



Bioenergy from forest thinning: Carbon emissions, energy balances and cost analyses

Robert B. Mangoyana

Mid Sweden University, Department of Engineering and Sustainable Development, Ecotechnology, SE-831 25 Östersund, Sweden

ARTICLE INFO

Article history:

Received 30 June 2010

Accepted 23 January 2011

Available online 17 February 2011

Keywords:

Energy balances

Carbon emissions

Costs

Forest thinning

Harwarder system

Two machines system

ABSTRACT

The growing demand for bioenergy in Sweden has drawn attention to the potential of forest thinning as bioenergy feedstock. There are, however, concerns regarding the cost effectiveness and environmental challenges of harvesting and processing forest thinnings into bioenergy. It is against this background that cost, energy and carbon balances were analysed to evaluate some of the economic and environmental sustainability issues of forest thinning based bioenergy systems. Primary data was collected from two thinning operations in two forest plots comprising spruce and birch stands. One operation involved the use of the conventional two machines (one separate machine for cutting or felling and another for forwarding felled trees) for the thinning work. The second operation involved a harwarder, which combines tree felling/cutting and forwarding in one unit machine. The results showed that forest thinnings provide a potential resource for the sustainable production of bioenergy.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction and background

Energy derived from biomass sources could play an important role in reducing emissions of greenhouse gases and providing an alternative source of energy in Sweden and elsewhere. In Sweden bioenergy share has been growing at an increasing rate over the years owing to increasing demand of bioenergy in the construction, district heating, electricity generation and the transport sector [1]. The bio-based final energy use share grew from 9% in 1970 to 27% in 2006 [2]. This growth has been attributed to the bioenergy promotional instruments being implemented in Sweden. The dominating instruments include market support (e.g. national authorities spearheading use of flex fuel vehicles), green certificates, carbon trading, heavy carbon taxes, subsidies on clean energy development and climate change investment programmes [3,4].

The growing demand for biomass based energy sources and the need to replace more fossil fuels have prompted increasing search for more sources of bioenergy feedstock. One source gaining increasing attention is forest thinnings. Commercial thinning for bioenergy use, like in commercial logging of fully grown trees, involves felling trees (removal of trees growing too close to each other); forwarding felled trees (primary/in-stand transportation); chipping (or any other thinned materials handling method); transportation to processing facility; and processing into biofuel often in the form of wood chips [5]. A number of questions have,

E-mail address: mangoyanar@yahoo.com.

however, been asked regarding the potential of forest thinnings to provide an efficient low cost and environmentally friendly bio-energy system. The economic and environmental performance of forest thinnings based bioenergy system could be determined by a number of factors including the thinning technology, stem volume, bucking, stand density, removal per site, handling unit, forwarding distances, terrain, load capacity, machine operator skills and work environment among other determinants [6–8].

1.1. Factors influencing thinning efficiency and effectiveness

Traditionally, thinning has been conducted by two machines, one for felling and another for forwarding felled trees to the roadside for processing and/or transportation to processing industries. However single multifunctional machines have been developed to reduce the number of machines in stands (per given working time) to reduce environmental challenges caused by movement of machines in forest stands and thinning costs, and therefore improve machine productivity [9,10]. Other advantages of multifunction machines have been reported to include reduced cost per volume of harvested materials and improved machine productivity when compared to the conventional harvesting equipment [11]. These advantages are largely attributed to time savings due to combining other separate work activities in the two machine systems. On the other hand it has been argued that multifunction machines may be less efficient by not maximising the use of components as opposed to single function machines [5].

A number of time studies have been conducted in deterministic models to establish the relationship of thinning effectiveness and efficiency factors focussing on commercial viability, yield, stand density, machine concept and forwarding distances. For example Talbort et al. [8] evaluated the productivity of harwarders (combined harvesting and forwarding machine) under different forwarding distances and stand densities; and concluded that harwarders are best suited for removals of less than 100 m³/stand with long forwarding distances of more than 500 m. However, a similar study by Kärhä [10] differed on the forwarding distance by suggesting that harwarders would be more effective in forwarding distances of less than 150 m suggesting better harwarder productivity under short distances. Studies comparing the economic efficiency of two machine systems and harwarders have shown that two machine systems are more viable as compared to multifunctional machines when forwarding distances are short and in high density stands [5,12]. Therefore stand density also plays a pivotal role in determining the overall performance of different machines.

