FORMEC 2010
Forest Engineering: Meeting the Needs of the Society and the Environment
July 11 – 14, 2010, Padova – Italy

PRODUCTIVITY OF FORWARDERS IN SOUTH ITALY

Giuseppe Zimbalatti, Andrea R. Proto

Dept. Agroforestry and Environmental Sciences and Technologies,
Mediterranean University of Reggio Calabria
Feo di Vito, 89122
Reggio Calabria, Italy
e-mail: gzimbalatti@unirc.it - andrea.proto@unirc.it

Keywords: forwarder, South Italy, extraction, efficiency

Abstract: *Thirty-five percent of timber production in Italy comes from terrain which is classified as having a very steep slope. Forests in Southern Italy are mainly located in steeply sloping mountainous areas where ground-based wood extraction is still the most common harvesting technique employed. The forest cover of Calabria, a region of Southern Italy particularly rich in forests, is equal to 31.8%. In particular, sixty percent of beyond 600.000 hectares of Calabrian forest surface are situated in lands with classes of slope between 20 and 60%. The low level of mechanization of forest utilization in Calabria is due to the site features of the forests, the characteristics of the forest property and the small dimensions of many forest enterprises. Indeed, the most widespread work methods envisage, on one the hand, the use of chainsaws for timber cutting operations and on the other hand the use of animals or tractors equipped with winches for gathering and yarding. Animals were commonly used in the past to extract timber to roadside. This option may still be suitable in small scale forestry or in environmentally sensitive forests areas. In Calabrian forestry, the most widely used means of timber yarding is the tractor with a utilization of 87%, similar to other regions in the South Italy. Fortunately today a possible innovative alternative to these systems of extraction is represented from forwarder. These specialized forwarding machines are the most common extraction system in Europe. Forwarders are common machines in the cut to length system. Similar to harvesters, forwarders can be fitted with tracks or chains and can remove on average 9-12 tones per journey. The research presented aimed at improving the technical knowledge concerning the use of this machinery in Southern Italy and how advisable its extension to other areas would be. A time and motion study showed that the productivity of forwarder tested was satisfactory although there are a number of organizational aspects that could be improved in order to fully exploit their potential.*

1. Introduction

As Italy belongs to the countries with the highest forest cover in Europe, forest management has been of central importance in this country. Challenges in forest management arise particularly from the fact that the main part of the Italian forest is located in steep terrain. Thirty-five percent of timber production in Italy comes from terrain which is classified as having a very steep slope. Forests in Southern Italy are mainly located in steeply sloping mountainous areas where ground-based wood extraction is still the most common harvesting technique employed. The forest cover of Calabria, a region of Southern Italy particularly rich in forests, is equal to 31.8%; they are also often highly productive; indeed, every year, in Calabrian forests, the average increase in wood volume, which is equal to 6-8 m^3 ha^{-1}, exceeds and sometimes doubles the increase estimated in the other forests of Southern Italy (Zimbalatti and Proto 2009). In particular, sixty percent of beyond 600.000 hectares of Calabrian forest surface are situated in lands with classes of slope between 20 and 60%. Beech, Corsican pine and silver fir are the most spread tree species. The low level of mechanization of forest utilization in Calabria is due to the site features of the forests, the characteristics of the forest property and the small dimensions of many forest enterprises. Indeed, the most widespread work methods envisage, on one the hand, the use of chainsaws for timber cutting operations and on the other hand the use of animals or tractors equipped with winches for

gathering and yarding. Animals were commonly used in the past to extract timber to roadside. This option may still be suitable in small scale forestry or in environmentally sensitive forests areas. The correct use of woodland resources of Calabria may account for an important solution for the problems of this Region whose levels of mechanization in this field are still very poor (Zimbalatti and Proto, 2009).
Calabria supplies numerous sectors of southern Italian wood industries. The annual amount of harvested timber in 2008 was 1.002.147 m^3 (ISTAT, 2008), about the 13% of the national amount and the 41% of the total amount of timber harvested in southern Italy. In the last fifteen years an increase of the harvested timber has been recorded: from the analysis of the national statistical database (ISTAT, 2008) (Figure 1), firewood harvesting increased more than roundwood harvesting (Cavalli et al., 2008).

