Development of forest machinery and labour in the EU in 2010-2030

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Abstract:
The demand of woody biomass both for industrial and energy use in the EU is estimated to increase markedly in the coming decades to satisfy the material and energy supply of bio-based economy. Moving towards more mechanized harvesting technology induces needs to invest in harvesting machinery, which may decrease the labour input/harvested volume ratio. The impacts of increasing harvesting volumes on machinery needs and labour inputs were estimated in this study at the EU level. In addition, the development trends in technology as well as requirements posed to machine operators were outlined based on recent and ongoing research. The study used the biomass demand estimates of three scenarios generated in the Euwood.. The typical harvesting systems for energy wood were selected on the basis of an expert opinion survey conducted within the Forest Energy COST action.
The procurement of the estimated timber removed in 2010 in EU, would have required 60 000 workers assuming the work was carried out with highly mechanized harvesting. To extract the total biomass potential (timber and other biomass components) from the low mobilization scenario in 2030 would require ca. 90 000 workers, whereas the medium and high mobilization scenarios would require 110 000 workers and 150 000 workers, respectively. This means a massive increase of labour input of the woody biomass supply. In fact real figures would be higher as fully mechanized operations and availability of skilled labour were assumed here.
A vast number of machines will be needed to procure the biomass potentials. For the medium mobilization scenario 21 600 forwarders, 18 600 harvesters, 17 200 timber trucks and 10 000 chip trucks, 7 200 chippers or crushers, and 600 excavators would be necessary. In energy wood harvesting the dominating system utilized in energy wood harvesting (logging residues, small diameter trees) used forwarder in the extraction of wood from the forest in most countries. Chipping was done at the road side and chips were transported by chip trucks to the end use. Also other systems (e.g. bundling of logging residues or supply of loose residues and crushing at the plant) are used, but their share is considerably smaller in most countries and therefore the dominant system was considered here.
The research and development work of biomass harvesting is focusing in the enhanced use of manpower by using operator supporting systems tutoring the operator in work and work cycle planning and giving feedback about his work.

Keywords: wood harvesting, harvesting machinery, labour

1 Introduction

1.1 Mobilization of forest biomass needs machinery and manpower

The EU's forest resources form an important source of renewable raw materials for products and energy generation. In 2005 about 382 million m^3 over bark was removed from forests in the 27 European Union (EU) member states as industrial roundwood and 98 million m^3 over bark as wood fuel (FAO, 2010). However, this is probably still an underestimation of the actual wood removals (Mantau et al., 2008). The demand for wood by forest industries has been estimated to increase by 15–35% in 2030 compared to 2010 (Mantau et al., 2010). At the same time, forests are becoming increasingly important for supplying wood for renewable energy production, given the targets by the European Commission (EC) to raise the share from renewable energy in energy consumption to 20% by 2020 in the EU (Directive 2009/28/EC). Forests are considered an important resource to meet these renewable energy targets, because several studies have shown that about 200 million m^3 more woody biomass could be used for direct energy generation and because the growth of forests is significantly higher than their current utilization (Asikainen et al. 2008).

The major part of forest operations in the EU are done by small private forest machine entrepreneurs employing one or a few machine chains. The share of mechanization in cutting operations has been steadily increasing in Eastern and Central Europe and is close to 100% in the Nordic countries and in the UK and in Ireland (Asikainen et al. 2009). The labour costs in the EU member countries has reached the level, where full mechanization of the harvesting and transport system has become competitive in practically all countries particularly in the harvesting of conifers. Several studies also suggest, that profitable forest energy harvesting also calls for full mechanization of the logging operations (Hakkila 2004). As a result, the investment need for the machinery has increased rapidly and financing of investments together with reliable long term contracts have become bottlenecks in the development and modernization of the European forest machinery.

The need of manpower has been decreasing as the use of machines becomes more common. This has partially solved problem of poor availability of forest workers. On the other hand the complexity of modern forest machines calls for long training before the man-machine unit reaches its full productivity. In addition, the differences between machine operators in productivity have been found to be large (Väätäinen et al. 2005, Ovaskainen 2009).

