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Comparative analysis of harvesting machines on an operational high-density short rotation woody crop (SRWC) culture: One-process versus two-process harvest operation☆

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ABSTRACT

Short rotation woody crops (SRWCs) are being studied and cultivated because of their potential for bioenergy production. The harvest operation represents the highest input cost for these short rotation woody crops. We evaluated three different harvesting machines representing two harvesting systems at one operational large-scale SRWC plantation. On average, 8 ton ha^{-1} of biomass was harvested. The cut-and-chip harvesters were faster than the whole stem harvester; and the self-propelled harvester was faster than the tractor-pulled. Harvesting costs differed among the harvesting machines used and ranged from 388 € ha^{-1} to 541 € ha^{-1}. The realized stem cutting heights were 15.46 cm and 16.00 cm for the tractor-pulled stem harvester and the self-propelled cut-and-chip harvester respectively, although a cutting height of 10 cm was requested in advance. From the potential harvestable biomass, only 77.4% was harvested by the self-propelled cut-and-chip harvester, while 94.5% was harvested by the tractor-pulled stem harvester. An increase of the machinery use efficiency (i.e. harvest losses, cost) is necessary to reduce costs and increase the competitiveness of biomass with other energy sources.

1. Introduction

Within the framework of the production of bioenergy from fast-growing trees, various aspects have already been studied and documented over the past decennia: importance of species and genotypes to be used [1,2]; impact of coppicing in short rotation cultures [3,4]; length of (coppice) rotation cycle [5,6]; interaction between soil type and genotype [7]. Theoretical studies and practical field experiments have led to the introduction of bioenergy plantations in several regions of the world. To bring the concept of the culture of bioenergy from the experimental to the commercial scale, efforts have been

Abbreviations: SRWC, short rotation woody crop; NRB, not recovered biomass; UB, uncut biomass.

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made toward a further mechanization of the culture: mechanical planting, weed management [8], nutrient and herbicide applications, irrigation [9,10] and harvesting [11,12]. For most of the management operations existing agricultural techniques have been modified and applied. In a short rotation biomass culture agricultural management approaches are being applied to woody crops. Since the main difference between agricultural crops and woody biomass crops is in the harvest of the crop, progress on the mechanization of the harvesting process has been slow thus far [4,13].

Although different harvesting machines have already been developed, mainly two different harvesting approaches have been developed for short rotation woody crops (SRWCs), i.e. the harvest-and-chip system [14] and the harvest-and-storage system [15] (Fig. 1). The harvest-and-chip system can be performed with a self-propelled cut-and-chip front harvester or with a tractor-pulled cut-and-chip side harvester. In most cases the self-propelled cut-and-chip front harvester is a converted corn harvester with a specific coppice header for SRWCs. In both cases chips are produced from wet stems, collected in an attached trailer or an additional tractor–trailer combination, and stored as wet chips. The storage of wet chips implicates a risk of dry matter losses, and further drying might be necessary. In the harvest-and-storage system, wet stems are cut, transported to a storage location to dry, and chipped afterwards to obtain dry chips. The storage of cut stems, also called 'rods', avoids the problems with wet chips. The expected productivity is 35.6 Mg of fresh biomass per scheduled machine hour for the self-propelled cut-and-chip front harvester, and 19 Mg for the harvest-and-storage system, but with similar operational costs [14,15]. The lower the moisture content of the obtained chips, higher calorific values for energy conversion. An overview of additional advantages and disadvantages of each system can be found in earlier studies [14,15].

Machinery costs represent the highest input costs for biomass production (Silveira [33] cited in Hannum [12]). Consequently, harvesting costs make up a large share of the total costs of biomass produced from SRWCs and might amount up to 45% of the total cultivation costs [24]. This is due to the fact that harvesting is mostly subcontracted by the farmer, as a harvesting machine is excessively expensive to be owned and used by a single farmer. Typical harvest rates (excluding transportation costs) charged by Belgian and Danish subcontractors range from 400 € ha^{-1} for a tractor-pulled stem harvester, over 600 € ha^{-1} for a tractor-pulled cut-and-chip harvester to 950 € ha^{-1} for a self-propelled cut-and-chip harvester [24].

The present study extends previous analysis by: (i) evaluating three different harvesting machines representing two harvesting systems at the same plantation; (ii) assessing the efficiency and performance of these harvesters on a field plantation at an operational scale; and (iii) discussing the economic potential, advantages and disadvantages of the different harvesters and harvesting systems.

We have been operating and intensively monitoring an operational bioenergy plantation with fast-growing poplar and willow trees in Flanders, Belgium (see http://webh01.ua.ac.be/popfull) since three years. The plantation was harvested after the first two-year rotation cycle. In this paper we compare and report on the performance of the three harvesting machines that were used to harvest this large-scale SRWC plantation.

2. Materials and methods

2.1. Description of the site

The field site is located in Lochristi, Belgium (51°06'N, 03°51'E) and consists of a high-density poplar and willow plantation

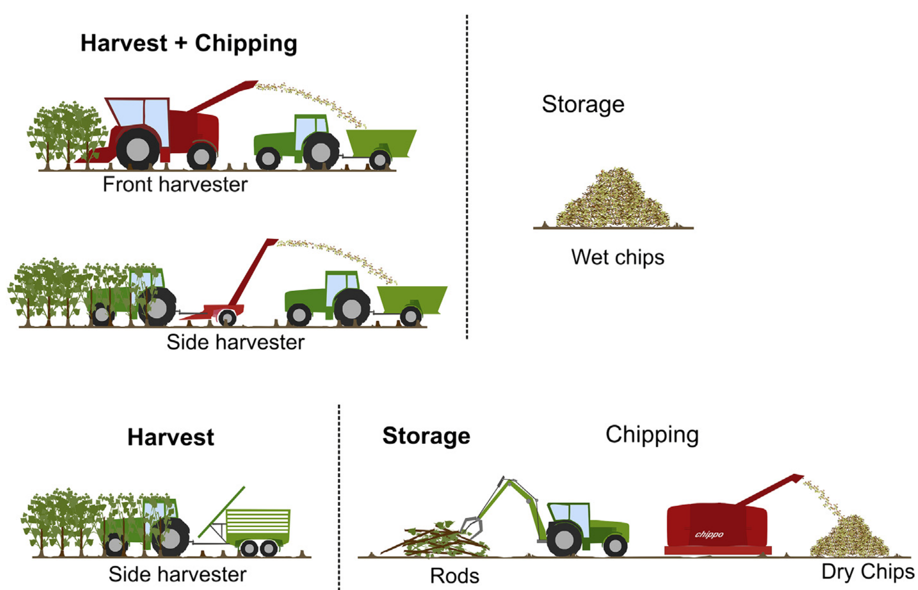

Fig. 1 – Representation of the harvest-and-chip and the harvest-and-storage systems. The harvest-and-chip system can be performed with a self-propelled cut-and-chip front harvesting machine or with a tractor-pulled cut-and chip side harvesting machine. In both cases the final product are wet chips. The harvest-and-storage system is operated using a tractor-pulled whole stem harvester. In this harvest system the final product could be dry chips at sizes and moisture demanded.