction distance: 0.3 m³/hr <ul style="list-style-type: none"> • Most have 4-wheel drive with good traction • Low ground pressure • Possibility to link with outdoor tourism in off-season use • Already idly used in small-scale operations in the United States and Scandinavia 	-Range of attachments limited to forwarding trailers, loading arches and small winches -Poor low speed power delivery -Limited rated pulling power -No power take off (PTO) for additional equipment or three-point linkage -Local appropriateness needs to be assessed
Small 4-wheel drive rural vehicle (SRV) 	4 000-5 000	1 000 m extraction distance: 3-6 m³/hr 5 000 m extraction distance: 1- 2 m³/hr <ul style="list-style-type: none"> • Can be equipped with removable hand tractor engines • Used by some plantation companies in the region 	Operation with loads restricted to operation on good road surfaces Off-road use needs to be assessed
Tractor wire loader 	500-600 If locally manufactured	Outreach: up to 100 m with respective winch size Performance similar to small single drum winches <ul style="list-style-type: none"> • Possible suppliers currently not known • Can be used for skidding and loading 	<ul style="list-style-type: none"> ➤ Maximum load below 0.5 tons ➤ Equipment with questionable safety standards ➤ Application needs further assessment

4. Assessing and selecting appropriate small-scale technologies

The following chart gives an overview of the most important aspects to be considered in assessing harvesting systems and subsequently selecting appropriate small-scale technologies. They can be grouped into 1) the internal factors under the control of the enterprise and 2) external factors, which, to a large extent, are outside the control of small enterprises. Factors like Improvements to transportation infrastructure and enhanced incorporation of support services could be, at least in the long run, addressed through cooperative structures that are beyond the current financial and managerial capacities of CFEs.

Figure 13. Internal and external factors affecting CFEs and subsequent selection of appropriate small-scale technologies (adapted and extended from Manavakun 2014)



4.1 Legal environment

From a political and legal perspective, the major challenge for promoting viable CFEs is to ensure that regulations effectively address the underlying development problems, including limited access to suitable land, lack of infrastructure, high transaction costs, low levels of technology, restricted access to services and limited capacities. Three factors are addressed below in more detail:

- (1) Do the respective laws allow the formation of CFEs in the wood sector and what legal enterprise forms and registration procedures prevail to set up the enterprise? While this issue can usually be addressed, it can cause considerable delays and unnecessary obstacles.
- (2) Are restrictions in place on equipment purchase, ownership and operation? In Southeast Asia, we find a range of regulations, which are hardly conducive for applying small-scale harvesting technologies. The following examples illustrate the situation: 1) In Thailand, the purchase of petrol engine chainsaws of any size requires an official permit issued by Thailand's Royal Forest Department; even already established enterprises find it difficult to get such permits and thus resort to harvesting systems in which bush cutters are used for felling small- and medium-sized trees. 2) In Lao PDR, chainsaws may be purchased freely – if available – but need to be registered and kept under control of the provincial forest authorities, the equipment only made available on special requests when the owner has to then prove operations to be undertaken are legal. Because many conservationists see chainsaws as the reason for forest destruction, they contribute to a mindset that does not support the cause of efficient small-scale operations.
- (3) The use of mobile sawmilling technology is apparently not foreseen in any of the laws in the Mekong region. Laws on establishing sawmills often include restrictions that do not allow construction of sawmills in close vicinity to natural forest areas. This approach makes the idea of mobile sawmilling inside forests not feasible. Furthermore some countries like Lao PDR have an installed over capacity of primary wood processing and further investments are thus difficult to rationalize.



Figure 14. Campaign against illegal logging by displaying chainsaws (Philippines 2002)

4.2 Product selection and product combinations

In the first step in assessing possible harvesting technologies, the forest manager would try to predict the dimensions/weights of the potential key wood products expected from the forest areas to be harvested. For this purpose, inventory data – which normally shows diameter distributions – would be accumulated and using it, the forest manager would arrive at the total number of trees in each diameter class. Each diameter class would then be segregated into percent classes of volume/weight classes, which in turn would indicate the total number of certain weight classes that need to be harvested from the respective forests.

Figures 15 and 16 illustrate such hypothetical distributions of natural forests and plantations. Manual operations would likely be restricted to weight classes of up to 250 kg. Smaller extraction animal- or small tractor-based systems would be limited to weights of up to 2 000 kg and heavier machinery would be needed for weights over 2 000 kg/piece.

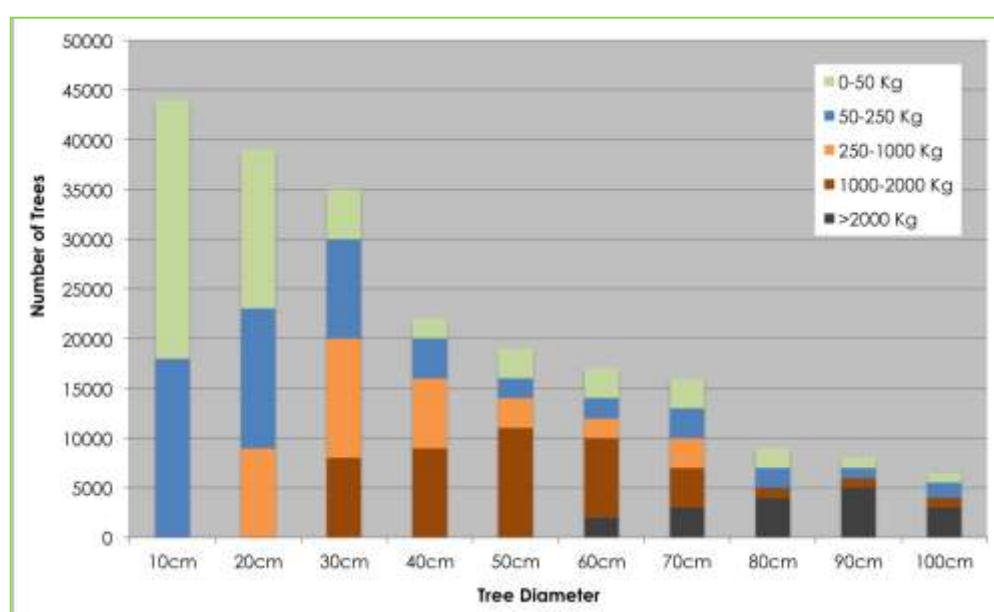


Figure 15. Hypothetical stem section weights over the diameter distribution in a multi-species natural forest

Plantations have a narrower diameter distribution than natural multi species forests and thus the forecast of possible stem and log segments can be very precise for plantations in comparison to natural forests. This method can be further detailed by relating the predicted log classes to thinning or final harvest (clear-cut) operations.

The extracted intermediate and end products in harvesting operations have a decisive influence on the selection of equipment and subsequent costs. In general, the so called 'law of piece-volume ratio' must be followed. The law implies that the bigger the volume (or weight) of an extracted log or pole, the smaller the extraction and processing time per unit volume (or weight).

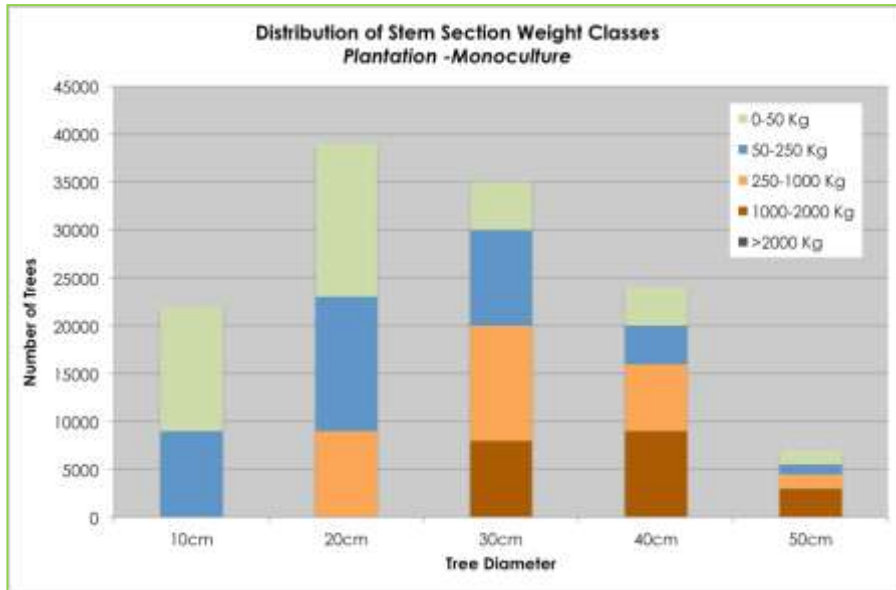


Figure 16. Hypothetical stem section weights over the diameter distribution in a single species plantation

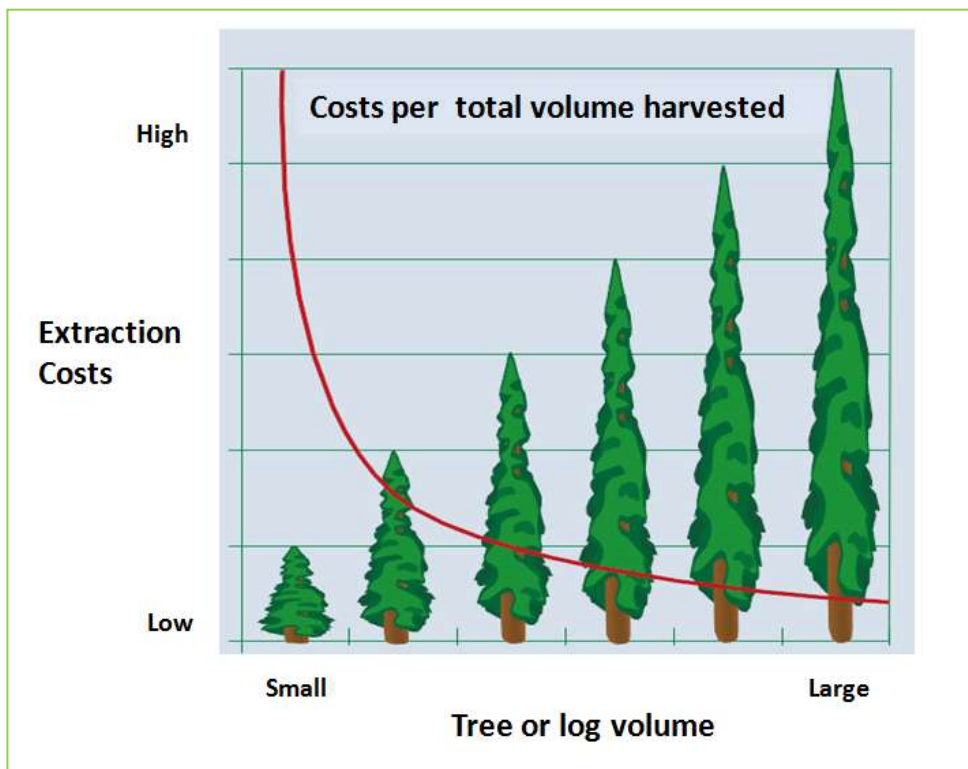


Figure 17. Illustration of the fundamental law of piece-volume ratio in forest harvesting

In most cases, this fundamental relationship largely overrides the effect of distance or slope, as shown by a classical study on timber extraction with mules in Figure 18. Thus, most harvesting studies present performance data and costs in relationship to the piece-volume ratio in terms of average log volumes or weights.

