COMPARING FOREST WOOD SUPPLY CHAINS OF NATURAL FORESTS IN VIETNAM USING SELECTED INDICATORS OF SUSTAINABILITY

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TRAN VT & BECKER G. 2013. Comparing forest wood supply chains of natural forests in Vietnam using selected indicators of sustainability. In the north of Vietnam, steep slopes are common. Harvesting is carried out using chain saws. Sawing of saw logs into small sawn wood is done at the felling site. The sawn wood is extracted by buffaloes to lower landing and transported further by trucks to the industry (FWSC1). In the centre and south of Vietnam, slopes are gentler. Harvesting is partly mechanised using chain saws for felling and tractors equipped with cables or winches for extracting saw logs to lower landing and then transported further with trucks to the industry (FWSC2). A sustainability impact assessment showed that FWSC2 had more positive impacts with 30% lower production cost, caused less occupational accidents but disturbed more areas on the ground compared with FWSC1.

Keywords: Sustainability impact assessment (SIA), harvesting systems

TRAN VT & BECKER G. 2013. Perbandingan rantai bekalan kayu hutan bagi hutan asli di Vietnam menggunakan penunjuk kemampanan terpilih. Terdapat banyak lereng bukit yang curam di utara Vietnam. Pembalakan dijalankan menggunakan gergaji rantai. Pemotongan balak gergaji kepada kayu gergaji pula dijalankan di tapak pembalakan. Kayu gergaji dikeluarkan dari hutan ke matau menggunakan kerbau dan diangkut seterusnya ke industri menggunakan trak (FWSC1). Lereng bukit adalah lebih landai di tengah dan selatan Vietnam. Pembalakan sebahagiannya dijalankan menggunakan mesin seperti gergaji rantai dalam penebangan. Traktor yang lengkap dengan kabel atau win mengeluarkan balak gergaji ke matau yang seterusnya diangkut ke industri dengan trak (FWSC2). Penilaian impak kemampanan menunjukkan yang FWSC2 memberi impak yang lebih positif berbanding dengan FWSC1 iaitu kos pengeluaran dikurangkan sebanyak 30% dan terdapat kurang kemalangan di tempat kerja. Bagaimanapun FWSC2 mengakibatkan lebih gangguan kepada tanah berbanding dengan FWSC1.

INTRODUCTION

Vietnam has a total of 13,258 mil ha of forests which cover 39.1% of the land surface. A total of 10,339 mil ha are natural forests (VNFOREST 2010), which provide more than 300,000 m^3 of large dimension logs annually as supply for all kinds of wood industry in the country (MARD 2005). The greatest part of these natural forests is located in hilly or steep terrain. In the north of the country, steep slopes (≥ 30%) dominate (MARD 2005). Harvesting is carried out using chain saws for felling and sawing sawn wood (0.20–0.35 m^3) at stumps and then mostly using animals for extracting sawn wood to the lower landing and transported further by small trucks to the wood processing industry (FWSC1).

On the contrary, in the centre and southern parts of Vietnam, slopes are gentler (< 30%) (MARD 2005) and the harvesting operations are partly mechanised using chain saws for felling and de-branching followed by extraction of the logs with tractors equipped with cables or winch. Saw logs are transported with bigger trucks to sawmills (FWSC2).

The forest wood supply chain (FWSC) applies the concepts of logistics and supply chain management to the field of forestry, and in particular to the area of logging and transport operations (Vötter 2009). FWSCs can be seen as a set of processes by which forest resources are converted into products and services (Päivinen et al. 2010). FWSC

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deals with all processes within this chain, starting from the regeneration of a new forest to the recycling of the produced end product, covering forest management, logging and transport and forest industry to end-use (Vötter 2009). A process is the basic element in the analysis of a Forest World Chain (FWC) (Päivinen et al. 2010).

According to the World Commission on Environment and Development Report, commonly known as the Brundtland Report, sustainable development is defined as meeting the needs of the current generation without compromising the ability of future generations to meet their needs. Generally, sustainability includes three dimensions—environmental, social and economic.