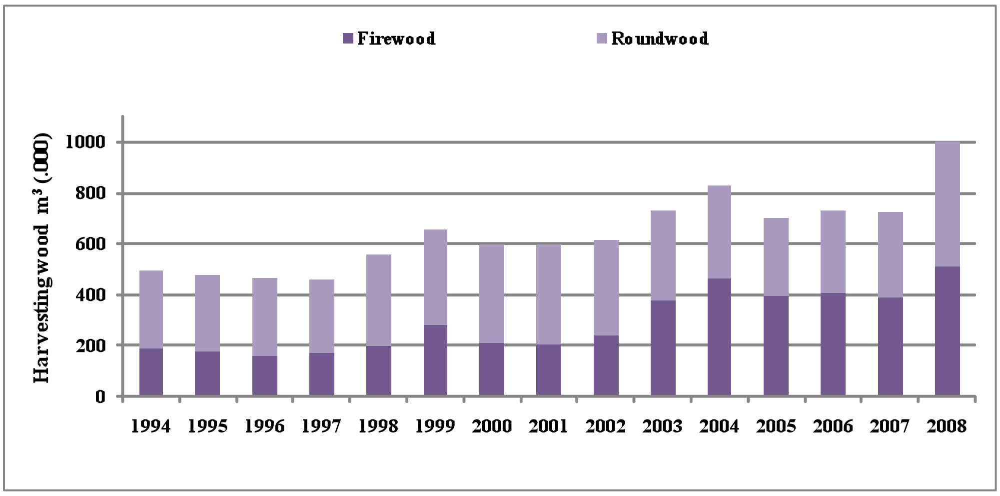


Figure 1. Harvesting wood in Calabria

In Calabrian forestry, the most widely used means of timber yarding is the tractor with a utilization of 87%, similar to other regions in the South Italy. Fortunately today a possible innovative alternative to these systems of extraction is represented from forwarder. These specialized forwarding machines are the most common extraction system in Europe. Forwarders are common machines in the cut to length system. Similar to harvesters, forwarders can be fitted with tracks or chains and can remove on average 9-12 tones per journey. The research presented aimed at improving the technical knowledge concerning the use of this machinery in Southern Italy and how advisable its extension to other areas would be.

2. Materials and Methods

The tests were carried out at two forest sites, indicated below by the letters A and B, both located in the Serre massif (VV). During skidding operations the machine was constantly monitored, the various work stages were calculated using a time motion study and the various distances were noted down. The total number of logs were counted and transported to calculate the volume of each load in order to obtain a good estimate of the total volume carried. Overall, data for the periods of work and the skidding cycle volumes on the test days was collected. On both sites, the level of elevation was measured using a handheld GPS while the gradient was assessed with a Suunto clinometer.
The logs obtained during the study of the two test sites were calculated by measuring the total length and diameter at half height. The volume of timber skidding was calculated using the Huber formula:

$$V = D^2 \cdot \pi / 4 \cdot L$$

where:

- V = Total tree volume (m^3);
- D = Mid-height diameter (m);
- L = length (m)

The first test site A, is located at an altitude of about 850 m above sea level. The crop is attributable to the high number of mixed trees and forest type, composed mainly of beech and Corsican pine but also the presence of poplar and alder. The second site B is situated 800 m above sea level and the crop is composed mainly of beech and chestnut. Table 1 illustrates the features and vegetation characteristics of the two test sites from surveys carried out beforehand.