1.2 Objectives

The objective of this study was to estimate the development of the harvesting and transport fleet in the EU by 2030. The numbers of machines needed to mobilize the available biomass in the EU's forests for industrial and energy use is estimated. In addition, the number of machine operators was estimated and technological means to reduce labour are introduced. The research and development needs of forest machinery are summarized based on recently published research articles.

2 Material and Methods

The annual harvesting volumes were based on the estimates of the potential supply of woody biomass for all uses from the forests in the 27 EU member states using the most recent National Forest Inventory (NFI) data and consider multiple environmental, technical and social constraints (Verkerk et al. 2011). This study uses the results of Verkerk et al. (2011) who estimated the potential supply of woody biomass for the period from 2010 to 2030 for stemwood, residues, stumps and woody biomass from early or energy thinnings in young forests. First, the theoretical potential was defined as the overall, maximum amount of forest biomass that could be harvested annually within fundamental bio-physical limits taking into account increment, the age-structure and stocking level of the forests. Second, multiple environmental, technical, and social constraints were defined and quantified that reduce the amount of biomass that can be extracted from forests for three future mobilization scenarios. Finally, the theoretical potentials were combined with the constraints from the mobilization scenarios.

The machinery needed in the harvesting and transportation of industrial wood and energy wood was estimated using the annual capacities of machines based on estimates on the realistic employment of the machines year around. The annual harvestable volumes of energy biomass components together with roundwood harvest were based the estimates presented by Verker et al. (2011). Subsequently, the potentials were divided by the annual outputs of each machine type, which resulted in the number of machines. The used annual outputs of forest machines and trucks by materials are presented in Table 1.

For the machine need calculations typical European supply chains were selected. The supply chain for timber harvesting consists of a harvester, a forwarder and a timber truck (Figure 1). Stumps are extracted with an excavator and small diameter trees for energy with a harvester equipped with an energy wood harvesting head. All energy assortments are forwarded to the roadside and chipped/crushed there (Diaz 2010). This approach was used also for stumps because of practical reasons despite the fact that largest share of stumps is crushed either in terminals or at plants (Diaz 2010). Timber is transported to the mills with timber trucks (60 tonne truck for Finland and Sweden, and 42 tonne truck for rest of the EU. For chip trucks similar weigh assumptions were made.