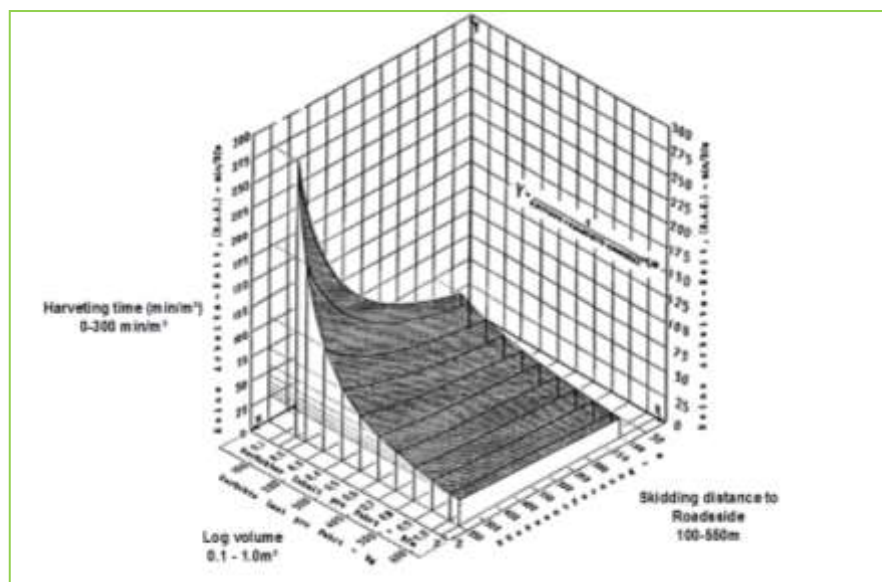


Figure 18. Effect of piece-volume ratio and distance on extraction costs (Efthymiou 2002)

One key conclusion of this fundamental relationship is that, in most cases, smaller size material is very sensitive to harvesting efficiency and needs (in at least the initial steps of mechanization) in order to provide competitive incomes. Another key recommendation is that small material should be harvested whenever possible in combination with large and more valuable products, at least in the initial extraction stages, and then be brought to roadside landings. This recommendation applies in particular to harvesting biomass energy, which could be produced from tips, defective sections, off-cuts and branches of saw logs, or as shown in the case of bamboo harvesting, higher value bamboo poles (Salakka 2014).

4.3 Assessment of terrain and transport infrastructure

Forest resources assessment in our target countries very often only consist of forest inventories and management plans focusing on silvicultural treatment. Transport infrastructure and terrain are normally assessed to a detail which would allow systematic and transparent decision-making on particular harvesting systems. It is therefore advisable to at least prepare maps which show transport access in categories of

- 1 **All weather** paved or gravel roads.
- 2 Roads useable by trucks at least in **dry season**
- 3 **Tracks** useable by tractors and other off road machinery

Obstacles like extremely steep road sections, gullies, river crossings, carrying capacity of bridges, etc. should also be highlighted in these maps. A second layer of information can be created by using slope maps which include an assessment whether up or downhill extraction is feasible in relation to the transport network.

In a final analysis, a combination of (1) road access network, (2) slope steepness with up and downhill options and (3) corridors of forwarding distances will determine different terrain/extraction categories. An estimate of the percentage of these categories for the total enterprise will indicate the choice of certain appropriate logging technologies. Different approaches and parameters for decision-making can be found in the literature for heavier logging equipment (Stergiadou, A, et al. 2009 Kühmeier, M. & Stampfer, K. 2010).

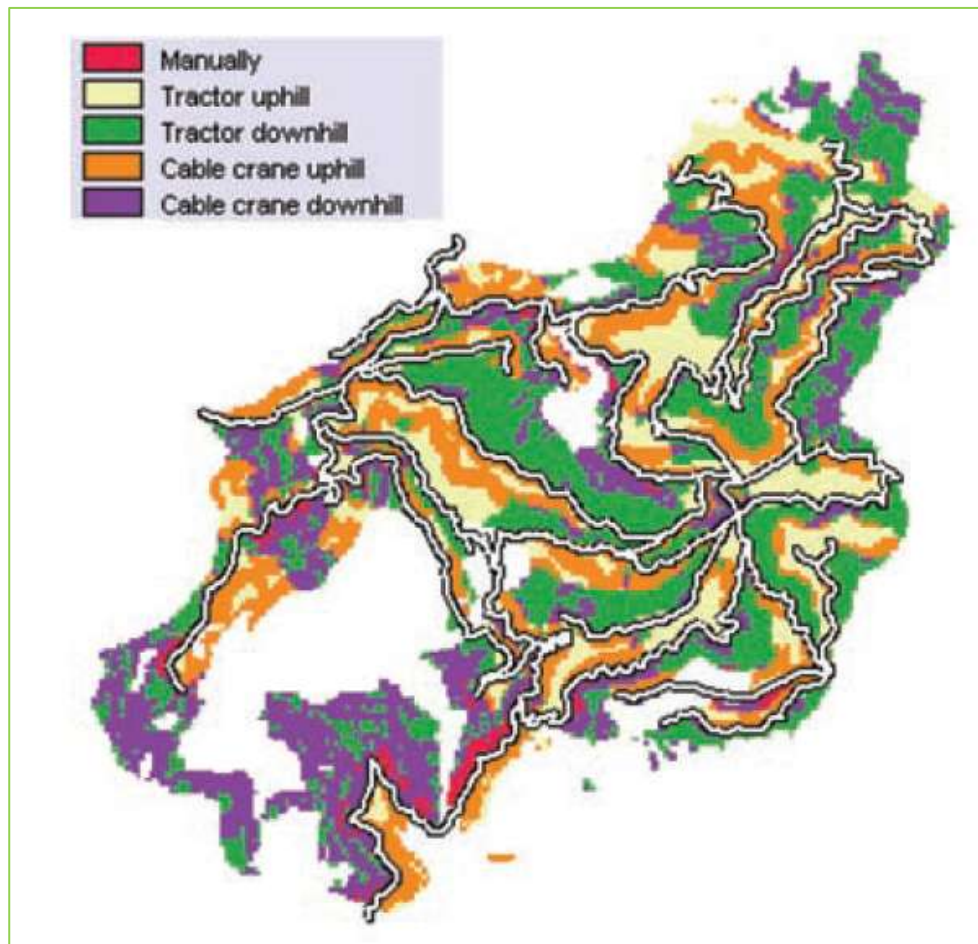
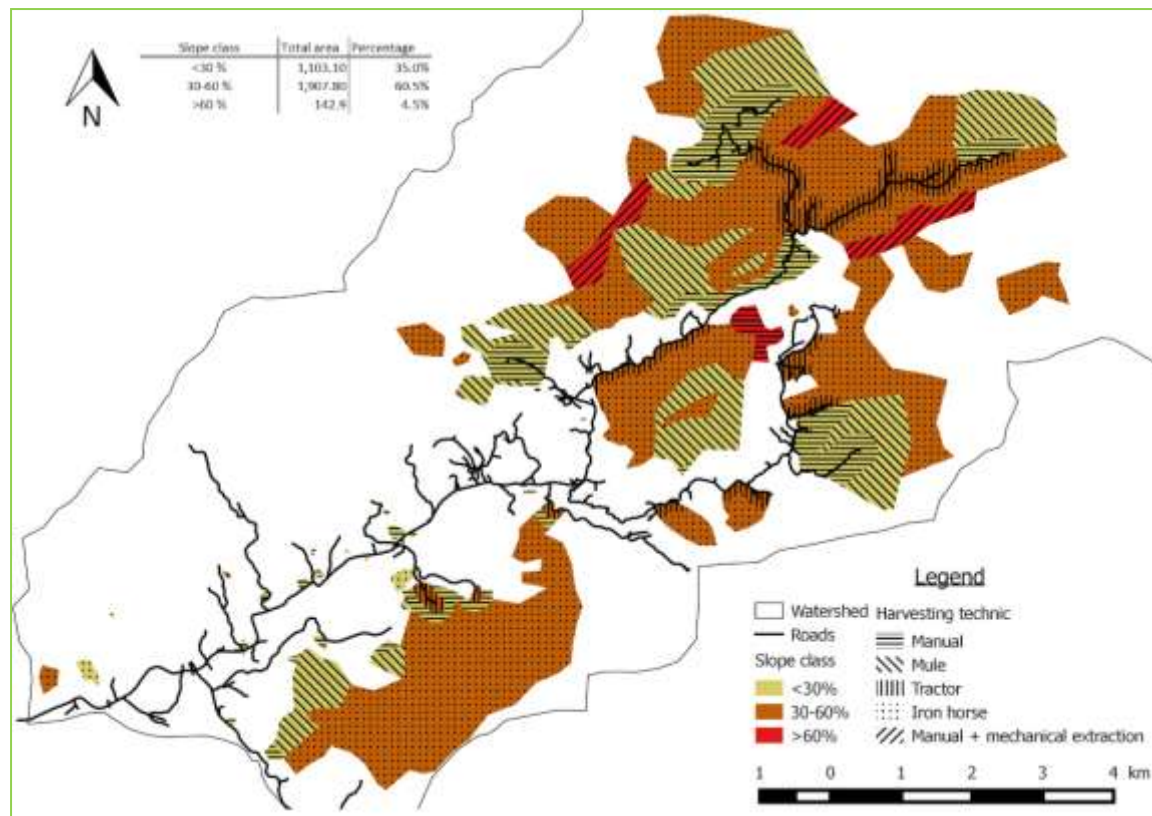


Figure 19a. Terrain assessment for different harvesting systems and extraction direction in northern Greece (Stergiadou 2009).

An example of this approach in the context of small-scale technologies is given in the following figures developed by a study on commercial scale bamboo extraction for energy biomass in Northern Lao PDR (Westeel 2015). Figure 19b shows the initial step of locating different extraction methods (manual operation, animal extraction (mule), tractor and rubber-tracked mini-skidder on slopes according to steepness, distances to extraction routes and extraction direction (up or downhill).

