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BIOMASS CHIPPING OPERATIONS: CASE STUDIES IN TUSCANY (CENTRAL ITALY)

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Abstract: *Many Italian logging companies produce substantial amounts of woodchips. Chip is usually a product obtained from less valuable trees and residuals. Chipping is the only way to get a market value to low – quality trees, branches and tree-tops. The aim of the Italian and European companies is to transform a low value residue into an industrial product. The main problem is due to the low value of the chip product, which requires the minimisation of the costs to optimize the whole production chain in general.*
The most important parameters that must be considered are chipping site, landing or terrain, and chipper configurations. So far, Italian companies use a very heterogeneous machines fleet including American, German and Scandinavian models. This paper describes chipping operations in 3 different sites in Tuscany (Central Italy), stretching between Pisa and Livorno:

1) *Pisa – San Piero a Grado: selective cut of poplar and Italian stone pine near Tombolo estate;*
2) *Pisa – Calambrone: clear-cut and chipping of a burned area of maritime pine;*
3) *Pisa – Santa Luce: vegetation clear-cut and chipping of the river's "Fine" banks.*

In each site the level of mechanization was high and different chip forwarders and working systems were used. Two different chip extraction systems were used: tractors with trailer and container, chip forwarder with an integral chip bin. The main aim of the study was to give a survey of the working systems and the methods in chipping operations and to analyse chipping times, productivity and costs.
The results show that to increase chipping time and productivity and to reduce costs is necessary:

- *organize chipping as soon as possible after cutting operations to have an easier work with the integral loader;*
- *bunch timber along the extraction trails to reduce chip forwarder movements and increasing chipping time;*
- *use 1 or 2 tractors with container on trailer for chip extraction instead of the chip forwarder with its integral chip bin, especially for long extraction distances (more than 500 metres);*
- *drive the chip forwarder on the extraction trails to spend less time for movements and to reduce soil impact.*

1. Introduction

In the last years public and scientific debate about the reduction of CO_2 and polluting emissions has intensified and the importance of renewable energies and fuel has increased. Scientific researches on the economic possibility to use wood and biomass to obtain electric and thermal energy has shown contrasting results.

At the present many Italian logging companies produce substantial amounts of woodchips. In most cases chip is usually a product obtained from less valuable trees, residuals and from special plantation (Short Rotation Forestry). The aim of the Italian and European companies is to transform a low value residue into and industrial product.

In the last few years in Italy several companies of the bio energy industry, attracted by generous Government subsidies planned to build dedicated power that use biomass as their main fuel. The average plant would seldom exceed the 15 MW and according to the project specifications most of their fuel is woodchips. Another important incentive in Italy, is the market price of woodchips for thermal plants, that has increased to the value of 35 – 45 € per ton instead of the 20 € paid for the same amount in the year 2000.

Surveys made in the centre of Italy has underlined that the main chipping operators have modernized their chipping machines, with more powerful and expensive engines. In the wood-energy industry, the wood harvesting represent the most expensive stage of the productive process, so is necessary to organize chipping yards with a suitable level of mechanization, to increase chipping time and productivity and to reduce costs.

At the present in Italy the main typologies of chipping yards are:

- residuals harvesting in the North of Italy where the working system adopted is the Full Tree System with skylines for wood extraction;
- clear-cut of Pine plantations for plants sanitary precautions;
- clear-cut and chipping of burned areas;
- vegetation clear-cut and chipping of rivers' banks;
- clear-cut of special plantations for energetic aims (Short Rotation Forestry).

2. Objectives

This paper describes chipping operations in 3 different sites in Tuscany (Central Italy):

1) Pisa – San Piero a Grado: selective cut of poplar and Italian stone Pine

Figure 1: San Piero a Grado (PI) - selective cut of poplar and Italian stone pine

2) Pisa – Calambrone: clear-cut and chipping of a burned area of Maritime Pine

Figure 2: Calambrone (PI) - clear-cut and chipping of a burned area of maritime pine

3) Pisa – Santa Luce: vegetation clear-cut and chipping of the river's "Fine" banks.