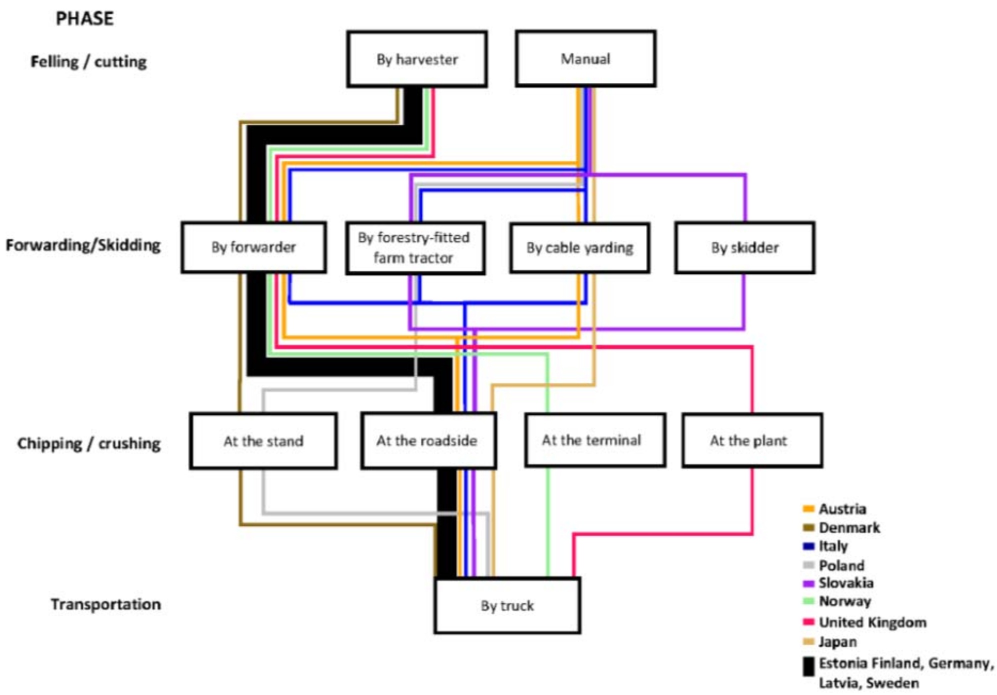

Figure 1: Procurement chain for logging residues from final fellings (Diaz 2010).

The investigation of research and development needs of forest machinery was based on research findings of Efftech research programme and on the literature review of contemporary future foresigths of forest machinery development needs and trends (Asikainen et al. 2011, Laitila et al. 2010, Diaz 2010, Riala 2011).

Table 1: Annual capacities of machines, m^3/a.

	Timber	Energy Stemwood	Energy Residues	Energy Stumps	Energy Early Thinning
Harvester	35 000	35 000			10 000
Excavator				17 000	
Forwarder	35 000	35 000	30 000	30 000	30 000
Chipper		30000	30 000	30 000	30 000
Truck	30 000	30 000	18 000	18 000	18 000

3 Results

3.1 Demand of forest machinery and labour in the EU

The annual potential harvest volumes from EU's forests are presented in the Figure 2. The 2010 situation consists of *estimated* roundwood harvesting and *potential* energy wood volumes that could be removed from the EU's forests according to existing national guidelines for forest energy biomass harvesting. It has to be noted that *actual* energy wood harvesting is significantly lower being less than 50 million m^3 annually.

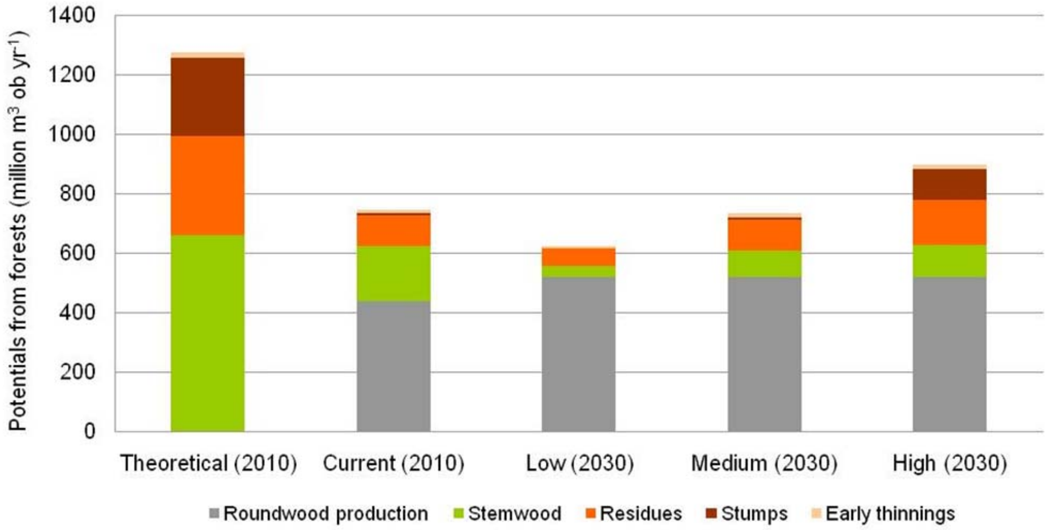

Figure 2: Annual estimated mobilization in the EU countries in 2010 and three scenarios for 2030 using industrial roundwood and energy wood (stemwood, residues, stumps and early thinning components for energy) . Adapted from Verkerk et al. (2011).