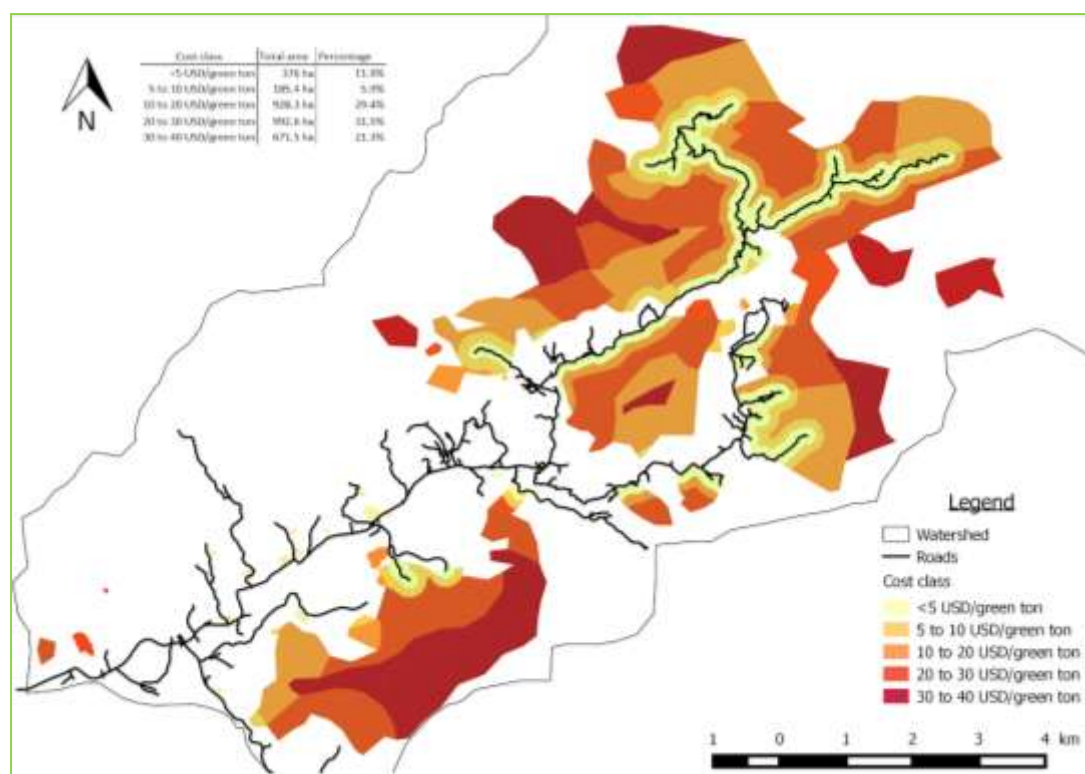
Figure 19b: Terrain assessment for different small-scale harvesting systems in bamboo extraction in relation to slope steepness and extraction distance



In a second step extraction, costs are calculated in relation to harvesting systems and extraction distances and/direction. Results of this calculation are presented in Figure 19c the method allows to analyze the entire potential supply area for a certain forest based industry with realistic operational costs for raw material supply as shown in a similar study in Japan (Yoshioka,T.,Sakai,H. 2005).

This or similar methods are recommended to be applied as a simple decision-making tool in all small-scale harvesting applications where investments on respective machinery is to be made.













Figure 19c: Cost estimates for bamboo extraction by applying different harvesting systems which match slope steepness and extraction distance



In most situations in the region, the technical dilemma for long distance forwarding exists. Basically all small-scale forwarding equipment developed so far is designed for maximum extractions between 100 and 500 m (e.g. long distance cable logging). Maximum extraction distances covered in the literature reviewed were **360 m** for mule-logging in Greece (**Gallis 2004**), **500 m** for farm tractors in Chile (**FAO 1986**). A very detailed study on mule-logging in Spain included distances of up to **3000m** where economical viability found its limits in extracting relatively valuable timber (**Maza 1967**).

Elephant logging with high value timber may still be feasible at these distances but no reliable records could be found in this review. Given the terrain conditions in our target countries, animal logging and possible low-cost rubber-tracked mini forwarders seem to be the only option to address the issue of forwarding in off-road conditions where agricultural tractors find their limits. Construction of access roads, though apparently out of reach by small-scale operations, may be the only long term solution for commercial-scale extraction in the CF context.

Figure 20. Suitability of small-scale technologies in relation to slope, extraction direction and harvesting distance.

Distance	2000											
	1000											
	800											
	500											
	300											
	200											
	150											
	100											
Slope		60%	30%	20%	40%	40%	25%	15%	35%	100%(max 120%)		
Harvesting Technology	Ground based											Suspended
	Manual Systems					Mechanized Systems						
	Saw	Log-line	Sulky	Mule	Rubber tracked mini skidder	Tractor with winch	Tractor with grapple	Tractor trailer/crane	Chain saw winch	Sledge winch	Mini cable system	Cable yarder
												
Slope			10%	20%	30%	50%	25%	15%	45%	100% (max 120%)		
Uphill	100											
	150											
	200											
	300											
	500											
	800											
Distance	1000											
	2000											

4.4 Choice of technologies

Once product selection has taken place and terrain and transport infrastructure has been assessed, a systematic set of options for harvesting technologies, as shown in shown in Figure 20 below, can be made. In this case, harvesting technologies ranging from manual operations to small skidlines are compared in terms of uphill or downhill extraction options slope percentage and extraction distance.

4.5 Worker safety and labor aspects

4.5.1 Worker safety and ergonomics

Worker and operator safety has a direct link to the technologies applied and should be an important criterion in equipment selection. Basic safety equipment like helmets with visors, goggles, gloves and chainsaw-proof safety pants and boots, should be standard outfit for workers who are directly exposed to work with chainsaws, steel cables and cranes. It should be realized however, that the wearing of full body safety pants can be extremely uncomfortable in a tropical climate and may slow down work performance dramatically. Thus, the use of chaps, which protect only the front and lower back portions of the legs are recommended.



Spiked boots are recommended for work on steep and slippery terrain. They can have a significant effect on work productivity and avoidance of accidents as shown by Kirk (1994).

As shown by Melemez (2013), many ergonomic factors influence motor, manual work and operation of machines used in harvesting. Some of these considerations are highlighted in more detail by the respective factsheets in the final part of this guidebook.

Figure 21. Protective chaps for work with chainsaws under tropical climate (<http://www.safetyglassesinc.com/Chainsaw-Chaps>)

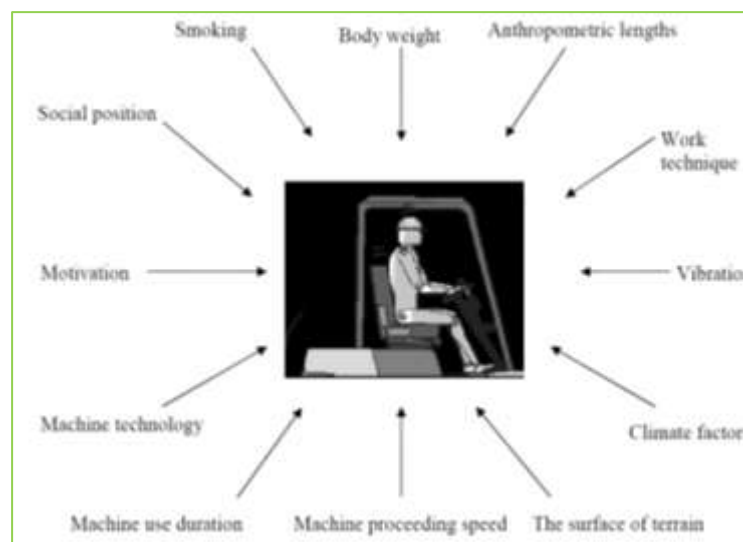


Figure 22. Influences on physiological workload of operators.

The importance of worker training also needs careful consideration. Most newly introduced technologies require considerable training to maximize their performance and to ensure safe operation. An important objective is to achieve sustained longer term impact of the training. As shown in Table 8, freshly trained crews may even exceed the productivity of experienced crews

during and immediately after training, but their learning can only be sustained if they continue to apply the gained knowledge; otherwise the performance drops down considerably below the performance level of experienced staff. Workers should therefore be retrained on the job rather than changing crews over short periods of time.

Table 8. Effect of workers training on system performance of crosscut and chainsaw operations in Tanzanian pine plantations (Silayo 2015).

Harvesting machinery	Work experience	Performance: log volume m ³ /hr		
		Before training	Immediately after training	After a 3-month break
2-man crosscut saw	<i>Start-up crews</i>	1.06	1.62	1.37
	Experienced crews	1.29	1.33	1.55
Chainsaw	<i>Start-up crew</i>	2.93	5.02	3.89
	Experienced crews	3.83	3.96	4.77

4.5.2 Competitive income opportunities

As highlighted in the introductory chapters and in some of the case studies, income from forestry operations often cannot compete with levels of other off-farm and migratory labor. This aspect is of increasing importance in the Mekong region where income opportunities, particularly in the commercial plantation sector (planted rubber, oil palm, banana, sugarcane, cassava, etc.) have significantly increased rural income and helped certain regions to step out of extreme poverty (e.g. rubber since the 1970s in Yunnan, China). Investments in more efficient operations with increased productivity are essential if employment and income levels in the forestry sector are to remain attractive and competitive. In most CFE situations, this serves as the key argument for the application of small-scale technologies. As a rule of thumb, rates of US\$ 10/day to 15/day should be applied as competitive income – at least over the next five years – in order to compare investments in small-scale operations with alternative off-farm employments. If these rates cannot be achieved, then it may not be advisable to invest in such operations unless it is foreseeable that alternative income opportunities will not exist or emerge as competition for labor in that specific location.

4.5.3 Labor productivity

Since labor productivity is crucial to high economic growth, it is also a key to the development of local communities. Low productivity prevents workers from earning more wages and thus impedes poverty reduction. There is no specific data available for the forestry sector in the region, but some trends can be noted by looking at labor productivity in the agriculture and fishery sectors of the Mekong countries. Similar to forestry, both sectors also lag behind in their level of mechanization. Table 9 presents average labor productivity in Viet Nam from 2006 to early 2010. Using constant 1994 prices, the average annual growth rate of labor productivity over this period was 4.18 percent. 'Industry' (industry and construction) is the sector with the highest labor productivity followed by the 'Services' industry. 'Agriculture' has the lowest labor productivity. Given that the largest share of employment in Viet Nam is still in agriculture, forestry and fisheries, with more than 24 million workers in 2010, the low growth of labor productivity is an implicit explanation of the higher poverty rate in this sector. It can thus be concluded that without some form of mechanization and subsequent increase in labor productivity, forestry will remain a poverty-stricken sector in the region.