There are a number of sustainability assessment methods currently available depending on needs and scopes in the assessment of sustainability. They can be categorised into (1) indicators and indices, (2) product-related assessments and (3) integrated assessments (Ness et al. 2007). Indicators and indices, e.g. ecological footprint and input–output energy analysis, mainly calculate the quantity of a set of economic, social and environmental indicators and indices. A summary of the overall sustainability level of separate indicators and indices reflects the overall sustainability in a simple way. Product-related assessments, e.g. life cycle assessment (LCA), material intensity analysis and process energy analysis mainly relate to flows of material and energy during the processes of production, consumption and the end of life of products. Integrated assessments can be defined as an interdisciplinary process of combining, interpreting and communicating knowledge from diverse scientific disciplines in such a way that the whole cause–effect chain of a problem can be evaluated from a synoptic perspective with two characteristics: (1) it should have added value compared with single disciplinary assessment and (2) it should provide useful information to decision makers (Rotmans & Dowlatabadi 1997). Historically, integrated assessments were rooted in scientific and public policy efforts to understand and control acid deposition in the 1970s in Europe and North America (Van der Sluijs 2002). To date, there are many tools developed for this method, e.g. multicriteria analysis, vulnerability analysis, cost benefit analysis and sustainability impact assessment (SIA).

SIA tools were recently developed in order to obtain a synthetic measure of the three pillars of sustainable development, including economic, social and environmental aspects. For example in the SENSOR project (www.sensor-ip.org), the Sustainable Impact Assessment Tool (SIAT) was developed. SIAT is a quantitative multi-modelling tool which relates the changes of policy to landuse changes and subsequent impacts on sustainability. SIAT includes only forest resource management and does not consider the production chains downstream of a forest (Päivinen et al. 2010).

Based on the idea of developing an SIA tool for analysing complete value chains of the forest-based sector, the project EFORWOOD (http://87.192.2.62/eforwood/Home/tabid/36/Default.aspx) was developed (Rosén et al. 2011). Two main products of EFORWOOD are the Database Client and the Tool for Sustainability Impact Assessment (ToSIA), which hold, calculate and integrate the extensive information and data collected. SIA of FWCs is based on measuring and analysing environmental, economic and social indicators for the production processes along the value chain (Lindner et al. 2011). ToSIA can assess forest value chains in different geographical regions covering local, regional, national and up to the continental scale (Lindner et al. 2011).

Logging and transport are labour- and cost-intensive operations and have inevitable impacts on the natural environment and also on social issues such as employment, health and safety. Depending on the level of mechanisation, these impacts are different. The aim of this study was to assess the sustainability impacts of activities in FWSC1 and FWSC2 for a selective set of indicators. Suggestions to optimise the chains were proposed to reduce negative impacts and enhance positive impacts.

MATERIALS AND METHODS

In order to assess the overall sustainability of FWSCs of natural forests in Vietnam, the method of SIA has been used. Two case studies that were typical for two different levels of mechanisation were chosen. All processes of each chain related to logging and supplying wood from the forest to the wood industry starting with harvesting planning and ending with the transporting wood to the mill gate were assessed. Sustainability indicators covering selected aspects of economy, environment and society were chosen and indicator values were linked to each single process of the two chains. In the field, parameters for each indicator were collected using time study results, personal observations or interviews with workers and the managing team. Quantitative and non-quantitative parameters were then processed by Excel and the LCA software UMBERTO. The results were compared and discussed with regard to advantages and disadvantages of each chain. The weak points of the chains in terms of sustainability impact were analysed and proposals to improve the chain were developed. This led to a set of optimised supply chains. The respective recalculation of the indicator values showed significant improvement of the overall sustainability.

Study sites

The first case study (FWSC1) was carried out in Van Ban, located in Lao Cai province in northern Vietnam. The second case study (FWSC2) was conducted in Vinh Thanh, located in Binh Dinh province in southern Vietnam. FWSC1 is typical for using chain saw to cut saw log into sawn wood at stump areas. Then sawn wood is skidded to landing I by buffaloes and further transported to sawmill by trucks. FWSC2 is typical for extracting saw log from stump areas to landing I by tractor and further transported to sawmill by trucks (Figure 1).

The climate of both sites is tropical with mean annual temperature of 22 °C in Van Ban and 27 °C in Vinh Thanh. The relative humidity is high, 80–85%. Annual rainfall is 1800 mm in Van Ban and 1716 mm in Vinh Thanh. The dry season often lasts from January till August and is relatively dry and warm. The rainy season is usually from September till December and is often rather cold and wet. However, seasonal variations are possible and rainfall of more than 80 mm per month may occur during the dry season which may interrupt harvesting activities. The characteristics of the two sites are shown in Table 1.

