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Mechanized coppice harvesting with new small-scale feller-bunchers: Results from harvesting trials with newly manufactured felling heads in Italy

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ABSTRACT

The revival of coppice management is being considered as one option to satisfy the increasing market demand for wood biomass. Commonly used harvesting systems in coppice forests (CF) are based on motor manual felling, but further mechanization of CF operations is desirable because of increasing labor costs and the high fatality rates associated with motor manual felling.

The goal of this study was to determine the machine performance in terms of productivity, cost-effectiveness and cut quality of new feller-bunchers, when used on different types of CF. The study comprised of five tests on different sites in Italy, four of which represented a specific type of CF.

Results showed that harvesting productivity varied from 3.1 to 8.6 dry t per scheduled machine hour (SMH) in multi-stem coppice stands (4.5–16 dry m^3 SMH^{-1}). Productivity reached 16.2 dry t SMH^{-1} in a short rotation forestry (SRF) control stand (39.4 dry m^3 SMH^{-1}) and it increased with stump mass. Recorded productivities tested in conventional CF were not as high as achieved in single-stem SRF, or in the mechanized felling of comparable softwood stands, but still matched the requirements of commercial mechanized logging. Costs varied between 3.57 and 20.56 € dry t^{-1} (1.47–14.17 € dry $m^{3^{-1}}$). Lowest costs were reached in the SRF stand and highest cost in the Mediterranean CF growing on moderate to steep terrain. Shear heads produced poor cuts and single-action shears performed worst. The disc saw produced very low cuts with low damage levels, which might be acceptable even under current cut quality specifications.

1. Introduction

All over Europe, many coppice forests have been converted into high forests in the last 150 years, with the aim to produce larger and more valuable trees [1,2]. However, conversion has met with partial success in Southern Europe and in the Balkans, due to the stronger survival of a rural economy and the specific ecological conditions [3]. Regardless of silvicultural strategy, coppice forests have been often neglected in recent

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times, due to a number of factors, and especially the rural migration to the cities and the introduction of fossil fuels [4]. The result is the current presence of many low-quality hardwood stands originating from coppice forests (CF), after management was discontinued for many years.

These stands gained renewed attention during the past two decades because of various reasons. For instance, with rising living standards, the protective, environmental, social and cultural functions of forests became more important [5], which has led to widespread concern about forest health. Furthermore, rising fossil fuel prices have led to an increased use of wood as an energy vector, reviving interest towards coppice management, which is now considered as one option to fulfill the market demand for energy wood [2].

Commonly, coppice sprouts are felled and processed motor-manually and extracted with forwarders or cable skidders, depending on log size and slope gradient [6]. The whole tree harvesting (WTH) system is used as well, but less frequently. In the occurrence, stems are bunched with winches or small excavators before extraction [7].

Both harvesting systems are time consuming, because CF often represent unfavorable work conditions: stems are small, branchy and often crooked; the terrain is generally rough (conversion tended to target easily-accessible stands); stems grow in clumps, and often present a marked butt sweep [8,9].

Low productivity and high labor inputs of traditional motor-manual operations result in high harvesting costs, which may reduce the financial sustainability of CF management. Furthermore, it is increasingly difficult to find skilled chainsaw operators [6]. However, the most critical problem is the high risk associated with manual felling, which is when most of the fatal accidents occur [10]. Replacing manual felling with mechanized felling may result in a dramatic fourth-fold reduction of accident rates [11].

For all these reasons, further mechanization is desirable. Nevertheless, harvesting of CF is technically and economically difficult, because of the small stem size and the occurrence of multiple stems on the same stump. One of the main problems seems to remain the capacity of a harvester head to approach stems growing in a clump. In particular, penetration of the head inside the clump is hindered by the feed rollers and the multiple delimbing arms, which are held back by the other stems surrounding the target stem. At the same time it is very important for forest owners that stumps present a clean cut, as near as possible to ground level [12]. Damage on the cut stump might lead to fungal infections, with negative consequences on stand regeneration. On the other hand, a cut that is too high above the ground affects the stability of the new sprouts, which may snap at the insertion under the action of wind and snow.

Feller-bunchers may prove better than harvesters at negotiating coppice stumps, since they are more compact and may approach stems with less difficulty. In fact, a number of small-stem feller-bunchers are available on the market, and some of them have already met with widespread popularity [13]. That is the case of Nordic thinning equipment, such as the various Bracke, Naarva and Nisula brands. Unfortunately, Nordic machines are designed principally for handling Nordic wood species, such as pine and birch. The wood of these species is much softer than that of the species managed as CF in central and southern Europe, such as beech, chestnut and oak. As a consequence, Nordic feller-bunchers have often proved too weak for effectively handling central and southern European CF [14].

Therefore, several manufacturers have developed heavier and stronger feller-buncher heads, specifically designed for the southern European markets. Some of these machines have been on the scene for several years, whereas others have just been launched on the market. Italian manufacturers have been especially prolific in their feller-buncher production, with at least five major companies offering one or more small-tree feller-buncher heads.

The goal of this study was to determine the performance of new feller-bunchers, when used on different types of CF. The performance was evaluated in terms of productivity, cost-effectiveness and quality of the cut. The hypothesis analyzed was that the mechanized harvesting could be carried out as cost-effectiveness as the manual harvesting of CF.

Technically, all the machines in the study are marketed as suitable for coppice harvesting operations, but until now no studies have been carried out to verify such claims.

2. Materials and methods

The study was carried out using Italy as an example, because the country is home to several feller-buncher manufacturers and presents a very large and diversified CF inventory. The study tested three different feller-bunchers under representative work conditions, as offered by commercial logging operations. The three machines on test represented three different cutting mechanisms, namely: a single-action shear, double shear and disc saw.

The study comprised of five individual trials, each representing a specific type of traditional namely: mediterranean CF (thermophile oaks), temperate CF (chestnut), river bank consolidation coppice (locust), ditch buffer strip coppice (poplars) and poplar single-stem short rotation forestry (SRF) (Table 1). The latter can be regarded as a benchmark for ideal harvesting conditions. Each machine worked on a different site, and it was often driven by different operators, which deprives our study of any comparative value. In fact, the goal of the study was not that of comparing machines and/or stand types, but rather describing general trends. In particular, we were interested in detecting any systematic effects of stem size and stump crowding on machine productivity, felling cost and cut quality.

All trials were conducted between the beginning of January and the end of February 2014. Each trial consisted in a time and motion study, conducting at the elemental level [[15], cf. [19]]. The observation unit was the individual stump.

A full inventory was carried out before the trial, in order to define stand characteristics. These were determined with conventional measurement instruments (caliper, vertex ultrasonic hypsometer, measuring tape, cruising rod, etc.). In order to link cycle times to stump characteristics, each stump was assigned a unique identifier, which was painted in bright colors on all individual stems sprouting from the same stump. Each stump was characterized for the following parameters: species, stems per stump, diameter at breast height (dbh) and