Specifics of handling units are also important factors regarding efficiency and effectiveness of a thinning system. Bergström et al. [6] concluded that the selection of handling units for corridor areas that harvest in “same crane movement cycles” as opposed to single tree handling units are key to reducing harvesting costs. The availability of midfield or skid roads was also seen to have an influence on a handling unit and hence the overall machine performance.

Thinning selection method within a handling unit can also influence machine effectiveness and efficiency results. For example, Yeo and Stewart [13] compared an operator selection system and prior tree marking system. Machine operator selection has been observed to save time and hence less costly as compared to selective thinning. This outcome, however, largely depends on the experience and skills of machine operators.

The machine productivity as determined by forwarding distances, terrain, tree density and the consequent energy yield has interesting bearings regarding the greenhouse gas emissions reduction potential

of forest thinning systems. Eriksson and Gustavsson [14,15], for example, estimated a significant displacement of CO₂ emissions from different forest fuel harvesting systems.

Responding to some of the issues discussed above and the need to find more sources of bioenergy, this study aims to assess the potential economic and environmental sustainability of forest thinning based bioenergy systems by comparing two different thinning systems. Carbon emissions, energy balances and thinning costs were used as indicators to determine environmental and economic performance of the system. Of note, however, is that any thinning regime has a number of silvicultural, environmental and social impacts not represented by the system performance indicators mentioned above. These issues are not covered in this paper. The major novelty of this study is the use of primary data to provide an assessment of the potential sustainability of bioenergy derived from forest thinnings.

2. Method and data

The study was conducted on two plots of 10 ha (ha) each. Two different machines, the harwarder and the conventional two machine technology, were used to thin (low thinning) each plot. Machine operators (through their representative companies) were selected based on their vast experience in forestry harvesting and management activities. The use of two different machines for the thinning operation was motivated by the literature suggesting that different machine concepts provide different opportunities and limitations to ensuring a cost effective, positive energy balance and low emissions thinning system. Each plot is therefore considered as a thinning system defined by the type of machine used for thinning. Accordingly, the two systems are referred to as the two machine system and harwarder system in this paper. The harwarder system used Timberjack 810 B with a Nisula 280E head which combined forest thinning and forwarding of thinned materials to the roadside. The two machine system used Valmet 911 with a Bracke C16.a head as a thinner and Timberjack 1710 for forwarding.

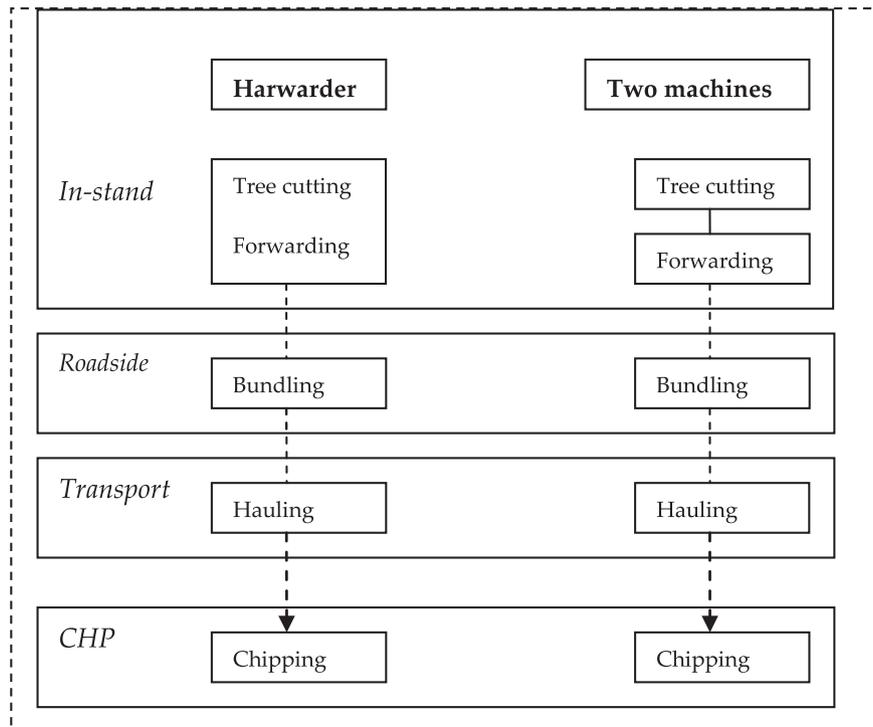


Fig. 1. Harwarder and two machine thinning systems.

متن کامل مقاله

دریافت فوری ←

ISIArticles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات