Comparing four harvesting methods using multiple criteria analysis in Western Australia

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Comparing four harvesting methods using multiple criteria analysis in Western Australia

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Introduction

Selecting the most efficient harvesting system is a difficult, decision making process and includes different environmental, economic and social factors. The multiple-criteria analysis (MCA) seems to be an effective methodology for helping foresters decide what system to apply depending on their operations specifications (Lexer et al. 2005).

In Australia, different individual case studies have been carried out by CRC for Forestry and AFORA to evaluate the productivity and costs of various harvesting systems. However, there has been no study to consider different economic and environmental criteria as a unit research project for helping industry managers with their decision making process under different impacting criterions. Thus this study was carried out to achieve following objectives;

- Assessing the preference of the industry users on the importance of different economic and environmental criterions.
- Evaluating the operating cost, yield, remaining slash, fuel consumption and bark content of four harvesting methods.
- Ranking the harvesting methods.

Materials and Methods

The study area was located in a *Eucalyptus globulus* plantation in south-west Western Australia, 58 km from the delivery point for all the products—the Albany Plantation Export Company (APEC chip mill). The study site covered 5.95 ha of flat terrain. Average diameter at breast height over bark (DBHOB) and tree volume were 17.8 cm and 0.207 m^3, respectively. Four different harvesting methods were used to harvest the site; cut-to-length (CTL), in-field chipping using a delimbing and debarking flail integrated with the chipper (IFC-DDC), in-field chipping using a chipper with a separate flail machine for delimbing and debarking (IFC-F/C), and whole tree to roadside (WTR).

A detailed time and motion study was used to evaluate machine productivity (Magagnotti and Spinelli 2012). Productivity was calculated from the delivered green metric tonnes (GMt) (derived from truck weights) and productive machine hours, excluding all delays (PMH_0). The ALPACA (Australian logging productivity and cost appraisal) model (Acuna 2012) was used to estimate the cost of operations. The alternatives included four harvesting methods; CTL, IFC-F/C, IFC-DCC and WTR. The decision criterions consisted of total operating cost (from stand to mill gate), yield per ha, harvesting residues, fuel consumption and bark content of the chips. An online survey was carried out with 30 participants from the forest industry sector in Australia to evaluate the importance of each criterion. The usual preference method was applied to run Promethee method to evaluate the harvesting alternatives using Decision Lab software. The Promethee-GAIA methodology was applied as one of the most efficient but also one of the easiest decision aid methods in the field (Brans et al. 1986).

Results

Table 1 presents the total harvesting cost and fuel consumption for the harvesting methods. WTR method was most expensive method with highest fuel consumption while IFC-DCC method resulted in lowest operating costs compared to the other methods.

Table 1: Total operating cost and fuel consumption of the harvesting methods

Harvesting method	Cost ($/GMt)	Fuel consumption (l/GMt)
CTL	36.62	3.33
IFC-DCC	23.74	4.76
IFC-F/C	25.77	4.05
WTR	38.12	6.53

The CTL harvest method retained higher biomass residues on the site after harvest (58.7 GMt/ha). The other methods left very small amounts of biomass at the site, as they extracted the whole trees to the roadside. Removal of the tree crown in whole tree extraction resulted in low retained biomass scattered on the sites (Table 2).

Table 2: Retained biomass after harvesting operation

Harvesting method	Retained biomass (GMt/ha)
CTL	58.7
IFC-DDC	4.2
IFC-F/C	6.5
WTR	7.7

The yield per ha was recorded based on bone dry tonnes (BDT) by using 40.75% moisture content for the chips from CTL and WTR methods, and 43.5% for the IFC-DDC and IFC-F/C systems (Table 3). Chip produced by IFC-DDC had highest bark content while chips delivered by CTL method consisted of only 0.02% bark content.

Table 3: Yield and bark content of the chips for different methods

Harvesting method	Yield (BDT/ha)	Bark content (%)
CTL	81.4	0.02
IFC-DDC	92.0	0.67
IFC-F/C	90.3	0.18
WTR	84.0	0.11

Ranking harvesting methods by Promethee method

Table 4 shows the ranking of the harvesting methods for the case of maximising harvesting residues and yield and for minimising operating cost, fuel consumption and bark content. Based on the calculated Φ (Promethee partial and complete ranking), the best alternative was IFC/DCC method due to its very low operating cost and high yield compare to other alternatives (Table 4). CTL method was ranked as third alternative as it resulted in highest harvesting residues after the operations (Table 4), but as its operating cost was higher than IFC/DCC or IFC-F/C and this criterion had highest weight according to the industry's preference. Thus, the IFC/DCC dominated the ranking despite leaving less harvesting residues. WTR method was ranked as worst alternative, mainly due to its high operating cost and fuel consumption.

Table 4: Ordinal and cardinal ranking according to the Φ^+, Φ^-, and Φ values for the harvesting methods (maximising harvesting residues)

Ranking	1	2	3	4
Harvesting method	IFC/DCC	IFC-F/C	CTL	WTR
Φ^+	0.59	0.56	0.55	0.31
Φ^-	0.41	0.44	0.45	0.69
Φ	0.18	0.12	0.10	-0.38

The ranking of the harvesting methods for the case of minimising harvesting residues, operating cost, fuel consumption and bark content and for maximising yield per ha was similar to the Table 4 (maximising harvesting residues). For this scenario, both in-field chipping operations methods was ranked higher than CTL method due to lower harvesting residues left on the site following harvesting operations. As IFC/DCC had lower harvesting residue and operating cost than IFC-F/C, it ranked better than IFC-F/C. Using same weight for all criterions and aiming to minimise harvesting residues, the ranking from the best to worst was as follow; 1) IFC/DDC, 2) IFC-F/C, 3) CTL and 4) WTR. When the analysis was run for same weight of the criterions objecting to maximise harvest residues, the CTL method was ranked as the best system while the second ranking belonged to IFC/DDC, third for IFC-F/C and WTR method was worst alternative.

Conclusions

The study confirmed that in-field chipping operations (IFC-DCC or IFC-F/C method) resulted in lower operating costs cheaper than CTL or WTR harvesting methods. WTR method was found to be most expensive harvesting method in the case study area. Main finding of the multiple criteria analysis was that if the weight of harvesting residue criterion is assumed to equal to the others (such as operating cost and yield), then the CTL method can be ranked as the best harvesting alternative.

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