Processes of FWSCs for SIA

SIA was conducted for all processes of the two FWSCs beginning with harvesting planning of pre-harvesting activities, then harvesting, post-harvesting, transport and ending with unloading and sawing sawn wood at sawmill (Table 2).

The first process of pre-harvesting activities is harvesting planning. This activity is done one year before felling. The aim of planning is to find out where and how the harvesting activities are carried out and to assess the harvesting costs and calculate the labour and equipment needed for harvesting and transporting the wood to landing II. The second step of pre-harvesting activities is field preparation. The purpose of this activity is to make the later felling activity safer. The work of this activity is to prepare routes to selected trees and clear the area around those trees as well as to clear away all climbing plants on harvested trees. However, the work of field preparation was not done in FWSC1 because the harvesting contractor did not want to pay for that. The last step of pre-harvesting activities is skid trails, landings and tent preparation. In FWSC1, a long old skid trail and landing were advantageous; only minor repair work was needed. In the FWSC2, all skid trails were newly made with the help of bulldozer and men.

After completing pre-harvesting processes, harvesting activities were carried out. In FWSC1, the activities of felling, debranching, cross-cutting and sawing into board wood were done by chain saws at the stump area. After that, all board wood was skidded using buffaloes to landing I. In FWSC2, harvesting process was carried out in a more mechanised way with felling and debranching by chain saw at the stumps. The round wood was extracted by crawler tractor to landing I where long logs were cross-cut into shorter logs by chain saw.

Post-harvest hygiene activity was done after all wood had been extracted to landing I. The aim of this work is to achieve minimum negative impacts of harvesting activity to the

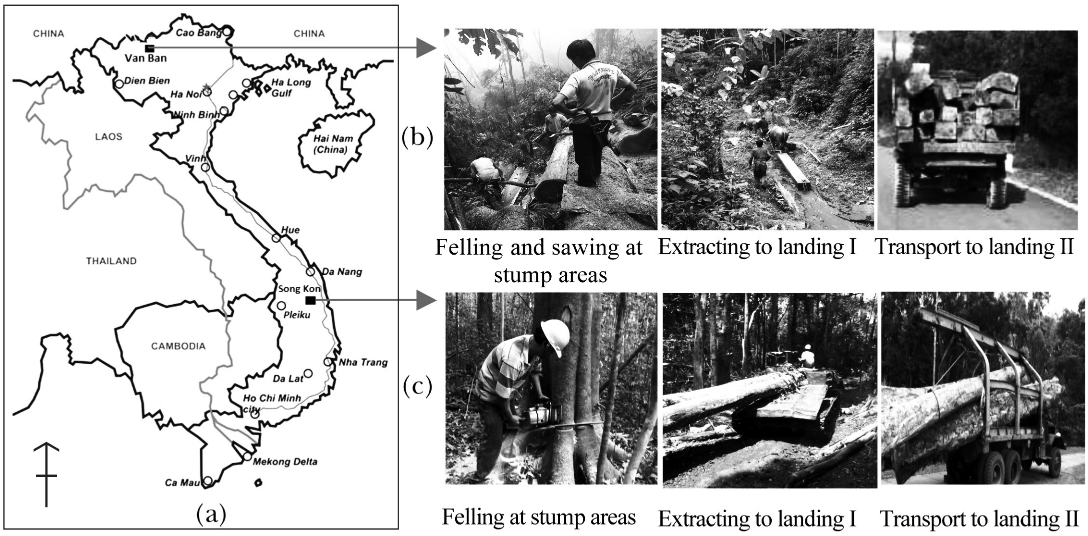

Figure 1 Selection of study sites for two case studies: (a) selected sites (b) main processes of the FWSC1 and (c) main processes of the FWSC2; FWSC = forest wood supply chain

Table 1 Characteristics of two chosen sites for sustainable impact assessment in FWSC1 and FWSC2

Feature	FWSC1	FWSC2
Area of study sites (ha)	10.2	8.2
Species	Mixed	Mixed
Total of stand at volume (m^3 ha^{-1})	272	278
Harvesting method	Selective felling	Selective felling
Harvesting intensity (% stand volume)	14.7	32.5
Number of harvested trees	80	153
Dimension of extracted wood (m^3)	0.2–0.35 (sawn wood)	1.2–6.8 (saw log)
Average harvested dbh (cm)	71	65
Average slope of terrain (%)	52.2	23.1
Average skid trail distance (m)	1575	697
Average slope of skid trail (%)	27.0	14.4
Transport distance from landing I to landing II (km)	14	15
Transport distance from landing II to sawmill (km)	400	120

dbh = Diameter at breast height; FWSC = forest wood supply chain

remaining tree and soil as well as to avoid potential accidents.

