Analysis of the procurement system of Eucalyptus residues with bundling technology

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Abstract:

Bundling technology is a well-established system for the procurement of forest biomass residues in Nordic Countries. The main benefits being a simplification of logistics and storage, with relative reduction of total procurement costs, particularly when long distance transportation is required (over 60 km). Most bundling technology was developed in Nordic Countries and designed specifically for handling conifer slash, thus its effectiveness may be somehow reduced when handling different tree species with higher wood density. In this study the performance of a Woodpac ENFO 2000 bundler, specifically designed for eucalyptus residues, was assessed considering the performance of the whole procurement.

Keywords: forest residues, bundling, eucalyptus, logistics, biomass

1 Introduction

The bundling system, intended as the collection of slash through their densification and production of compact residue logs (CRL), is a well-known practice carried out especially in Nordic countries for the procurement of forest biomass fuel (Eriksson and Gustavsson, 2010; Gustavsson *et al.*, 2011; Karha and Vartiamaki, 2006). CRL main advantage is the simplification of logistics and storage of biomass for the procurement of fuel to large scale power plants (Johansson et al., 2006). For this reason CRL was considered as a viable option also by Southern European companies who tested the Nordic equipment in Mediterranean forests (Cuchet et al., 2004). In this working conditions, dominated by broadleaves, the bundling system proved to be less performing than in the original area characterized by softwood species. In order to overcome this problem a Spanish firm designed a bundler specific for the treatment of hardwoods slash (i.e. Eucalyptus spp. and Castanea spp.), named "Woodpac ENFO 2000". This machine is generally stronger than most of the slash baler models, but the main innovation relies in cutting device: the chainsaw generally installed is substituted by a powerful double guillotine system, which guarantees reliable bales sectioning in all working conditions, including when operating with contaminated residues (i.e. by presence of stones). Presently 10 Woodpac ENFO 2000 are working in Spain, mostly operating on Eucalyptus plantations grown for industrial pulpwood production. Typically eucalyptus is managed as coppice, harvested in large clear-cuts with the cut-to-length system (CTL) leaving on the ground large amounts of residues composed by tops, branches and bark. The collection of this materials is at the same time a mean for mobilizing a biomass resource and a required operation for the reduction of forest fire hazard and for improving the access to the forest. In this study the whole working system was considered: CRLs production, extraction by forwarder, piling at roadside landing and loading on trucks for delivery to power plant.

2 Material and Methods

The study was conducted in Northern Spain (Asturias) on commercial forest residue recover operations. The experimental area was part of a 145 hectares of eucalyptus (E. globulus) plantation managed as coppice and harvested with clear-cut. Harvest and timber extraction took place 5 months and ended 1 month prior to the beginning of bundling operations. Trees had been harvested at the age of 14 years, relatively young and small sized according to local common practices. Felling had been performed by chainsaw, while processing was carried out by mean of an excavator equipped with processing head and operating mainly along the forest roads. The only assortment produced was pulpwood logs, to a minimum diameter of 7 cm, no debarking rolls had been used so that the only residues on the ground were tops and branches. Harvesting and bundling were conducted by different firms, and no slash recovery was planned, so that residues were not arranged in any form (piled or windrowed).

The Authors carried out a time-motion study in commercial operations during 4 days, aimed at evaluating machine productivity (Bergstrand 1991). The study was conducted separately for all the main working phases: moving, feeding, compacting, tying and cutting. Each processing cycle was stop watched individually. All work time elements were recorded with hand-held all-weather computers running the dedicated Siwork3 software (Kofman 1995). Distances were measured by mean of GPS receivers placed onboard or optical telemeters. Productivity was considered in terms of bundles produced, and the number of bundles produced or forwarded in each time element was recorded. The average mass of bundles was measured by weighting 6 truckloads and counting the number of bales for each load. For the evaluation of moisture content biomass samples were collected by mean of a chainsaw from the top ends of 5 bales, put in sealed bags and then weighed fresh and after drying for 48 h at a temperature of 103 C° in a ventilated oven, according to the European standard CEN/TS 14774-2: 2005. On a subsample of 20 bales length and diameter (average of two perpendicular measures) were measured in order to estimate the average size and volume.

2.1 Bundler

The bundling unit was composed of the actual bundling machine, the Woodpac ENFO 2000, mounted on a 8-wheeled Dingo 24-52A forwarder with an engine power of 147 kW equipped with a Guerra 77A crane at an operative range of 7.7 meters. The bundler held an integrated winch which served to anchor

itself now and then for overcoming particularly uneven paths. The cutting device was a powerful double guillotine system, and the binding system employed synthetic rope coiled up on two spools. The machine was 1.5 years old and by the time of the study it had produced around 7,400 bales. The operator had 1.5 years' experience in this specific task, having started this new job since the purchasing of this specific unit.

2.2 Forwarder

For bundles extraction from the field, timber forwarders are used. In the study a 11 years old 6-wheeled Dingo with an engine power of 92 kW was used. The machine was equipped with a Guerra 624 crane, with an operative range of 6.9 meters and the load space was defined by a vertical metal wall on the left side (for debarked timber load) and posts on the right side. The operator was long experienced both forwarding timber and bundles. The nominal payload of the machine was 8.5 tons. For the extraction of bundles the machine generally entered the field up to an extreme and returned towards the exit road while loading the bundles randomly left along the forest roads or off road. Most of bundles were scattered individually over the cut and rather seldom were piled in small number. Once completed the load the forwarder proceeded along the forest roads for extraction. The bundles were finally piled at roadside landings or at intermediate landings along the rural road network. The average height of piles on flat terrain was about 4.2 meters, allowing a considerable optimization of the stocking area.