Figure 3: Santa Luce (PI) - vegetation clear-cut and chipping of the river's "Fine" banks

Two different chip extraction systems where used: tractors with a container on trailer and chip forwarder with an integral chip bin. The main aim of this study is to give a survey of the working systems in chipping operations and to collect chipping times in order to calculate productivity and costs.

3. Materials and methods

Chipping times where collected with the separate survey of working times and every stages of chipping operations were timed.

In the first chipping site (Pisa – San Piero a Grado) was studied a selective cut of Poplar and Italian Stone Pine and in details the single operations have been:

- All fellings were carried out by feller machine mounted on a tracked excavator. Average cut diameter was between 25 – 60 cm.
- Chipping operations were carried out by forwarder mounted drum chipper with a 340 kW powered engine and without chip container.

- Chip extraction was made using two tractors with container on trailer on maximum distances of 900 metres.

Using forwarder mounted chipper, trees were chipped on the felling site, chips were stored in the containers on the two tractors and then transported to the landing. Working time analysis is explained in the graph below.

Figure 4: Productive and unproductive time compared to the gross time

It is important underline that not all of the productive time is chipping time; in this portion there are other productive stages of the chipping process that need to be improved. In details these times are: feeding time, repositioning time and moving time.

The second chipping site is Calambrone on the coast of Tuscany (Central Italy) included in a Regional Park. Here was studied a clear-cut and chipping of a burned area of Maritime Pine. The province of Pisa administration planned and managed post-fire logging by using both its own forest workers and a private farm.

All fellings were carried out by chainsaw and average cut diameter was 5 – 15 cm. Before chipping trees were winched by hands on the felling site. Chipping and chips extraction were carried out by forwarder mounted drum chipper fitted with a container (chip forwarder), with 300 kW powered engine. Chip extraction distances were about of 700 metres.
The chip forwarder working system in spite of the winching of the trees was neither schematic nor rational and the unproductive times were very high. Working time analysis is described in the graph below.

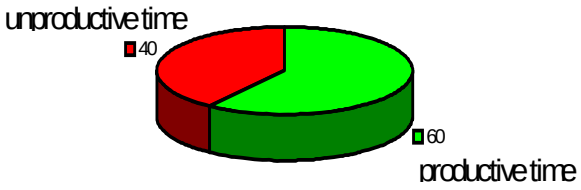

Figure 5: Productive and unproductive time compared to the gross time

The third chipping site was Santa Luce in the South of Tuscany. Here was analyzed a vegetation clear cut and chipping of the river's "Fine" banks. All fellings were carried out by chainsaw, average cut diameter was 20 – 40 cm.
Before chipping trees were winched along the banks by a little tracked excavator. Chipping was carried out by a forwarder mounted drum chipper fitted with a container with 300 kW powered engine. Chip extraction was made using a tractor with a container on trailer on distances of 800 metres. In this case the

integral chip bin was used only to store chips during extraction operations carried out by the single tractor. Working time analysis is described in the graph below.

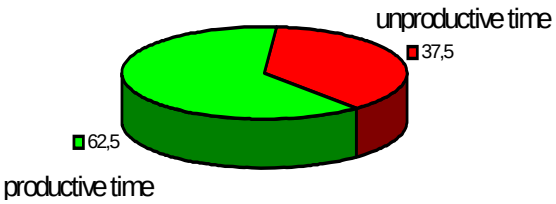

Figure 6: Productive and unproductive time compared to the gross time

4. Results

4.1 Productivity and working time analysis

Unproductive times were due primarily to a bad organization of the chipping yard especially to:

- random distribution of the chipping site on the felling site;
- numerous movements of the chip forwarder on the ground;
- feeding difficulties using the integral loader;
- interruption of the production chain because of the retard of the tractors during chip extraction;
- numerous breakdowns occurred to the chipping machine.

