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Review

Current and innovative technologies for pruning harvesting: A review

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ABSTRACT

Pruning residues can provide a significant amount of biomass despite being rarely used as a renewable sources to replace fossil fuels. Exploiting such residues entails creating a sustainable and cost-effective supply chain in which the harvesting and initial processing of the residues play a crucial role. The study is a detailed and accurate survey of the harvesting technologies available in Europe for harvest pruning. After defining the main harvest technologies and the distribution of manufacturers in Europe, the survey details the main groups of implements: shredders, chippers and balers. For each group, the most important configurations are discussed, together with the main characteristics of the machine. Some of the main innovations are detailed (modular machines, non-stop balers, densification of the biomass) which can improve the quality of the product and the economic sustainability of the chain.

Contents

1. Introduction

Residues of permanent crops in Europe are a substantial reservoir of renewable biomass for energy and industrial use. The 10.6 Mha currently covered by permanent crops generate 13 Tg

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(oven-dry basis) of pruning. However, the rational use of this biomass source is being hindered [1,2]. Firstly by an increase in surfaces, and a conversion from traditional to intensive systems is forecast as well as a growing demand for fuel biomass [1,3–5]. Secondly, there are various barriers tied to the use of prunings and the development of a sustainable logistic chain to produce energy from it [6,7].

Pruning (branches and shoots of fruit trees) is considered a problem rather than an opportunity and, hence, it is not used or incorrectly disposed of [8].

Environmental concerns regarding the use of fossil fuel and their depletion have boosted a cultural change in the sustainable use of renewable sources. As a result, the formulation of more strict regulations regarding pruning in most European countries [2] has led to a renewed interest in pruning recovery. Over the last fifteen years several scholars have identified cost-effective technologies for harvesting, processing and delivering pruning residues. In fact, harvesting is a key stage that influences the product quality, the type of logistics chain and the economic sustainability of the pruning supply chain. In reality, over the years, many machine manufacturers have developed dedicated implements for collecting pruning residues [9–14].

Equipment that facilitates the harvesting and processing of agricultural pruning is already available on the market and many manufacturers offer different models that are tailored to specific harvesting chains. The aim of the present work is to provide a thorough overview of the technologies available for harvest pruning, from basic equipment to the state of the art.

2. Pruning collection and fuel quality

The source of the biomass as well as the techniques employed during the supply chain affect the quality of woody biomass. Apart from aspects related to biomass properties (such as moisture, ash, foliage content, and chemical composition), comminution and storage have a strong influence on other important parameters such as the presence of contaminants (soil, stones), particle size and bulk density, which may impact on the quality of the biomass. Comminution is exploited for baling, where the benefit of a more stable and prolonged storage period is diminished by the cost of this extra step.

Biomass losses and contamination are directly related to the regulation of the pick-up device. Low-lying pick up mechanisms help to reduce losses, but increase the inlet of soil particles, to the detriment of fuel quality [15]. The ash content of the shredded material has been reported to be higher than the branch material collected directly from the trees, and the ash are also responsible for a reduction in the heating value as well as a number of serious power plant problems through slagging, corrosion and fouling [16].

Biomass losses can be also a consequence of the working width of the machine and the lack of suitable windrowing. As hypothesized by Acampora et al. [15] the mismatch between windrow width and machine working width can lead to a high loss of biomass, but with voluminous pruning, such as those of olive orchards, building a narrow windrow can be arduous. Losses can also increase when the height of the pick-up is raised excessively in order to prevent soil contamination.

The shape, size, number and type of chipping devices, and the machine settings can greatly alter the feedstock quality [17–19]. An incorrect comminution, can lead to serious problems with the wood fuel such as high dry matter losses, high ash content, reduction in energy value, and self-ignition [20]. The particle size distribution of woody biomass plays a pivotal role in producing a high-grade fuel, because it directly influences the bulk density, the storage behavior, and the transport costs, and it can also create problems in the fuel feeding at the heating plant. The particle size is fundamentally determined by the machine design and settings, and can be a benchmark of the machine performance in terms of product quality [21]. Using the wrong machine can lead to uneven-sized chips with a high proportion of oversized or undersized particles, and any attempt to decrease one class may result in an undesirable increase in the other, even when refining devices are used [13,15,22].

Beside the particle size, the comminution of pruning must take into account the morphology of the wood pieces. The most commonly-used shredders produce wood particles with de-fibered ends unlike the homogeneous pieces resulting from chipping. This difference has significant implications during storage because the unclean cut of the shredders can cause the biomass to be more prone to degradation and fermentation. All types of biological and chemical changes in wood fuels during storage and drying leads to changes in fuel properties. However, the use of a chipper may also lead to a lower chip quality. This has been observed in the wood energy chain where the wear of the knife alters the chip quality and the productivity of the machine [22]. When the knives are not sharp, the chipper tends to break the wood rather than cutting it, thus producing finer and oversized wood particles [22].

The role of quality becomes more pronounced as the supply system varies in different countries and in different plant systems. An important goal of quality control is to reduce quality variations and as much as possible to obtain a homogeneous product [16,19].

3. Pruning management

3.1. Traditional handling

The pruning stage produces branches, shoots and buds which are then left in the field. In several areas of Europe is the biggest pieces of wood pruning are used for firewood. Farmers usually obtain firewood pieces from thick branches, with a diameter larger than 50 mm [14]. They perform the cut with chainsaws and gather the firewood manually or with a trailer and then put it at the side of fields. Pruning used for firewood is mainly carried out in small plantations, for self-consumption, or for local markets.

Due to the lack of a well organized pruning biomass supply chain in Europe, there is no real market for pruning residues (<50 mm). Thus small branches and shoots that have been pruned and left on the ground are usually not collected, chipped and used for energy production (excluding rare cases), but usually are disposed of by farmers in two ways:

1. they are removed from the orchard, and then piled and disposed of or piled and burned at the side of the field;
2. they are mulched and left/incorporated on/into the soil.

The branch removal phase is usually carried out by a tractor equipped with a fork or similar device which pushes the pruned branches down the rows until the edge of the field.

Pruning can be also left on the soil after mulching. Hammer mulchers (also known as hammer mowers or simply mulchers) are usually used to comminute the dendromass into small pieces. These machines are mounted on the back of the tractor on a three-point hitch and are supplied with the power take-off (PTO) of the tractor.

In rare cases, prunings with a small diameter can also be recovered for energy purposes using specific machines that chip, shred or bale the dendromass so that it can be transported, stored and used in specific boilers mainly for heat production.

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