Table 9: Labor productivity 2006-2010 (VND 1 000/worker) for Viet Nam (GMS-DAN 2014)

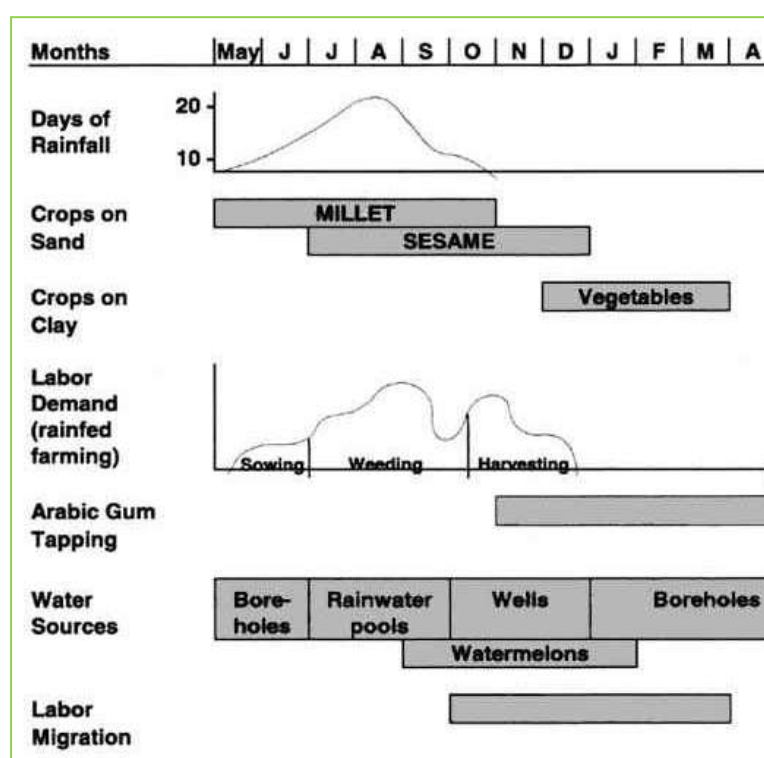
	2006	2007	2008	2009	2010
Average GDP per worker (constant 1994 prices)	9548	10124	10556	10820	11246
<i>Agriculture</i>	3272	3463	3542	3557	3792
<i>Industry</i>	21358	21993	21033	20887	21762
<i>Services</i>	14256	14308	16240	16857	15814
Average GDP per worker (current prices)	21870	25093	31963	34753	40387
<i>Agriculture</i>	8158	9942	13493	13990	17059
<i>Industry</i>	49601	55069	61129	64889	76582
<i>Services</i>	30841	23184	45677	50847	52279

4.5.4 Seasonal labor

Forest work may be extremely seasonal – harvesting may only be possible in dry seasons if issues of access, difficult site conditions and high humidity levels (prohibitive for any work with safety equipment) – are addressed. Rafting of logs and bamboo is possible only during the wet season when water levels are sufficient to move material downstream without encountering obstructions in rivers. Availability of labor in rural areas may also be highly seasonal with peak demands at the onset of the wet season and recurrent peaks for crop-specific harvesting and similar activities.

Other tasks, such as the collection non-timber forest products (NTFPs) or tasks related to festival seasons may also have considerable effects on labor availability. This can become very crucial if time-bound supply arrangements are needed in the anticipated production process. It is therefore advisable to assess this situation in great detail (see Figure 23) through interviews with the local communities planning to set up CFEs. As mentioned above, most of the small-scale technologies presented in this guidebook are linked with agricultural mechanization, particularly 4-wheel drive tractors. The availability of such base machines, however, largely depends on their availability outside periods of agricultural work. Thus, their availability should clearly be identified within the production calendars.

Figure 23. Example of a seasonal agricultural production and labor calendar



4.6 Organizational aspects

This guidebook can only touch on some of the aspects related to the organization of CFEs. These aspects are relevant to the selection of small-scale technologies and to ensure their appropriateness in specific applications. The cultural context and the perception of local people in terms of cooperative action have to be reflected in the organizational set up and profit-sharing mechanisms. The organizational structure must also reflect prevailing laws, registration procedures and room for improvement.

Normally, cooperatives are vertically organized in a 3-tiered system: primary cooperatives at the district level and federations at the provincial and national levels. A primary cooperative consists of individual members – in this case communities or tree plantation smallholders – while members of provincial and national federations are cooperatives.

The members of a cooperative elect the board of directors (BOD) through a general assembly for cooperative development policies formulation. The BOD appoints a manager and staff to run the cooperative business. In the case of horizontally organized agriculture or forest machine ring type cooperatives, sections would be required for (1) administration/finance, (2) machine maintenance, (3) operations – possibly with permanent operator crews – and (4) product sales.

It is possible for a private sector enterprise (e.g. a sawmill or mechanical workshop) to become a member of a cooperative. Joining the cooperative would offer the advantage of timber sales and/or machinery maintenance being directly linked to the enterprise. However, doing so would be a step towards vertical integration, which, as explained above, should be treated with caution.

Figure 24. Basic cooperative structure according to legal provisions in Thailand (www.fsct.com)



The role of support services, moreover, such as machine and spare parts suppliers, mechanical workshops, training institutions or vocational training centers should not be underestimated.

4.7 Silviculture and ecology

There is no fundamental difference between technologies for harvesting in natural forests and plantations except that natural forest may have difficult site conditions – often having steep terrain – while plantations are more accessible because they are often established on former agricultural lands. Harvesting in natural forests is often focused on enhancing natural regeneration and must be carried out with greater care compared to harvesting on plantations. Moreover, suspended systems as shown in Figure 20 may be necessary for harvesting on steeper slopes common in natural forests. Numerous studies have shown that suspended systems reduce soil compaction and erosion. Extraction methods based on rubber-tracked crawlers or animals may also be a better choice for such conditions rather than agricultural tractors if erosion and damage to the residual stand is considered (Ezzati 2011, Ghaffariyan 2008, Shrestha 2006, Wang 1997, Dykstra 1995). However, these selection criteria are highly site specific and need to be assessed within a given context.

Small-scale technologies can also be applied in forest restoration activities particularly in fuel load reduction and the control of invasive or unproductive early succession species in forests, along roads, power lines or waterways. Such situations may allow for biomass energy harvesting once economically viable value chains are in place. RECOFTC is currently exploring this possibility in northern Lao PDR (Salakka 2014).

Concerns have emerged in recent years and intense discussions taken place on the issue of carbon footprints emanating from all economic and social activities. In line with REDD+ discussions and accepted strategies on carbon storage and life cycle assessments in wood products over longer periods, carbon footprints of respective operations will rise in volume.

Available data on small-scale forestry equipment sourcing and application is very limited. However, it is the belief of the authors of this guidebook that this issue will become increasingly important in political and economic decision-making. It is possible that the equipment shown here, particularly on the non-mechanized levels of hand- and animal-based extraction, will have the ability to provide more eco-friendly and sustainable solutions. As further research becomes available, this may become a decisive factor when comparing small-scale machinery to larger sized, heavily motorized equipment, especially when assessing long distance water-based and road transportation options.

In this context, forest-harvesting systems could be compared in terms of their emissions – produced over the process of constructing, maintaining and operating them – particularly in terms of material renewability and energy inputs. Carbon footprinting can be studied by applying energy – the quantitative measure of the resources required to develop a product, whether it is a mineral resource, a biological resource or a commercial product and it expresses the resources using units of one type of energy, usually, solar energy joules (sej) – analysis, which measures both economic variables and ecological systems.

The only study within the context of small-scale forest harvesting technology found for this guidebook was carried out by Rydberg (2002). His research investigated the shift from animal-powered to tractor traction as an example of a shift from humans employing living systems to humans employing mechanical systems. Results in terms of energy use are presented in Table 10. While the total renewable resources use by the tractor was only nine percent compared to 60 percent for the horse, the energy use by the tractor per unit traction or pulling power was only 64 percent of the equivalent use by the horse-based system. This means that 2-horse systems would be needed to substitute for one tractor-based system in terms of energy (though ignores the needed costs).

Table 10. Comparison of resource use for horse and farm tractor traction (Rydberg 2002)

Index	Unit	Horse	Tractor	% of horse
<i>Flows</i>				
(1) Traction input	MJ/ha	357	595	167
(2) Emergy/man-hour	E+12 sej/h	3.6	23.2	644
(3) Emergy use/generated J traction	E+06 sej/J	1.87	1.20	64
(4) Emergy use/J traction exclusive driver	E+06 sej/J	1.15	0.89	77
(5) Emergy use for driver/J generated traction	E+06 sej/J	0.72	0.31	43
(6) Emergy use/ha	E+14 sej/ha	6.7	7.2	107
(7) Emergy use exclusive driver/ha	E+14 sej/ha	4.2	5.3	126
(8) Emergy use for driver/ha	E+14 sej/ha	2.5	1.9	76
<i>Indices</i>				
(9) Local renewable component ^a	%	15	0	
(10) Indirect renewable component ^b	%	45	9	
(11) Total renewable component	%	60	9	
^a Items 2, 3, 4 and 5 in Table 3. ^b 54% of the emergy for service and labour to the horse is added as renewable emergy and 13% of the emergy for service and labour to the tractor is added as renewable emergy, as found in respective national analyses.				

The transition to a future with less available net-yielding energy sources will require greater changes in those societies that are organized and strongly dependent on fossil fuels. In forestry and agriculture, energy and nutrients will have to be recycled by integrating crops and animals.

4.8 Cost analysis in forest harvesting

Cost analysis in forest harvesting must consider all elements that make up the system and contribute to its cost (i.e. all machine costs separated into fixed, variable, personnel and overhead costs). In such assessments, the cost elements are generally expressed per unit of timber output (i.e. US\$/m³ or tons). The further breakdown of the cost elements is depicted in the following diagram (Figure 25).

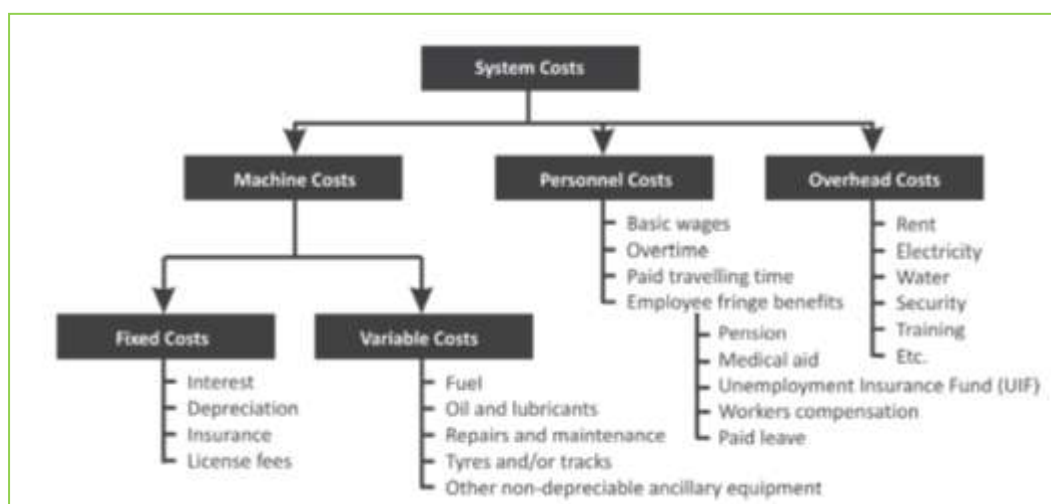


Figure 25. Cost breakdown of harvesting system

There are two primary objectives for small-scale mechanized timber harvesting alternatives: 1) that they have a low capital investment requirement and 2) that they are small in physical size, which in the current context, allows linking them to prevailing agricultural machinery. A low capital system will have reduced overhead costs making it more cost-competitive on smaller, lower volume tracts. An additional benefit of a low-capital system is enhanced opportunities for CFEs because of the reduced financial risk for getting started and sustaining the business. Small physical size pertains to both the number of machines in the system (e.g. a cooperative structure) and the size of the individual machines.