The transport distance between landing I and II in FWSC1 was 14 km. The road was steep and rough and was not accessible to big trucks. At landing I in FWSC1, the sawn wood was loaded by men into 3-ton trucks and then transported to landing II. After that, the sawn wood was unloaded by men. In FWSC2, the transport distance from landing I to II

Table 2 Summary of labour and equipment information in each process of FWSC1 and FWSC2

Process	Labour and equipment used in each process	
	FWSC1	FWSC2
Planning	Five technicians	Five technicians
Field preparation	No	Eight workers
Skid trail and landing preparation	Eight workers	One bulldozer + two operators + twelve workers
Felling, cross-cutting, sawing	Two chain saws + four operators	One chain saw + two operators
Extracting	Eight buffaloes + five drivers	One crawler tractor + three operators
Post-harvest hygiene	No	One chain saw + two operators + fifteen workers
Loading at landing I	Five workers	One 9-ton truck with winch + three drivers (1 ton = 1000 kg)
Transport to landing II	Two 3-ton trucks + two drivers; 14 km	One 9-ton truck + three drivers; 15 km
Unloading at landing II	Four workers	One 9-ton truck with winch + three drivers
Loading at landing II	Eight workers	One 7.5-ton crane truck + two drivers
Transport to mill	One 15-ton truck + two drivers; 400 km	One 8.5-ton truck + two drivers; 120 km
Unloading at mill	Six workers	One 7.5-ton crane truck + two drivers
Sawing at mill	No	One band saw + three workers

FWSC = forest wood supply chain

was 15 km. The road was asphalted and the permittable load transported could be up to 20 tons. Therefore, a 9-ton truck was used for transporting saw logs to landing II. At landing I, saw logs were loaded using a winch mounted on the truck, then transported to landing II where they were unloaded by the same winch.

In FWSC1, most of the sawn wood at landing II was sold to a customer in Hai Phong located 400 km away from Van Ban. The sawn wood was transported to this sawmill by a 15-ton truck. In FWSC2, logs were sold at landing II to a regional customer. Saw logs were loaded by crane truck and then transported by an 8.5-ton truck to a sawmill 120 km away. At the mill, saw logs were also unloaded by the crane truck.

The wood transported to the customer in FWSC1 was sawn board wood. In FWSC2, the product for sawmill was saw log. In order to be able to compare the two FWSCs under equal condition, FWSC2 included the sawing process at sawmill where saw logs were sawn into sawn wood.

Indicators and method of data collection and calculation

In order to assess sustainability impact, sustainability indicators need to be selected. Sustainability indicators need to cover economic, social and environmental dimensions (EFORWOOD 2006). The key criterion for selecting indicators is their ability to capture impacts of the FWSCs on sustainability. In this study, three sustainability indicators were selected (Table 3).

Production cost of the whole chain is calculated by totalling the production cost of each process. Production cost of each process includes all costs accrued from machine or animal, labour, administration and tax. The machine cost (or animal cost) includes fixed cost (interest, depreciation, insurance) and variable cost (fuel and lubricant oil, maintenance and repair, parts). Production cost in this study was calculated for 1 m^3 sawn wood (sw) with unit cost as €/m^3_{sw}. In 2010 December, 1 Euro was equivalent to about 28,000 VN Dong.

Occupational accident is an accident at work that is a discrete occurrence in the course of work which leads to physical or mental harm (EUROSTAT 2008). This indicator reflects the working conditions of employees as well as occupational safety training and safety protection equipment. There are two types of occupational accidents: fatal and non-fatal accidents. Fatal occupational injury is defined as an occupational injury leading to death within 1 year from the day of the occupational accident (ILO 1998). Non-fatal occupational accident is defined as the absence of work for more than three working days (EFORWOOD 2006). In Vietnam, the data of occupational accidents in forest activities were not recorded by any agency. Therefore, no data were available. In order to obtain data for calculating this indicator, the workers of each activity were directly interviewed about accidents occurring between 2008 and 2010. The indicator was calculated based on the total number of accidents and the total volume of saw logs (sl) harvested between 2008 and 2010 in unit of cases/10^{-4} m^3_{sl}.