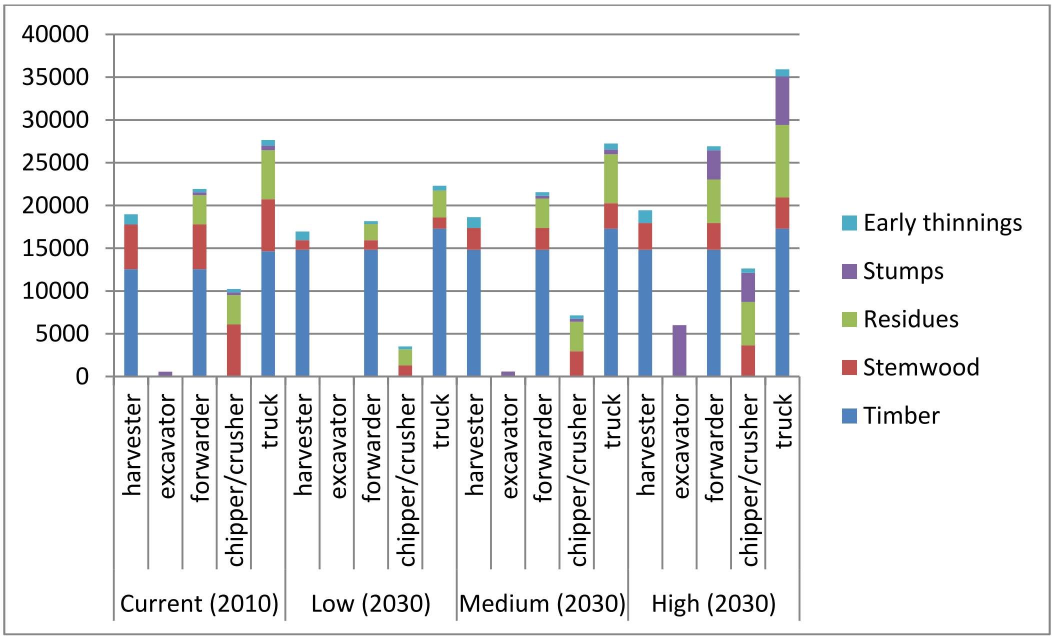

Figure 3: Number of machine units needed in the supply of industrial and energy wood, if the forest biomass potential is mobilized.

The number of machine units needed to mobilize the EU's biomass resources in 2010 and in 2030 according to three mobilization scenarios are presented in Figure 3. The background calculation assumed that the volume of the timber harvesting in all scenarios is constant and that only the energy wood varies. Therefore, the changes in machine numbers are caused by the different mobilization of energy wood assortments. In the low mobilization scenario excavators are not present due to the fact that stump harvest has been prohibited because of strict environmental restrictions. The medium scenario is close to the current techno-ecological potential and finally, the high scenario represents the highest demand of machinery induced by high demand of energy biomass and less restrictive environmental and social constraints. The total numbers of machine and transport units needed by 2030 in the low, medium and high scenarios are 60 929, 75 162 and 100 931, respectively. The corresponding numbers of operators to run the whole harvesting and transport fleet are 91 393, 112 742 and 151 397 assuming 1.5 operators per machine unit.

3.2 Forest machine development needs

The most recent research on the forest machines development needs focuses on forest energy harvesting. This is natural, because compared with well established roundwood harvesting systems the forest energy machinery and the whole supply chain is still under development. In Finland, the high cost of cutting, skills of operator and availability of skilled labour were found the main challenges in the small diameter energy wood harvesting (Laitila et al. 2010). In general, harvesting technology of small diameter trees was estimated to have more development potential than those of logging residues and stumps. The fuel quality issues related to the use of stumps and logging residues were considered to be problematic.