Table 1. Characteristics of the two test sites

Features	Measurement Units	Site A	Site B
Altitude	m.s.l.m	850	800
Prevalent species	-	Beech, Corsican pine	Beech, chestnut High forest
Government	-	High forest	High forest
Treatment	-	Clearcuts with reservations	Clearcuts with reservations
Stand density	n. p./ha	1300	900
Average volume per tree	m^3	1.00	1.54
Total volume	m^3/ha	65	68
Average slope Max gradient Min slope	%	25 40 12	23 43 9
Roughness	-	Strongly rough	Average rough

The forwarder employed during this study is the John Deere model 1110D (Tables 2 and 3 - Figure 2). It is a relatively compact forwarder considering that it is 2.7 m wide, ideal for thinning operations, but flexible enough to be used for wood hauling. The light weight (15 tonnes) and 8-wheel drive make it more manageable on tough terrain, especially with slopes greater than 30%. The John Deere 6 cylinder engine 6068HTJ provides 125 kW of power, while the articulated arm CF5, is equipped with a 10 m radius.

In order to determine the productivity of the forwarder, the operating cycle of the machine has been divided into three elements (Cavalli et al., 2009):

Load: the moment when the forwarder operates the crane to load the first logs. This phase also includes the time needed to travel along the road and skidding, from one pile of logs to the next.

Unload: the forwarder, unloads the stumps accumulated in different piles depending on the variety. (pruning, firewood and timber work).

Locomotion: the machine moves uphill with no load and then downhill with a full load , including short stretches along the forest road. It is not handling any timber with the crane.

The set of collected data has allowed a hypothesis of the following models (Cavalli et al., 2009):

- Model for the loading phase

effective load = f (distance, slope distance, volume loaded, average volume loaded, number of stumps loaded)

- Model for unloading

effective unload = f (volume discharged, the average volume unloaded, number of stumps unloaded)

- Model for locomotion

effective locomotion = f (distance of unloading, the volume transported, average slope of skidding on the distance)

Variables included forwarding distance, piece volume, load volume and slope. "Distance of unloading" means the total distance travelled by the machine without a load on the outward journey (or upward) and the distance travelled with a full load on the way down (i.e. downhill).

Table 2. Measurements of the forwarder 1110 D

Model	**Features**	**Measurement Unit**	**Value**
1110D - 8	Power	kW	125
	Transmission	-	IDM
	Numeber of wheel	n.	8
	Wheel drive	n.	8
	Max speed of progress	km h^{-1}	24.5
	Total weight empty	Tons	14.6
	Load capacity	Tons	13.5
JD CF510	Arm lenght + Extension	m	10
	Lifting moment	kN	102

Table 3. Measurements of the forwarder 1110 D

Parameters		**Unit**	**Value**
A	Length - *Standard Wheelbase*	mm	9.700
B	Bogie Boss - Centre Joint		1.700
C	Centre Joint - Bogie Boss		3.700
D	Guard Screen - Bogie Boss		2.956
E	Bogie Boss – Rear		2.300
F	Width		3.106
G	Minimum Transportation Height		3.700
H	Ground Clearance		605
Load Space Options			
I	Overall Length	mm	3.303
J	External Width Cross Sectional Area	m^2	4.8