Logging often leads to soil disturbance that may cause soil erosion or compaction (Rice et al. 1972). The rate of this negative impact is closely correlated with vegetative cover, especially litter on the soil surface, depending on the level of disturbance. According to Murphy (1982), classification of soil disturbance is divided into five levels: undisturbed (DC0), litter layer disturbed (DC1), top soil exposed (DC2), subsoil exposed (DC3) and subsoil exposed and compacted or puddled (DC4).

In this paper, the soil disturbance is divided into three levels as follows:

(1) Low, i.e. disturbed area where the forest floor is disrupted, litter or slash disturbed but top soil not exposed. This treatment is equivalent to DC1 under the classification system described by Murphy (1982).

(2) Moderate, i.e. disturbed area where mineral soil is exposed and removed to a depth of 5 cm. This level is equivalent to above DC2.

(3) Heavy, i.e. disturbed area where mineral soil is removed to a depth greater than 5 cm and the subsoil is probably exposed. This level is equivalent to DC3 and DC4 combined.

The data were collected by direct field investigation and indicators were calculated in m^2 ha^{-1}.

RESULTS AND DISCUSSION

Production cost

Figure 2 shows that the total cost of FWSC1 to the mill (cost of transport to landing II and to the mill calculated for 10 km) is 50.83 €/m^3_{sw}.

Table 3 The sustainability indicators used for assessment

Indicator	Unit	Data collection	Data calculation
Economy: production cost	€/m^3_{sw}	Field investigation:	
Society: occupational accident	cases/10^{-4} m^3_{sw} (2008–2010)	Time study Observing Interview	Microsoft Excel 2003 and Umberto 5.5
Environment: disturbed area	m^2 ha^{-1}	Some from literature	

SW = Sawn wood

A total 40.9% of the cost was spent on skidding to landing I, 28.1% on felling, cross-cutting, sawing and 31% on other activities. The cost of transport to landing II was 3.90 €/m^3_{sw} per 10 km. Transport to the mill cost only 0.89 €/m^3_{sw} per 10 km. In FWSC 2, total cost to the mill was 35.73 €/m^3_{sw}. The costs of pre-harvesting and post-harvesting were highest, accounting for 32.9 and 15.6% of the total. Felling, extracting and sawing at the mill cost only 2.25, 3.84 and 2.86 €/m^3_{sw} respectively. The cost of transport to landing II was 0.89 €/m^3_{sw} per 10 km while that to the mill was higher with 1.30 €/m^3_{sw} per 10 km.

Total cost of felling, cross-cutting and sawing at the mill for FWSC2 was 5.11 €/m^3_{sw} while that for FWSC1 was 14.29 €/m^3_{sw}. Using tractor for extracting saw log to landing I had reduced the cost of sawing and extracting in FWSC2. That was the main reason why the total cost of FWSC2 was much lower although its pre-harvesting and post-harvesting costs were higher than those of FWSC1. For transport, the biggest truck (loaded 40 m^3_{sw} while only 15 tons permitted) transporting sawn wood to saw mill in FWSC1 had lowest cost, only 0.60 €/m^3_{sw} per 10 km while the smallest truck (loaded 5.1 m^3_{sw} while 3 tons permitted) in FWSC1 transporting sawn wood to landing II had highest cost of 3.90 €/m^3_{sw} per 10 km. The bigger truck in FWSC2 also had lower cost of transportation.

Occupational accidents

Figure 3 shows that most of the accidents in both case studies happen during harvesting, loading and unloading. The total rates of non-fatal accident (NFA) and fatal accident (FA) in FWSC1 which used more manpower were 6.42×10^{-4} and 0.92×10^{-4} cases/m^3_{sl} respectively. In FWSC2, due to higher mechanisation, the rates of NFA and FA were lower with 2.94×10^{-4} and 0.59×10^{-4} cases/m^3_{sl} respectively. In both FWSCs, activities of harvesting including felling, cross-cutting, sawing and extracting were the most dangerous work with highest rate of accident. All employees in both chains lacked safety equipment and had not been trained in occupational safety. The tractor and truck used for transporting to landing II in FWSC2 was too old and did not have any operator protection. In both case studies, there were no accidents occurring during transport activity. However, generally accidents are common in timber transport in Vietnam.