A smaller system preferably linked to agricultural tractors means less time and costs required to operate them seasonally and move them between sites, making them more cost effective for harvesting smaller, lower volumes. There are many possible combinations of equipment and operators for systems to meet these objectives. Which combinations will be the most promising depends on factors such as system balance, costs, safety and the availability and acceptability of the technology – an important factor that is often overlooked. CFEs are more likely to adopt harvesting equipment that has evolved from proven (agricultural) technology and can be adapted whenever possible to current harvesting technologies. Alternatives should also be evaluated in this context.

Individual technologies will have to be added into a harvesting system, which can be described as a combination of processing stages and locations where the process takes place. Each carries a cost per unit of material processed. These costs can be added up to any stage needed within the overall process. Figure 25 illustrates how such an analysis can be structured.

4.8.1 Machine costs

Machine costs include all expenses directly related to owning and using machines. Two types of costs can be separated: fixed and variable. Figures 26a and 26b show the two categories per year and machine hour in relation to total annual productive hours respectively.

Figure 26a. Fixed and variable costs per year

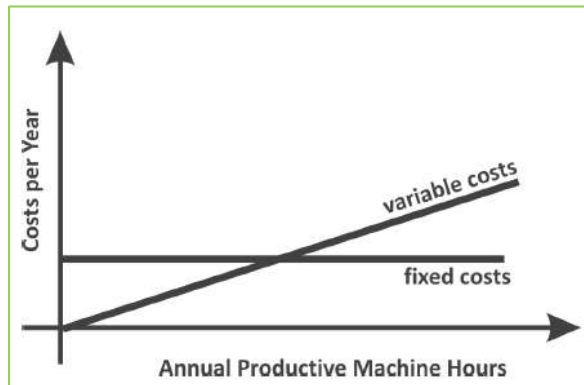
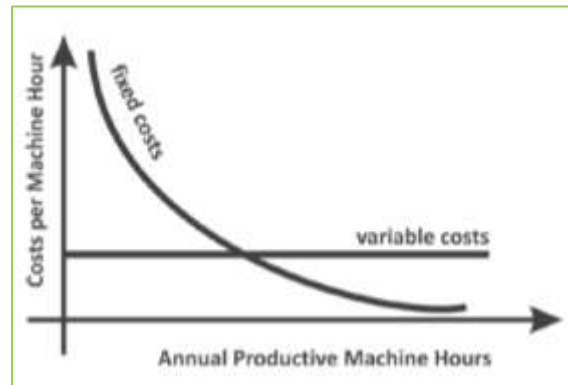


Figure 26b. Fixed and variable costs per productive machine hour



4.8.1.1 Fixed costs

Machine ownership leads to fixed costs that are incurred whether the machine is used or not. They remain constant through time and are charged to the owner on either a monthly or annual basis. They are expressed on a time basis in the cost calculation (US\$/month or year). Fixed costs include:

Interest, also known as **cost of capital** interest, is the cost associated with investing money in a machine. The monthly/annual value assigned to this cost is expressed as a constant, though in reality the value could change over time with interest rate fluctuations. There are two categories of interest: 1) **balanced interest**, which is also called **realised interest**, the actual interest to be paid on borrowed capital and 2) **calculated interest**, also called **speculative interest**, the cost for investing money in machinery as opposed to depositing it in a savings account at a fixed interest rate. In comparing machinery cost calculations, the calculated rate of interest should be used.

Depreciation. A machine has a limited economic lifetime in which it can operate. It is affected by wear and tear, maintenance operating techniques, accidents, availability of newer technologies, as well as other factors. Once its economic lifetime is over, the machine will still have a remaining value. Depreciation is a method of accumulating funds for machine replacement throughout the lifetime of the machine currently in use by writing its original value off to an expected residual (salvage) value. The easiest and often applied **straight line method** depreciates the machine value in equal amounts over the machine's lifetime.

Insurance. This cost only considers insurance directly related to the machine and can include fire, theft and third party insurance. Medical, life and business premises insurance are not included here (these are overhead costs). No calculation for insurance cost is required because the insurance provider determines this value, often as a percentage of the machine's book or

market value. This value is expressed as a constant per month or annum, although in reality, it decreases over time as the machine's value diminishes.

License fees. These include machine registration, machine licensing (if it is to use public roads) and the operator's driver's license (if applicable). Once again, no calculation is required for this expense since law dictates its value.

4.8.1.2 Variable / running costs

Variable (running) costs are incurred when the machine is working. These costs are dependent on machine utilization and productivity and are therefore charged on an hourly or production unit basis. They include fuel, oil and lubricants, repairs and maintenance, tires and/or tracks, as well as other non-depreciable equipment and accessories.

Fuel cost. This cost is driven by consumption and the unit price of fuel. The higher either of these values is, the higher the machine's fuel cost will be. Consumption is determined by engine size, load factor (how difficult the work is), machine condition and operator habits.

Oil and lubricants. This cost is usually expressed as a percentage of the fuel cost per productive machine hour (PMH). The reason for this is that traditional forestry machines consume a mixture of fuel and oil. Although modern technology has resulted in this no longer being the case, because oil and lubricant costs are relatively low, the link to the fuel cost remains. Oils and lubricants in modern forestry equipment include engine oil, transmission oil, final drive oil, hydraulic oil, grease and filters. Factors influencing consumption of these items are the type of machine employed (e.g. equipment with complicated hydraulics leads to a higher oil consumption than equipment with simple or no hydraulics), the environment in which the work takes place (i.e., temperature and dust) and maintenance.

Repairs and maintenance. This cost includes all money paid to keep the machine in running order. It incorporates all services, repairs, maintenance work and spare parts associated with this role. It is generally calculated using a 'repair and maintenance factor', which is a percentage of the machine purchase price over the life of the machine. As the machine gets older, repairs and maintenance become more frequent and this cost increases. The percentage is generally taken from experience or is estimated or calculated. If calculated, the anticipated repair and maintenance cost is divided by the machine purchase price and the answer expressed as a percentage.

Tires and/or tracks. Tire and/or track life is usually shorter than machine life, meaning that replacement has to be factored into machine costs. As such, these items are classified as non-depreciable items: they do not depreciate with the machine but are written off over their own economic lives according to usage. Factors influencing tire and track life include driving habits of the operator, vehicle speed, operating conditions (slope, rough terrain), machine load (difficulty of work) and maintenance (tire pressure and track tension monitoring and other care). One should take note that the term 'tracks' refers only to tracked machines. Tracks and/or chains mounted on the tires of wheeled machines are not computed as costs here but treated as non-depreciable ancillary equipment.

Non-depreciable ancillary equipment and accessories. Items such as cables, sliders, cuffing chains, cuffing bars, delimbing knives, tire chains and other similar items that have to be replaced during the machine's economic life make up this category. Like tires and tracks, these

items are classified as non-depreciable because they do not depreciate over time with the machine but are consumed according to their usage. Expected economic lives and prices for these items can be obtained from respective manufacturers.

4.8.2. Personnel costs

The term 'personnel' includes both machine operators and workers. Costs for personnel include basic wages, overtime, employee fringe benefits and paid travel time (if applicable). They are usually expressed on a cost to company per man-day basis. The wage per day may depend on the rate (time-rate, piece-rate and premium bonus) that has been fixed by employers and employees. Piecework wages are linked to individual performance per unit of time. Incidental labor costs are somewhat more complicated. They are not paid for any direct performance by the employee but rather are paid to comply with legal requirements, collective contracts or work orders. In addition, an employer may make voluntary payments that go beyond statutory obligations. Incidental labor costs are found from data obtained in previous years, for example, from a balance sheet or from estimates based on experience such as the effect of sick leave. Incidental labor costs may change significantly for different wage rates and working sites.

In some cases, therefore, it is advisable to determine labor cost data in detail. Minimum basic wage and overtime wage are determined by legislation in most countries. Overtime wage is usually expressed as a percentage of the basic wage rate in cost calculations. Fringe benefits are indirect employment costs incurred by the employee, often calculated as a percentage of the direct wages paid to the employee for normal work time and overtime; they include pension plans, medical aid, unemployment insurance fund (UIF) contribution, workers compensation and paid leave. Travel time, which takes travel time to and from work into account, may be a transport subsidy paid to the employee.

4.8.3 Overhead costs

Overhead costs include all costs indirectly related to the system. Overhead costs sometimes serve more than one harvesting system (e.g. rental for an office from which administration for two different harvesting operations is carried out). In this case, a percentage is generally assigned to the overhead cost, based on how much the overhead serves the respective system. This leads to weighted overhead costing.

4.8.4 Calculation sheet

The example in Table 11 describes a typical 40-hp farm tractor with a utilization period of 1 200 hours per year and a depreciation lifetime of nine years. The fact sheets in the Annex of the guidebook contain, wherever possible, meaningful machine cost calculations in the format presented in this table.

Table 11. Agricultural tractor

A. Base data					
Price of the complete machine incl. delivery, discounts, import duties, etc.	P		15 000	USD	
Rest value after operational time	R		6 000	USD	
Utilization period in years	N		15	years	
Annual utilization in machine hours (for depreciation)	H		1 500	(Mhrs)/year	
Depreciation period	Dy		9	Years	
Depreciation period in machine hours	Dmhrs		900	Mhrs/year	
Annual utilization H:N	Ua		667	Mhrs/year	
Planned annual utilization (Mhr/year)	a		1 200	Mhrs/year	
Fuel consumption liter/Mhr	Fmhr		2.00	Liters/Mhr	
Fuel costs incl. storage	Fc		1.00	\$/Liter	
Factor for annual repair and maintenance 20 % of P	r		0.20		
Factor for lubricants engine oil and grease 5% of P	l		0.05		
Interest rate in %	i		12.00	%	
B. Material costs		\$/year	Sum	17.21	\$/Mhr
Depreciation D					
if a is greater or equal to Ua, then (P-R):Dmhrs					
if a is smaller than Ua then (P-R) : (Dy x a)			10.00	\$/Mhr	
Financing costs/year $((An+R) : 2) \times i \% : 100$	Σ	1 260.00	1.05	\$/Mhr	
Maintenance costs (M)					
$(P : H) \times r$			2.00	\$/Mhr	
Fuel and oil costs (B)					
$Fmhr \times Fc \times (1 + l)$			2.10	\$/Mhr	
Costs for shifting between harvesting sites/year	Σ	960.00	0.80	\$/Mhr	
- Material costs transport of machine 0.50 \$/Mhr		600.00			
- Operator costs \$ x 0.10		360.00			
Other costs/year (S)					
Differentiated pre-calculation	Σ	1 510.00	1.26	\$/Mhr	
- Third party accident insurance		200.00			
- Machine insurance 1.4 % of P		210.00			
- Garage costs					
- Administrative enterprise overhead costs 3.0 % of P		450.00			
- Organization and supervision 1.0 % von P		150.00			
- Financing of outstanding payments (1-2 months)		500.00			
Alternative: lump sum pre-calculated costs					
9% of P	Σ	1 350.00	1.13	\$/Mhr	
C. Labor costs			Sum	3.00	\$/Mhr
Labor cost with taxes and benefits			3.00	\$/Mhr	
- Operator 1: 3 \$/hr		3.00	\$/Mhr		
- Ratio of actual to planned work hours		1.0			
- Operator 2: 3\$/hr		0.00	\$/Mhr		
Total costs				20.21	\$/Mhr

4.9 Summary system analysis

The following diagram (Figure 27) provides a framework for assessing system costs based on a summary of individual harvesting stages. The calculation requires the following input data:

- The quantity of input factors (labor and machines) per unit of performance;
- The price of these inputs per hour or per unit of volume;
- Average volume per stem; and
- Skidding distance (skidding direction).