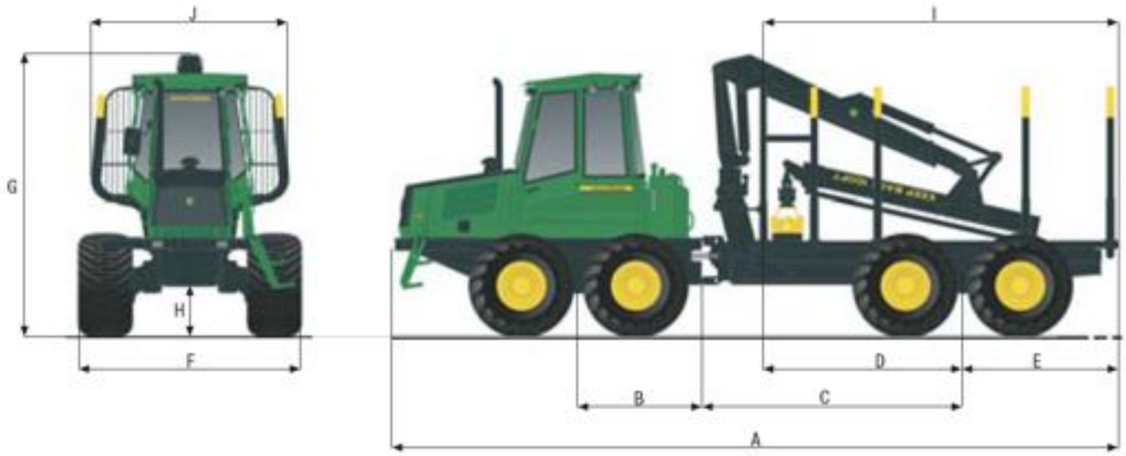


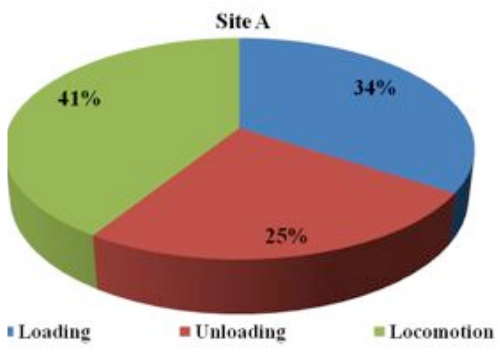
Figure 2. Overview of the forwarder

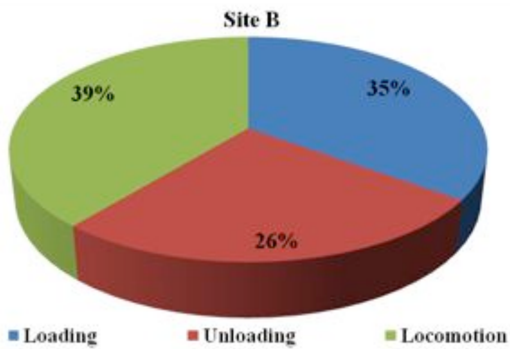
3. Result and Discussion

Table 3 shows the mean values with standard deviation of the parameters in the two test sites in order to examine forwarder productivity. Figure 3, summarizes the average frequency of all three work phases, showing that time spent on the locomotion was greater than for both timber yard test well values found for the other two phases. With an average skidding cycle of 37 minutes, the forwarder carries 8.6 cubic meters of timber, covering a total distance of 1084m. On site B, where features and vegetation characteristics are very similar to site A, the skidding process has a journey time of around 40 minutes. Elaboration of statistical data shows that load efficiency presents a high dispersion of data due to factors such as the average volume of stumps loaded on the truck and the distance travelled during the load (R^2 = 0.12 for Site A - R^2 = 0.18 for site B). During the unloading process, however, both sites revealed that the average volume unloaded only affected the time required to deliver a cargo of lumber stacked along the forest road (R^2 = 0.36 for site A - R^2 = 0.34 to site B). Finally, results for the locomotion process demonstrate that the main variables that affect the operating time of the forwarder are the average slope and distance (R^2 = 0.47 for Site A - R^2 = 0.52 for site B). This confirms the importance of forest roads as a primary element for the forestry Industry. In fact, a good road density allows skidding distances and therefore high productivity. The productivity of the forwarder, which was designed to take work time and downtime into consideration depends on an internal road, not always easy for loading because the concentration may not be in a specific direction. The slope is also not a factor that limits the productivity of the forwarder provided that the maximum slope values do not become too demanding for the mobility of the machine. Indeed, findings demonstrated that the feed rate remains constant with slope inclines that are less than 30% then it gradually decreases as the slope itself increases. The average production (based on free delay hours) was estimated as 14.41 m^3/h in site A and 15.11 m^3/h in site B.