Disturbed areas

Figure 4 shows that low, moderate and heavy disturbed areas in FWSC1 accounted for 3.7, 3.4 and 3.4% of total area respectively. In FWSC2, the low, moderate and heavy disturbed areas took 3.8, 2.7 and 6.2% of the total area respectively.

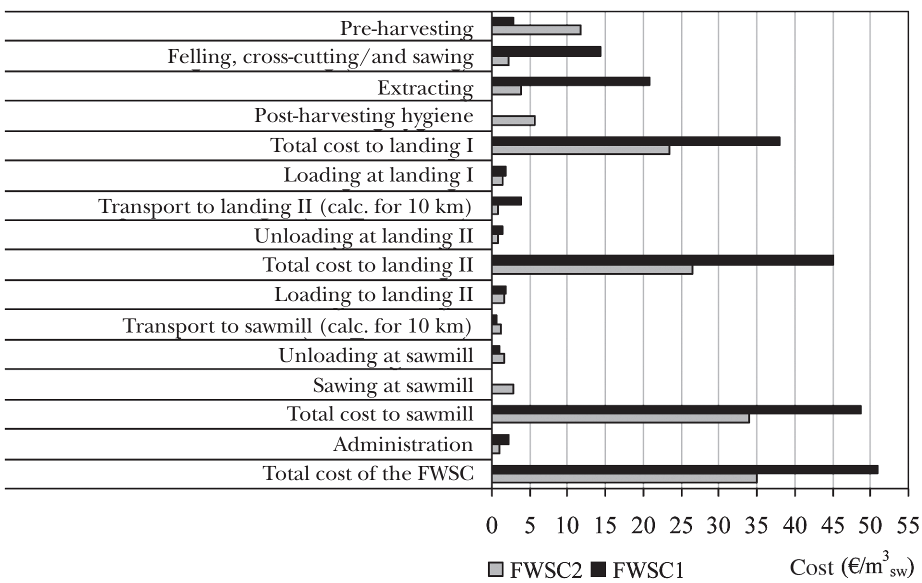

Figure 2 Production costs of activities in FWSC1 and FWSC2; FWSC = forest wood supply chain; sw = sawn wood

The heavy disturbed areas caused by FWSC2 was 80% larger than FWSC1 while moderate disturbed areas was 20% smaller and low disturbed areas was nearly the same as FWSC1. Most of the disturbed areas in both FWSCs were caused by skid trails and were mainly heavy disturbed areas. The use of tractor for extracting round wood to landing I caused FWSC2 to have more negative impact on soil than FWSC1, which used mainly animal and manpower.

CONCLUSIONS

In FWSC1, due to steep and difficult terrain of the harvesting area which was located far from the existing road, together with low harvested volume per hectare, opening of road or skid trail would be costly and not economic. Thus, a low mechanisation (labour intensive) method using buffaloes for extracting sawn wood over a long distance to landing I and manpower for loading and unloading was employed. On the contrary, in FWSC2, the slope of the harvesting area was gentler, a transport road system existed near the harvesting area and a larger volume per hectare was harvested. All these factors were suitable for mechanisation. Therefore, a higher mechanisation method using tractor for extracting saw logs over a short distance to landing I and using crane truck for loading and unloading was applied.

Sustainability impact assessment result showed that there were significant differences in economic, social and environmental impacts between FWSC1 and FWSC2. FWSC2 had more positive impacts on the economic aspect with lower production cost. However, with regard to the problem of health and occupational accidents, fewer people in FWSC2 led to lower rate of occupational accidents. With regard to environment, felling at a higher intensity together with using tractor for skidding saw logs to landing I, FWSC2 caused larger disturbed areas.

SUGGESTIONS

In order to increase the sustainability of wood supply from natural forest to sawmill in Vietnam, these suggestions should be considered.

(1) When felling at places where tractors or other log extracting equipment could have access, the use of mechanisation should be considered. Mechanisation will be costly at first, but in a long run it may offer economic and social benefits. A study for determining the level of mechanisation as well as selecting appropriate machines and equipment for