Total costs are determined by multiplying costs per unit of performance with quantity of performance. In some cases, overhead costs (management, supervision, accounting) may have to be added to harvesting costs if separate accounting does not take place.

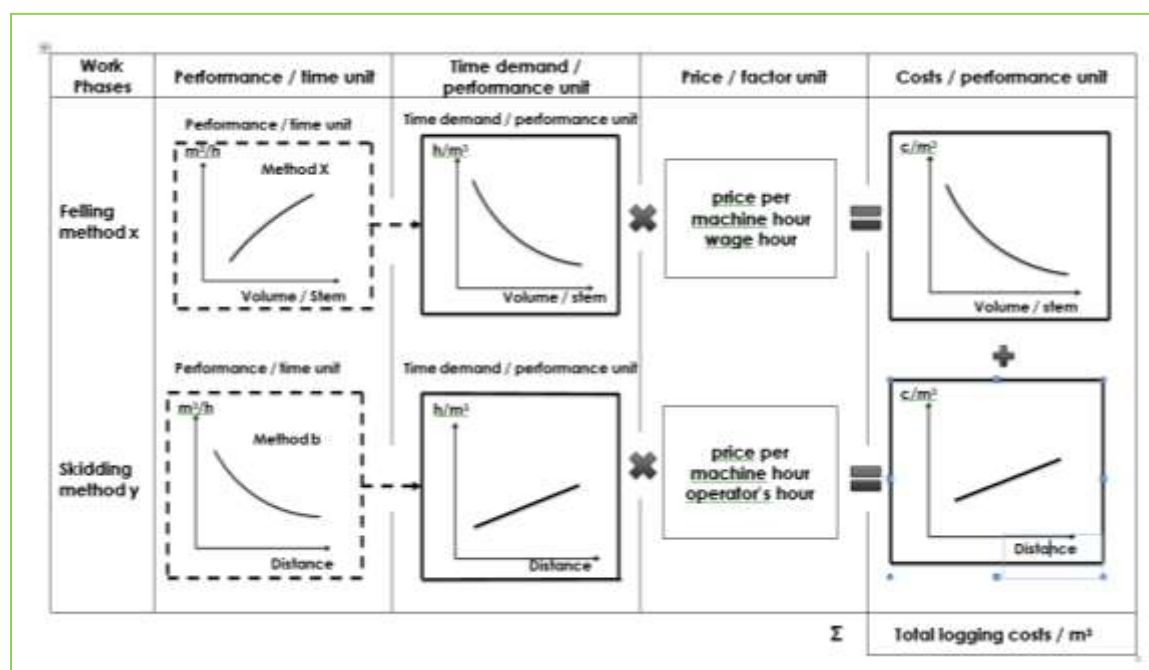


Figure 27. Diagram of basic data and elements of cost accounting for a given logging method (FAO 1985)

Data on the required quantities can be obtained from tables, diagrams, experiences and special calculations. In order to increase accuracy, results obtained in practice are of particular value (piece-rate statistics, influence of distance and slope, training level of workers and machine operators, etc.). However, such data always applies to specific systems and methods (special man-machine combinations).

If different alternative technologies are to be analyzed for a given harvesting stage, a breakdown of costs according to Figure 28 is recommended. Assessment of individual cost categories is described in the previous chapters.

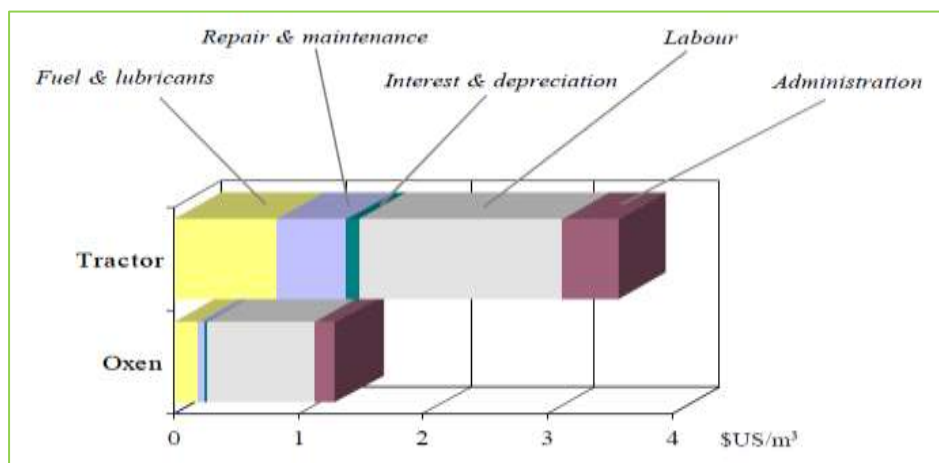


Figure 28. Comparison of cost structure of tractor and oxen logging in Tanzania (Abeli 2003)

Harvesting technologies as applied in each step of extraction can be summarized in a matrix form as shown in Figure 29. The diagram uses locations (felling site, trail, road, etc.) and the harvesting or processing stage as its axes, while technologies are placed in the respective boxes. Cost determination can be done for each box and their respective totals can then be derived.





Task \ Location	Felling site	Skidding trail	Road	Primary Processing site
Felling				
	\$/m3?	\$/m3	\$/m3?	\$/m3?
Skidding				
	\$/m3?	\$/m3?		
Transport				
	\$/m3?	\$/m3	\$/m3?	\$/m3?
Primary processing				
	\$/m3?	\$/m3	\$/m3?	\$/m3?
Total				

Figure 29. Extraction system according to location and harvesting and processing stage

5. Time and motion studies

Introduction of new logging systems will always require new time studies for the preparation of performance and input data. Such studies should also include:

- Details of logging method;
- Available machinery with sufficient detail (e.g. chain length of saws);
- Training level of staff;
- Total volume harvested in the observations;
- Terrain conditions and observations on work performance;
- Tree species; and
- Diameter distributions of logs, etc.

5.1 Analysis of cycle time elements

In a first step, the systems to be studied are simply observed in the field and segregated into cycle time classes. Cycle time elements are defined in Table 12.

Table 12. Sample format of cycle time elements according to classes of productive and non-productive time consumption

Direct productive time	Productive auxiliary time	Rest periods	Unproductive or non work related time
Felling	Refueling chainsaws	Lunch breaks	Interruptions due to machine failure
Delimbing	Sharpening tools	Rests during work steps	Accidents
Sorting	Walking from and to starting point of work	Etc	etc
Stacking	Waiting time		
Hooking to tractor	Etc		
Pulling out winch cable			
Pulling in winch cable			
Walking between trees			
Walking in return trips			
Etc.			

Respective sample sheets need to be prepared according to these categories, which allow recording of the time elements for several cycles. A minimum of at least five cycles is recommended to allow statistically sound calculation of average values. The number needs to be increased according to the observed variance in data.

Cycle elements are then observed by either measuring the total cycle or by observing one or a maximum of two workers per observer in case both can be watched from one observation point. This will yield at the end a total by adding up the actual time of individual cycle elements.

The other method possible is to take systematic subsamples in fixed time intervals. In this case, the beginning and end of a cycle is recorded and the subsamples will give a percent distribution of time elements within the total cycle. The advantage of this method is that one person can observe several workers while in difficult work situations and terrain. The results of such observations can be visualized as shown in Figure 30 below.

It is also necessary that the volume or weights of the products harvested are measured and recorded separately for each piece or load harvested in order to relate the total volume to the specific cycle time and to calculate the piece-volume ratio, which is a key variable. This data will finally give a measurement of volume or weight per hour. It is advisable that other parameters like extraction distance, slope, terrain conditions and other similar factors are also recorded. The data can then be analyzed as discussed in Chapter 3.8.1.

As explained in Chapter 3.4, it is important to use the same team or at least those with similar performance levels in order to make observations truly comparable. Time and motion studies should be conducted once a certain performance level is reached with all workers involved.

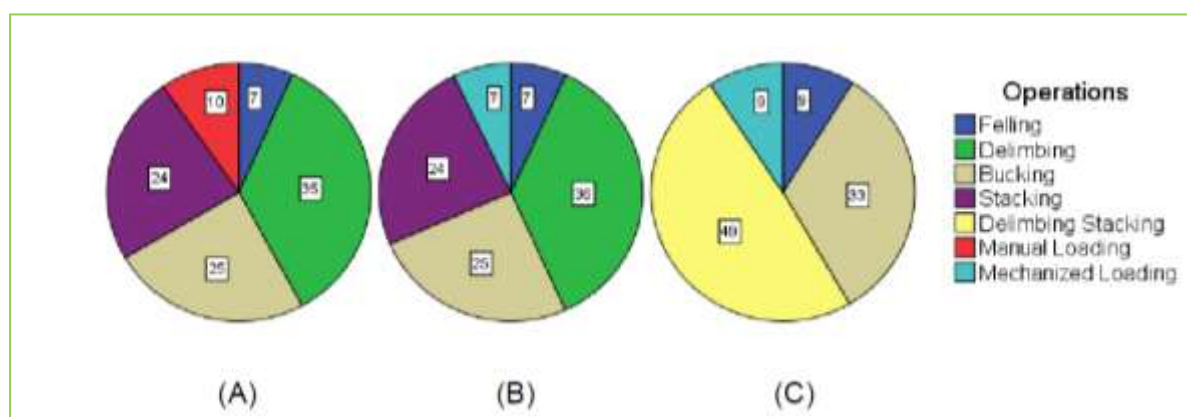


Figure 30. Percent relative time allocation of three conventional plantation timber harvesting systems in Thailand: (A) chainsaw + manual loading; (B) bush cutter + mechanized loading; and (C) Bush cutter + combined delimbing/loading (Manavakun 2014)

In addition to pie chart visualization, cycle times can also be shown using bar charts through which different criteria can be built in and can be visually compared directly.

