Chipping model: a tool to predict the productivity and cost of chipping operations

Mohammad Reza Ghaffariyan¹, Raffaele Spinelli², Mark Brown¹, Luke Mirowski¹³

¹Australian Forest Operations Research Alliance (AFORA), University of the Sunshine Coast
²Consiglio Nazionale delle Ricerche (CNR)-IVALSA, Italy
³University of Tasmania

Introduction
Chipping is an important component of some of the harvesting systems used to produce woodchips for biomass and pulp. The raw materials for chipping can be harvesting residues, pulpwood, energy wood or whole trees.

Spinelli and Hartsough (2001) developed a tool (Chipcost) for productivity and cost forecasting of decentralised wood chipping using 102 case studies in Italy, which was validated later by Spinelli and Magagnoti (2010). The model was based on four variables: chipper power, piece size, chipper mobility and work site (landing or stand).

To update and increase the scope of the model, the Cooperative Research Centre (CRC) for Forestry and the Australian Forest Operations Research Alliance (AFORA) partnered with Consiglio Nazionale delle Ricerche-Istituto per la Valorizzazione del Legno e delle Specie Arboree (CNR)-IVALSA to add Australian chipping productivity studies and new Italian chipping case studies to the previous data reported by Spinelli and Hartsough (2001). This larger and more geographically diverse dataset was analysed to develop a new productivity and cost-prediction model for decentralised chipping operations. The resulting model was then validated based on local (Australian and Italian) and international data (chipping productivity studies in different continents). The tool (a spreadsheet of the chipping model) can be downloaded from the AFORA website at http://www.usc.edu.au/research/research-partnerships/australian-forest-operations-research-alliance/.

Research method
The standard time study method was applied to measure the productivity of different chipping operations in Italy and Australia. The dataset included 25 chipping productivity case studies in Australia (Victoria, South Australia and Western Australia) and 180 case studies in different parts of Italy. The data was collected by CNR-IVALSA (a leading research group on forest operations in Italy) and the CRC for Forestry/AFORA. For model validation, five case studies were removed from the database prior to modelling to be used as witness samples in addition to 17 international witness samples on chipping productivity in different countries. To develop the model, the impact on chipping productivity was evaluated for:

- machine power (kW)
- piece size (m³)
- crew size (one man, two men, etc.)
- operation type (clear cut, thinning, other)
- species (hardwood or softwood)
- tree part (whole tree, log, top, slash)
- wood condition (fresh, dry, semi-dry)
- wood layout (bunched, stacked, loads, scattered)
- comminuter type (disc or drum)
- propulsion (self, towed, forwarder/tractor, truck)
- feeding method (built-in, tractor, loader, hand)
- point of comminution (landing or terrain)
- season (spring, summer, autumn, winter)
- location of chip discharge (truck, container, heap, self)
- country (Italy, Australia) and
- product type (biomass chip or pulp chip).

The productivity-prediction model was developed using backward stepwise regression.
The productivity model was combined with the standard costing methodology developed by COST Action FP902. This spreadsheet calculates the machine cost and unit cost using the standard machine cost and productivity calculation (Bjoerheden et al. 1995, FAO 1992, Warkotsch 1994).

**Results**

The regression procedure yielded a model in which machine power, piece volume, location of chip discharge and product type were significant and included as independent variables. The range of the machine power in the dataset was quite large, varying from very small chippers in Italy with only 22 kW power to large chippers in Australia with 1074 kW. Average piece size varied from 0.002 to 0.70 m$^3$ in the dataset.

**Model validity**

The model was tested at the local and international level. Testing the model using five witness samples from the local case studies in Italy and Australia confirmed that the model is valid under Australian and Italian chipping operating conditions. Seventeen international case studies on chipping operations were used to evaluate the productivity model including three studies in Canada, two studies in Northern USA, two studies in Southern USA, one study in Chile (South America), three studies in Austria (Central Europe), four studies in Ireland (Atlantic Europe) and two studies in Denmark (Northern Europe). One case study in British Columbia, Canada and another case study in Chile did not confirm the model’s validity as their chipping productivity was less than the lower limit of the prediction by the model. However, the recorded chipper productivities in the other 15 case studies were within the statistical limits of the model predictions, indicating that the model can be reasonably applied internationally.

**Impact of different variables on chipping productivity**

According to the analysis, the more powerful the chipper, the higher the productivity. Figure 1 shows the impact of machine power and product type on chipping productivity, in which the chipping productivity for producing pulp chips was higher than for biomass chips. The pulp chip productivity was greater due to the large and uniform piece size of the logs used compared to biomass production, which mostly included slash, tops and whole trees with lower density which diminished the chipper’s productivity.

![Figure 1. Impact of machine power on chipping productivity for two different product types (biomass chips vs pulp chips)](image-url)
Larger average piece size resulted in higher chipper productivity due to a decreasing chipping time per cubic metre (Figure 2).

**Figure 2.** Impact of average piece size on chipping productivity for two different product types (biomass chips and pulp chips)

Productivity was higher (Figure 3) when the chips were blown into a truck, possibly due to the larger capacity of the truck bin. It is also likely that chipping into a truck imposes greater time pressures on the operators, thereby driving them to push for higher productivity compared to when they are chipping to a heap or into their own built-in container. Built-in bins resulted in the lowest productivity due to their limited capacity and to the resulting frequent need for unloading into a truck, trailer or landing after filling. This operation requires the chipper to move to the unloading location, which takes significant time out of the productive cycle. However, these results are valid for productive time only, and must be interpreted with caution. Ranking may change significantly after including delays, which are often much higher when discharging into trucks, due to the difficulties in balancing the chipper’s productivity with the truck fleet (Spinelli & Visser 2009).
Figure 3. Impact of location of chip discharge on chipping productivity for two different product types (biomass chips and pulp chips)

Cost of chipping operation

The Excel-based chipping model spreadsheet calculates the machine cost and unit cost using the standard machine cost and productivity calculation. The inputs include machine type, machine fixed cost, machine variable cost, personnel and productivity. The outputs are annual, monthly, hourly and unit costs classified in four sections including fixed, variable, personnel and total costs. The chipping model spreadsheet can be downloaded from the AFORA website at http://www.usc.edu.au/research/research-partnerships/australian-forest-operations-research-alliance/.

Take-home messages

- The combination of Australian and Italian chipping productivity studies yielded a valid model for predicting the productivity and cost of different chippers operating within different supply chains under the conditions of two different regions.
- Testing the model against international studies indicated that it could reasonably be applied on a global scale, although with caution.
- The main factors influencing chipping productivity were machine power, average piece size, product type and location of chip discharge.

More information

Project scientist: Mohammad R Ghaffariyan - ghafari901@yahoo.com

Alliance Director: Mark Brown - mbrown2@usc.edu.au

AFORA website: www.usc.edu.au/research/research-partnerships/australian-forest-operations-research-alliance/

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References