2.3 Timber trucks

For road transportation common timber trucks are used. In North-West Spain the most common configuration is a semitrailer truck equipped for timber transport with posts or net-walls. This last option is required for the transport of debarked eucalyptus pulp logs, being those slippery and unsafe for transport on common post-equipped platforms. Semitrailers have a 10.5 meters long load space (resulting with 2.5 m width and height in a nominal load volume of 65.6 m^3) and are generally equipped with crane for self-loading but some unit depend for this operations on a different machine (i.e. the forwarders may unload directly on the semitrailers, or serve at landing for loading from pile). In the first case trucks can independently reach the roadside piles and load themselves with the crane, which can be finally separated from the truck (it is powered by an independent diesel engine) and leaved on the loading site, reducing the total tare weight by 3.8 tons. Unloading at the plant is generally performed by more efficient heavy duty excavators which are also used to manage the stocking areas.

3 Results

3.1 Bundling

Overall 684 bundles were produced during the 35.49 hours of the study. The CRLs produced had an average length of 250 cm (the bundler was set to produce 245 cm long bales) while the average diameter was 77.3 cm, so a bit shorter even not less wider than the unit produced by other bundlers brands (Kärhä and Vartiamäki, 2006). Variability in size was quite strong and the resulting average volume was 1.17 m^3 ranging from a minimum of 0.80 to a maximum of 1.59 m^3. Utilization rate was very high, around 89% if considering PMH_{15}. Hourly productivity ranged from 7.7 (PMH_{15}) to 10.3 t h^{-1} (SMH), corresponding respectively to 24 or 21 composite residue logs per hour.

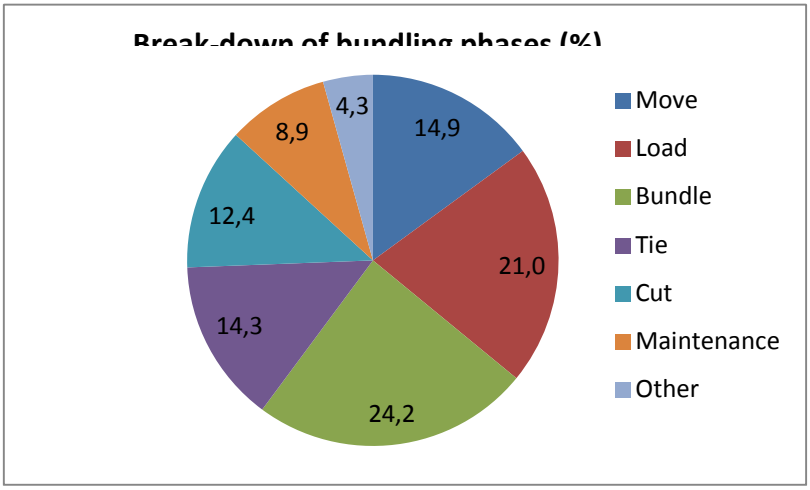

Fig. 1: Working time spent in the different bundling steps

3.2 Bundles forwarding

The forwarding study had a duration of 9.58 hours (a whole working day). During this time 335 bundles were collected, forwarded over an average distance of 950 m (one way) and piled at roadside or loaded directly on truck by the forwarder. The machine had less than 10 % of delay times, mostly due to mechanical problems of the brakes (related to the ageing of the machine) or to interactional delays since no-crane-equipped trucks required the presence of the forwarder at the landing. As a total 16 round trips were performed with an average load of 21 bales. This corresponds to a weight of 7.8 tons, or 92% of the technical payload of the machine. The average round-trip could be completed in about 31.7 minutes (not including delays), being faster the cycles where bales were unloaded at the landing and longer those where unloading was performed directly on the timber truck. Overall the recorded forwarding productivity was 35 bundles/SMH or 13 green tons/SMH. The corresponding forwarding cost, considering an hourly machine value of 52 €, is 1.5 €/bundle or 4€/green ton.

3.3 Truck loading

Almost 25.8 tons of effective payload was transported as an average (n.6) corresponding to 69 bales (ranging from 71 to 68 per load). Recoded loading time varied from 29 to 49 minutes (0.48 to 0.82 hours) being the difference related to different operators and, mainly, to the extra time required to cover the load in the post-equipped timber semitrailer. This operation was much faster (11 minutes less) for trucks equipped with net-walls for debarked logs, where the coverage had to be arranged just on the top area of the load. Overall, the loading operation had a cost of 0.86 and 1.45 €/green ton respectively for net-wall and post semitrailers. Assuming a distance of 140 km, a travel time of 3.5 hours (round trip), and unloading time of 21 and 25 minutes respectively for net-wall and post semitrailers total road transport cost was 7.7 and 8.4 €/green ton or 2.9 and 3.2 €/bale.

4 Discussion

The bundler proved to have a productivity comparable to that reported for other machines operating with piled or windrowed residues (Cuchet *et al.*, 2004). Due to the difference in terms of tree species and forest management it is difficult to make a direct comparison, specific studies are required in this sense, but as an overall result the bundler resulted to be efficient and reliable. Particularly the guillotine cutting system appears to be slower than the chainsaw system, but definitely more trustworthy. Along an operative life of 1.5 years the tested machine had produced about 7,400 bales and no maintenance (not even sharpening) had been done to the cutting system. Which, according to the chain bar and chain costs estimates of Karha et al. (2006), means a reduction of the operative cost of 2.9 €/PMH_{15}.

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