Table 3. Mean values with standard deviation of the parameters measured in the two sites

	Unit	Site A	Site B
Loading time	min	12.7	13.2
	±	5.7	3.5
Unloading time	min	9.1	10.8
	±	2.5	2.3
Time of locomotion	min	15.2	16.4
	±	1.1	1.6
Volume load	m^3	8.6	8.4
	±	1.8	1.7
Average volume	m^3	0.21	0.32
	±	0.11	0.16
N° logs	n	50	52
	±	15	21
Distance of load	m	57.7	57.5
	±	35	60
Skidding distance	m	1084	1150
	±	235	280
Slope	%	23	22
	±	10	9





4. Conclusion

The presence of this innovative, articulated machine used to transport logs, has attracted particular interest in the forestry industry. Forwarder productivity in cut-to-length forest harvesting system is strongly correlated to the volume of payload size and the average extraction distance, and is expected to increase with increases in the payload, but decrease with the increase in average extraction distances. The transportation of timber has always been challenging, especially in mountainous environments where the slope has caused processing limitations. In light of this research, levels of productivity at the two test sites far exceed the average productivity of a typical traditional skidding process. The numerous observations recorded in this study confirm that this type of machine is a good investment, allowing high levels of productivity. The forwarder is essential for efficiency in timber handling, thinning and regeneration harvesting. When the forwarder is only used for the very highest concentration, slowdowns on the sites have been observed. It is important that the two operations are not carried out at the same time so that once the machine is brought to the site it can work continuously and therefore speed up the operation of skidding. It would be better if the choice of trees that are cut down are made in relation to the characteristics of topsoil, the areas topography and road network that allow easy movement for the forwarders. This would allow seamless integration between forestry and utilization, thus ensuring success in economic terms. Outlining a skidding path could represent the necessary conditions for the machine to operate with higher levels of productivity. the results have quantified the variation of forwarder productivity with extraction distance whereby the productivity was found to be higher for shorter extraction distances and larger payloads. In terms of future road building, the position of these roads should be such as to minimize the extent of forwarding that may be economical. The developed models therefore provide a basis for site-specific costing of forwarding operations and potentially a convenient and transparent means of negotiating contract timber extraction.

References

Cavalli R., Grigolato S., Bergomi Z. L. (2009). Esbosco in ambiente montano con cable-forwarder. Atti del Terzo Congresso Nazionale di Selvicoltura per il miglioramento e la conservazione dei boschi italiani. Firenze, 1476-1481.

Cavalli R., Zimbalatti G., Grigolato S., Proto A.R. (2008). “Forest woodchips supply chain in Southern Italy”. Proceeding of International Symposium on Forestry Mechanization, Schmallenberg, 117-124.

Ghaffarian M.R., Stampfer K., Sessions J. (2007) “Optimum road spacing of forwarding operations: a case study in Southern Austria”. Proceeding of International Symposium on Forestry Mechanization, Vienna.

ISTAT, 2008. “Wood fellings and removals on forest, by use and region”, National Institute of Statistics, http://www.istat.it/agricoltura/datiagri/foreste/elefor.html

Neruda J., Valenta J. (2003). “Factors of the efficiency of harvesters and forwarders in logging”. Proceeding of International Symposium on Forestry Mechanization, Schlaegl, 117-124.

Tiernan D., Zeleke G., Owende P.M.O., Kanali C.L., Lyons J., Ward S.M. (2004) “Effect of working conditions on forwarder productivity in cut-to-length timber harvesting on sensitive forest sites in Ireland”. Biosystems Engineering, 87, 167-177.

Zimbalatti G., Proto A.R. (2009). “Prospects of forest utilizations in the South of Italy”. IUFRO - Unit 3.06.00 - Workshop Forestry utilization in Mediterranean countries, Reggio Calabria, 2335-2339.

Zimbalatti G., Proto A.R. (2009). “Cable logging opportunities for firewood in Calabrian forest”. Biosystems Engineering, 102, 63-68.

The authors participated equally in all the phases of the present work