Gross productivity of the chipping operations is described in the table below.

Table 1: Productivity

Chipping site	Area ha	Chips amount mst	Gross time h	mst/h	ton/h
SAN PIERO A GRADO	2,43	594	18,7	31,7	9,5
CALAMBRONE	2,30	645	48,2	13,4	4,0
SANTA LUCE	2,95	462	36,7	12,6	3,8
			1 mst of chips = 0,3 ton		

The higher value of productivity was obtained in the first chipping yard where unproductive chipping times were lower.

4.2 Chipping costs analysis

Costs have been calculated with standard hourly cost methods, which include ownership costs and operating costs. In order to calculate the hourly cost of chipping machine many parameters were considered. Some of them are:

- depreciation;

- average annual investment;
- interest cost;
- insurance, tax, garage;
- repair and maintenance;
- fuel consumption;
- fuel cost;
- lubricant consumption;
- lubricant cost.

In the chipping cost analysis operative time was considered the same as the productive time, operators hourly cost was of 14 € and at final destination chips were sold at the price of 40 € per ton.
Machine costs analysis is described in the table below.

Table 2: Chip forwarder and tractor hourly costs

Parameters	**1° chipping yard S. Piero a Grado Chip forwarder**	**2° chipping yard Calambrone Chip forwarder with integral chip bin**	**3° chipping yard Santa Luce Chip forwarder with integral chip bin**
Purchase prise decreased of the recovery value, €	400000,00	360000,00	360000,00
Rate of interest	0,04	0,04	0,04
Annual costs of consumer products, €	2500,00	2500,00	2500,00
Depreciation period, years	10	10	10
Technical life, h	10000	10000	10000
Repairing coefficient	0,50	0,50	0,50
Various costs percentage	0,07	0,07	0,07
Daily utilisation, h/d	6,36	5,79	5,74
Annual utilisation d/year	140	140	140
Fuel hourly consumption l/h	47,13	38,07	34,81
Fuel price (agrarian) €/l	0,80	0,80	0,80
Lubricant hourly consumption kg/h	0,07	0,07	0,07
Lubricant price €/kg	4,90	4,90	4,90
Chip forwarder hourly cost €/h	**146,21**	**136,27**	**134,42**
Tractor hourly cost €/h	**53,06**	**Not used**	**46,83**

In order to calculate the production cost of 1 mst of woodchips, in chipping and extraction operations have been considered the following parameters: the number of operators, operator hourly cost, machines hourly cost, wood chips amount and working times. Woodchips costs analysis is described in the table below.

Table 3: Woodchip costs

CHIPPING YARD	WOODCHIPS COSTS (CHIPPING AND EXTRACTION OPERATIONS)	
	mst	t
S. PIERO A GRADO	€ 4,66	€ 15,5
CALAMBRONE	€ 8,73	€ 29,1
SANTA LUCE	€ 9,76	€ 32,5

5. Conclusions

Productive time and productivity depend primarily on the working system and on the operators experience. Unproductive times, especially in the second and in the third chipping yard show that the chip forwarder machine should be used primarily for chipping not for chips extraction and for wood winching with the integral loader. The lower costs of wood chips were obtained in the first yard where the productivity and productive time have been higher.

The following specific conclusions are apparent from this study. To increase chipping time and productivity and to reduce costs is necessary:

- organize chipping as soon as possible after cutting operations to have an easier work with the integral loader;
- bunch timber along the extraction trails to reduce chip forwarder movements and to increase chipping time;
- use 1 or 2 tractors with container on trailer for chip extraction instead of the chip forwarder with its integral chip bin, especially for long extraction distances (more than 500 metres);
- drive the chip forwarder on the extraction trails to spend less time for movements and to reduce soil impact.

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