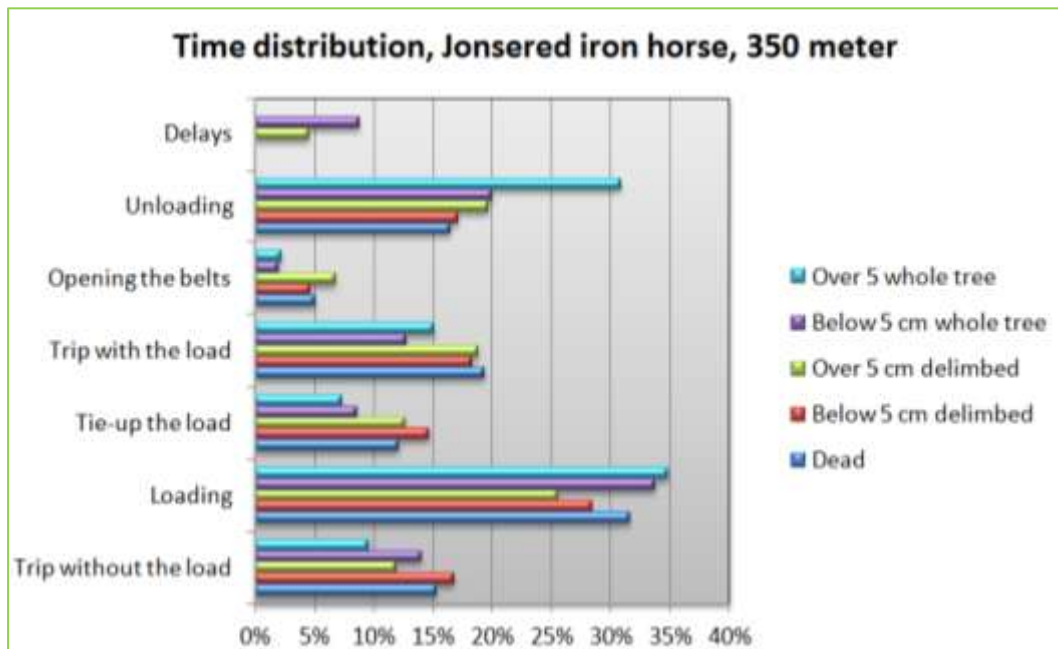


Figure 31. Detailed cycle element analysis for forwarding different sizes/types of bamboo with Jonsereds Iron horse mini-skidder (Salakka 2014)

5.2 Assessing work load and ergonomic issues

Time and motion studies are used to analyze issues of physical work load for workers and operators. This can be achieved by studying the type and duration of work postures (Figure 32) occurring in a cycle time with simple recording together with the above cycle element assessment. Work postures can, in a second step, be related to the specific cycle times and subsequently, a complete harvesting system. A visual presentation of this is given in Figure 33.

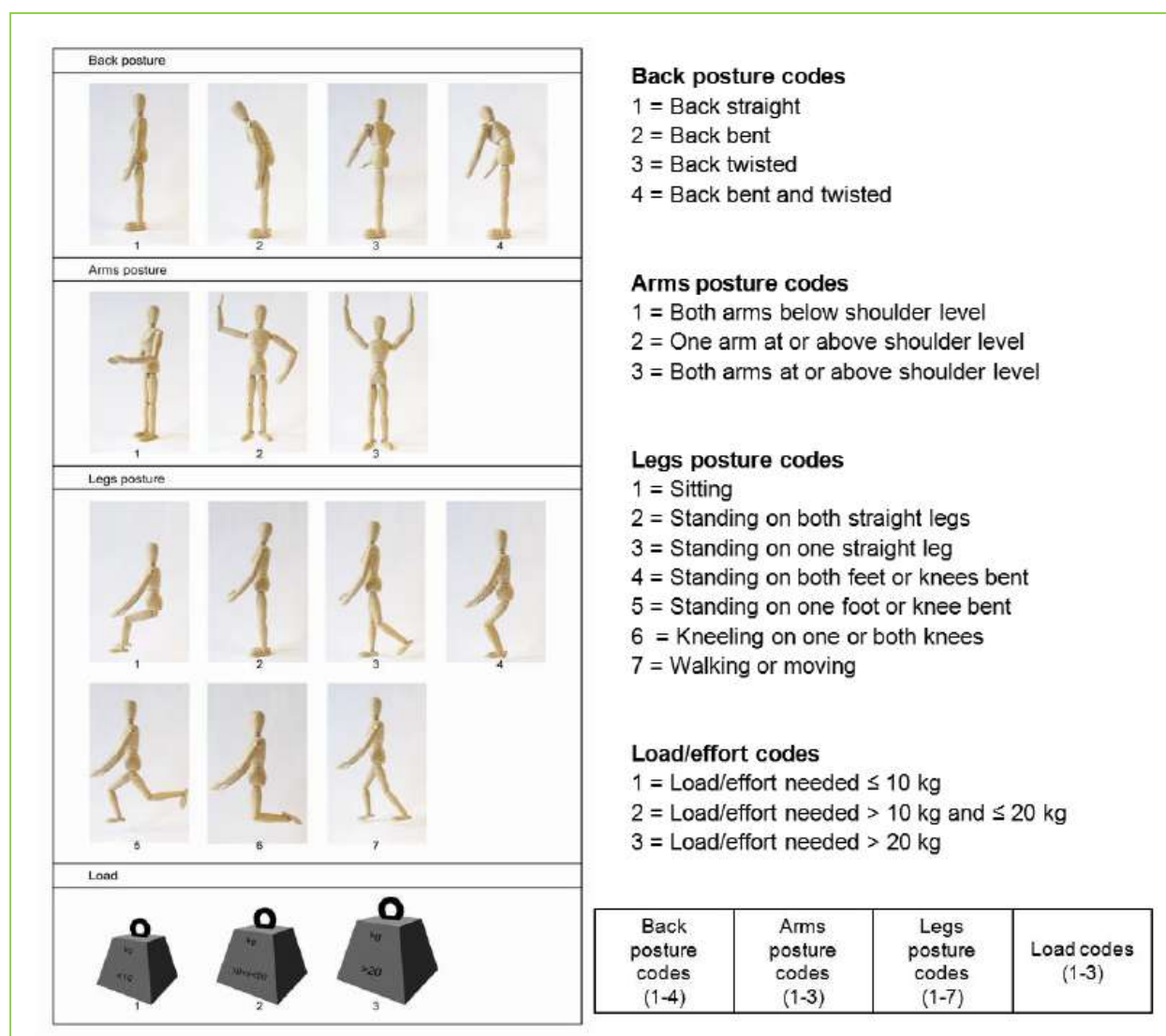


Figure 32. Different work postures for analysis of workload and physical strain according to OWAS method (Grzybowska 2010 and Manavakun 2014)

The following workload categories can be created from a combination of postures (as shown in Figure 32), weights lifted or moved in other ways, and other parameters.

The relative proportion (percent time share) of these categories can then be studied by observing the respective activities in the cycle time study (Table 12). An example is shown in the following tables.

Legend:

Action categories		
Action category		Recommendation
AC 1	Normal	
AC 2	Demanding	
AC 3	Strenuous	To be reduced to a minimum
AC 4	Extremely harmful	To be eliminated completely if possible

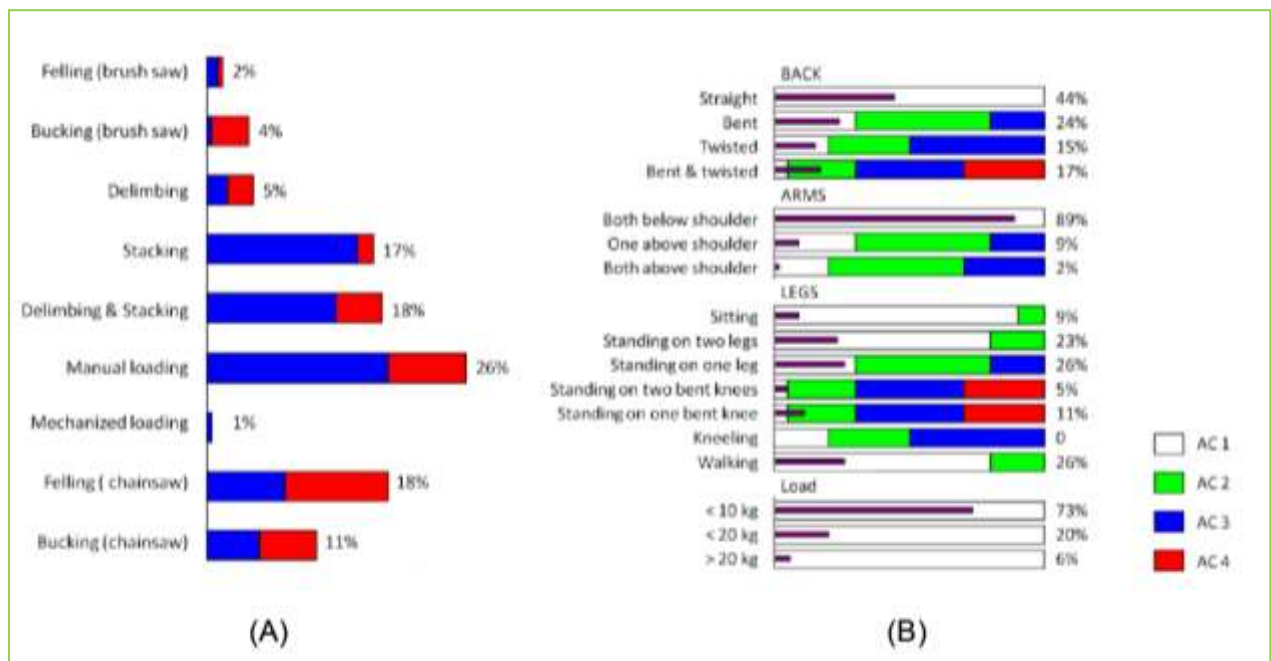


Figure 33. Proportion of work operations in work categories (A) and frequency of body postures (B). Frequency of different work categories are presented as a percentage of total cycle (work) time (Manavakun 2014)

The analysis allows the clear identification of strenuous work periods and may help to address these with improvements in equipment. An example is given in the following picture, which shows a simple holding device for chainsaws in order to allow felling or crosscutting in upright instead of the harmful bent down body posture.



Figure 34. Holder for chainsaw to allow operation in upright body posture (www.Husquarna)

Measuring heartbeat/pulse rate in relation to the respective body posture can further substantiate the analysis of posture studies. As shown in the example of Figure 35, the electric shear applied in tree pruning is by far less strenuous to operate compared to the two other systems studied. Pulse rate measuring instruments are readily available and easy to handle.