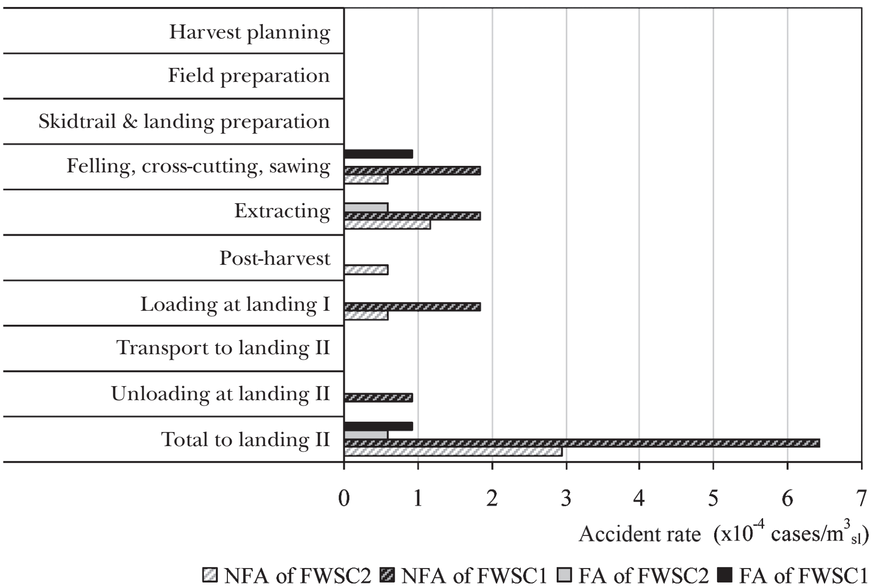

Figure 3 Occupational accidents in FWS1 and FWSC2 between 2008 and 2010; NFA = non-fatal accident, FA = fatal accident; FWSC = forest world supply chain; sl = saw log

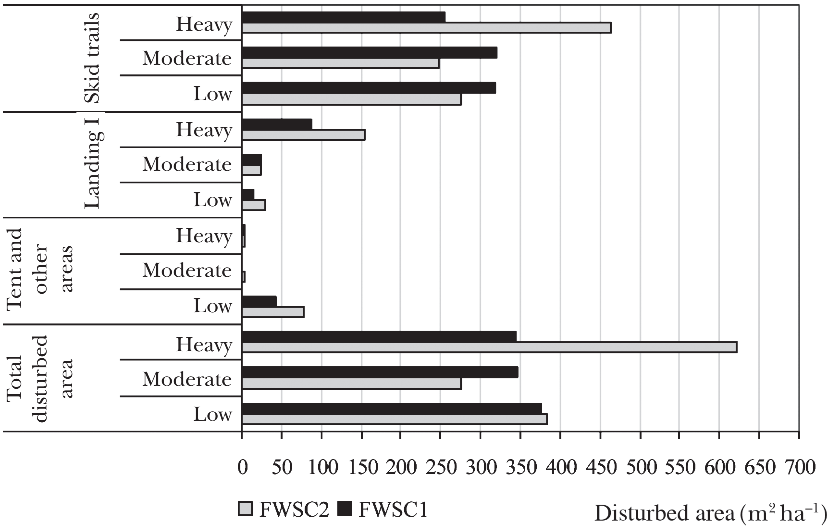

Figure 4 Soil disturbances caused by logging activities in FWSC1 and FWSC2; FWSC = forest wood supply chain

different cases should be considered. In this case the operational planning for harvesting should be improved to limit soil disturbance.
(2) On steep terrain inaccessible to tractors and other equipment, animals are used for skidding. However, trees harvested in natural forest in Vietnam usually have a large diameter at breast height. Therefore, after felling and cross-cut, logs need to be sawn into small sawn wood at stump areas small enough so that animals are able to skid them to landing I. In this case, the chain saw operators should be better trained to know how to cross-cut and saw sawn wood to obtain the highest recovery and higher productivity to reduce production cost. The improvement of chain saws or the use of mobile band saws for sawing sawn wood at stump areas should be considered. Loading and unloading of sawn wood at landings should also be mechanised to reduce the number of employees involved in this dangerous and hard work.
(3) Training courses on occupational safety should be conducted to protect employees and reduce accidents. All machines in use must have complete safety equipment.
(4) Skid trails and landings should be carefully pre-planned to reduce disturbed areas. After felling and extracting, skid trails and landings must be planted and covered with small wood waste to prevent soil erosion.
(5) In FWSC1, after harvesting, post-harvesting hygiene activities should be carried out to remove potential danger such as hanging dead branches and twigs. In addition, all remaining residues of wood should be cut into smaller pieces to cover the ground, especially in disturbed areas. Post-harvesting inspection should be fully and strictly implemented to make sure that harvesting activities are done correctly.

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