The improvement of the forest machines ability to sense soil properties and to estimate the soil bearing capacity based on CAN BUS data on the wheel moving resistance and direct sonar measurements is under intensive development. Particularly on the sensitive organic soils reliable estimates on the traffic ability of a certain part of the forwarding trail network enable the planning of forwarding and adjustment of load weights optimally (Lamminen et al. 2010, Asikainen et al. 2011). Researchers believe that a technological leap can be achieved in the driving and maneuvering of forest machines through the innovative fusion of data collected by forest machines, machine perception (i.e. machine vision and laser scanners) and ground sensors. These data are integrated and interpreted into meaningful feedback and guidance for the machine operator, enabling the operator to improve his performance to match the machine's capabilities (Asikainen et al. 2011). In addition, tree mapping data measured during cutting using SLAM (Simultaneous (machine) Localization and (tree) Mapping principles could be used in the updating and quality monitoring of stand databases for future stand management purposes. A radical innovation is to apply the latest findings and solutions of machine and AI-assisted feedback, advising and tutoring of pilots/operators of moving machines such as military and aviation equipment to the forest operations environment. Modern forest machines provide an excellent platform for studying and developing this concept (Asikainen et al. 2011).

In a European survey of mainly forest engineering experts the development focus of novel tutoring software and systems for the machine operators was sought. Results suggest that the planning of both felling operation and forwarding are work phases, where the benefit of a 'virtual operator assistant' would be greatest (Riala 2011). Results of the survey are presented in Figure 4.

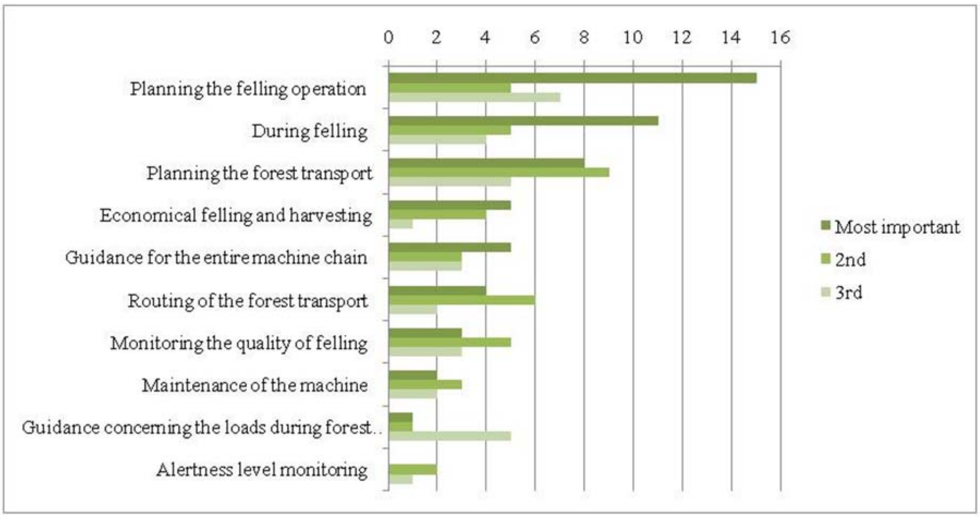

Figure 4: Focus of the 'virtual operator assistant' development (Riala 2011).

4 Discussion

The harvesting and transport fleet needs to grow considerably if the European Union aims to mobilize its industrial and energy wood potentials. Results presented here do not express the number of machines needed to fulfill the production volumes. They can be interpreted as machine work input that is needed, when the machines work close to their realistic capacities and all wood harvesting work in the EU would be mechanized. By 2030 it can be estimated that mechanization degrees in forest operations will be close to their theoretical maximums. This, in return, will resul in a decrease of manual labour and increased demand of skilled forest machine operators.

It also has to be noted that in the machine demand calculations only the dominant supply chains were modeled. It is a fact that tree length method and associated machinery (feller-bunchers, delimbing machines and skidders) together with cable yarding units will be employed. However, the dominance of the cut to length method and mechanization of wood harvesting will proceed in the EU (Asikainen et al 2008). Particularly in energy wood harvesting a plethora of machines and methods will be applied and the harvesting of industrial and energy wood is often integrated (Laitila et al. 2010). To get a more detailed picture on the harvesting fleet developments a country by country survey would be needed.

Machine development needs differ between raw materials. Novel and more complex harvesting methods call for pure mechanical technology development. To use expensive machines efficiently, emerging virtual operator assistants call for intensive development focusing especially in the planning phases of the work and work cycles.

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