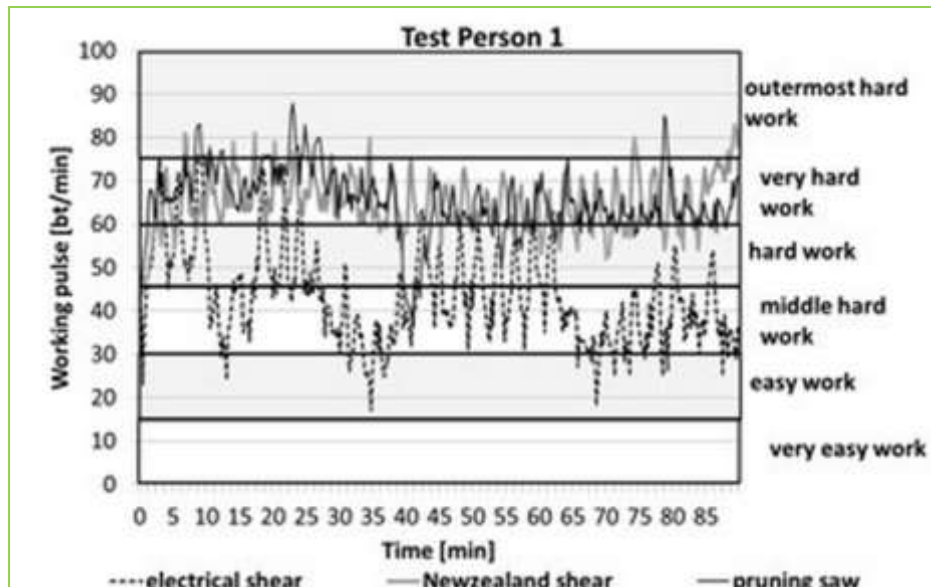


Figure 35. Measurement of heartbeat frequency for three pruning tools (Nutto 2013)

5.3 Assessing safety issues

Time and motion studies should also observe and keep records on any safety issues such as poor handling of tools, chainsaw kickbacks, workers slipping or getting hit by falling branches and trees as shown in a study by Caliskan (2010). Workers should be made aware of these issues with visualized information wherever possible in all machine training. Many distributors of forest machinery have excellent information material on this subject.

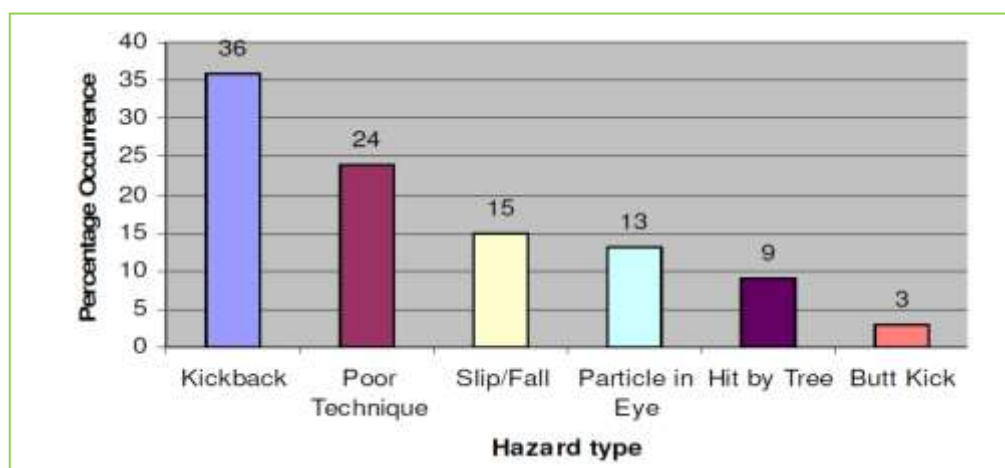


Figure 36. Occurrence of hazard types in tree felling operations during time and motion studies (Caliskan, 2010)

5.4 Drudgery work by women and children

One of the saddest aspects of forest harvesting is the drudgery work by women and children. In many societies – particularly in some ethnic groups in the region – women are burdened with the heaviest agricultural work (e.g. transporting crops over steep hills and long distances). Forest work is no exception to this sad truth and it is still common practice that women and girls are responsible for collecting fuelwood, as shown in a recent fuelwood survey in Nepal (Mohns 2013).



Figure 37. Mother and four girls carrying bedding material for cows and fuelwood in central Nepal. The bundles weigh between 20 and 30 kg (Mohns 2013).

Besides men sharing in this kind of work, there are simple tools like logging sulkies or – at least in part – animal traction that could make all the difference to address this issue, even on difficult terrain.

6. Knowledge dissemination and learning

This guidebook aims to serve as a dynamic knowledge source, to be available to practitioners free of charge in electronic form. The authors welcome feedback and comments on the suitability of the publication, the fact sheets in particular, as well as contributions for future editions. Extracts from the guidebook may be used freely provided that titles and authors are appropriately acknowledged as sources. Suitable download websites are being researched to ensure that this guidebook is available to as wide an audience as possible.

The guidebook contains a set of separate factsheets on harvesting systems with their own reference sections and machine cost analyses, which can be used separately as handouts (e.g. for distribution in trainings and demonstrations). These factsheets enable the user to focus his or her material distribution for covering specific topics rather than distributing the entire lengthy guidebook to end users.

The guidebook focuses on a number of key issues relating to safety, ergonomics, equipment ownership and operation. Research for this document highlights significant knowledge gaps that could be reduced through further studies. Besides carbon footprint issues, there is a need for more knowledge and better understanding of the potential, performance, limitations and factors affecting operation and costs. RECOFTC plans to develop additional guides covering aspects of training and equipment maintenance, as well as topics in the context of vocational training. The benefits of appropriate technology approaches will not be realized unless all sector stakeholders act in coordination to disseminate, support and ensure the mainstreaming of the concepts and approaches embodied in this guidebook.

Table 12: Examples of different modes of learning in the context of small-scale AHT (adapted from Lewarck 2010)

LEARNING MODE	TYPE OF KNOWLEDGE DISSEMINATION	
	Personal	Shared
Informal learning	Role model learning by example (e.g. from trained workers or teams)	Learning within communities of practice
Informal learning	Training courses organized by training institutions, extension centers and machine distributors	Visits of tradeshow in groups with guidance Group learning by coaching in enterprise
Formal learning	Vocational training particularly on agricultural machinery maintenance and primary wood processing apprenticeships	Information technology (IT)-based knowledge management systems sharing

Lewark (2010) provides the above framework on knowledge transfer and competence development for forestry operations. As shown in Table 12, it is composed of a set of learning modes and types of knowledge dissemination. This basic structure also holds for the future extension approach for small-scale forestry harvesting technologies, particularly in the regional context with multiple actors of learning networks ranging from grassroots support to formal training institutions and private sector service providers, which are needed to further promote small-scale AHT.

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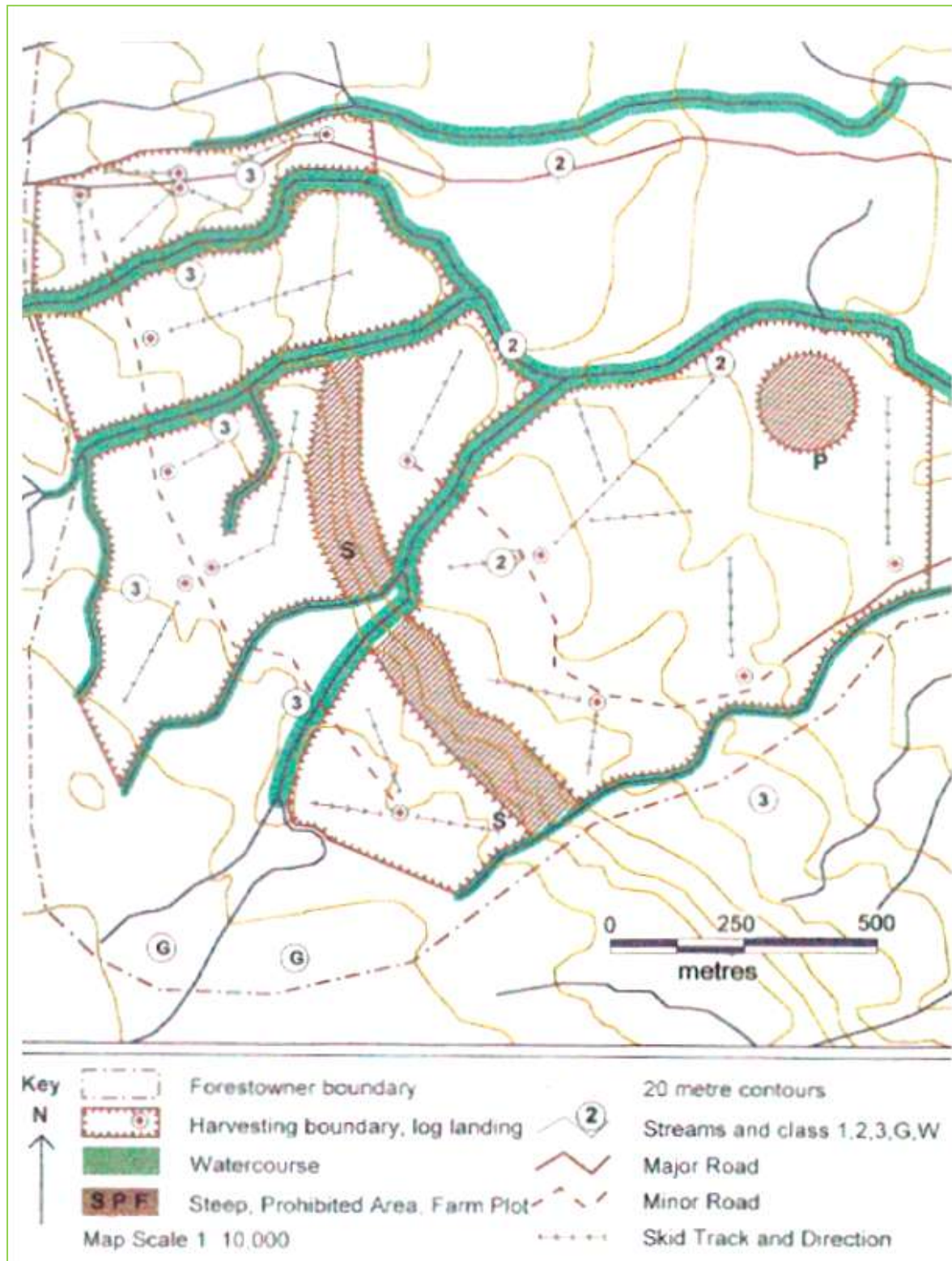
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Annex

Annex1: Example of a Forest Operation Planning Map from FAO 1999



Annex 2. Factsheets

1 Manual operations and hand tools

- 1.1 Hand tools
- 1.2 Log chutes
- 1.3 Sulkies
- 1.4 River rafting

2 Animal traction

- 2.1 Horse-mule-donkey
- 2.2 Buffalo-oxen
- 2.3 Elephant

3 Mechanized harvesting and transport

- 3.1 Chainsaws
- 3.2 Hand held winches
- 3.3 Self powered/propelled winches
- 3.4 Tractors and attachments
- 3.5 Small cable logging system
- 3.6 Rubber-tracked mini crawlers

4 Mobile Processing

- 4.1 Chainsaw mills
- 4.2 Mobile sawmills



RECOFTC's mission is to enhance capacities for stronger rights, improved governance and fairer benefits for local people in sustainable forested landscapes in the Asia and the Pacific region.

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