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Wood energy plants and biomass supply chain in Southern Italy

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Abstract

In the last ten years in Italy several companies of the bio energy industry, attracted by Government subsidies planned to build dedicated power that use biomass as their main fuel. The biomass for energy purposes, coming from farms, forestry, timber industry and Short Rotation Forestry (SRF) for energy, can provide various environmental and socio-economic benefits. First of all, the production of forest biomass for energy involves the reduction of CO2 emissions and the improvement of forest functions, such as hydrogeological and biodiversity conservation. Moreover, forest biomass consumption could contribute to the socio-economic development of rural areas, through the restoration of agro-forest activities and technological advances in the bio-energy field. The primary goal of this study is to analyse the local forest wood supply chain. Therefore, field surveys have been done in order to classify the management and the characteristics of the woodchips supply chain (wood sub-product availability, forest enterprises, working systems, forest woodchips quality).

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*Keywords:*Biomass;Wood supply chain;Forest; Eenergy.

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1. Introduction

In the last few years in Italy several bio-energy companies, attracted by Government subsidies, planned and build wood biomass power plants (Emer, Grigolato,Lubello&Cavalli, 2011).In the last ten years the use of wood for heating was promoted with European structural funds, rural development plans, energy projects, regional and provincial fundswas also promoted in Sothern Italy (Proto, Zimbalatti, Abenavoli, Bernardi&Benalia, 2014).

Biomass include all the organic components like wood, wood waste, animal waste, etc. In particular, an attractive opportunity is the waste biomass as agro-industrial sub – products or urban wastes. Biomass can be used to produce heat by combustion, mechanical energy by internal combustion engine or gas turbine (Colantoni, Allegrini, Boubaker, Longo, Di Giacinto& Biondi, 2013: Friso, Grigolato&Cavalli, 2011),power energy directly by the fuel cells (Bocci, Sisinni, Moneti, Vecchione, Di Carlo &Villarini, 2014) or indirectly by mechanical energy (CE,ST,GT,CC) and generator (Moneti, Delfanti, Marucci, Bedini, Gambella, Proto &Gallucci 2015).

Every year, the average increase in wood volume in Calabria (equal to 6-8 m^3ha^{-1}) exceeds and sometimes doubles the estimated increase in other forests in and around Southern Italy (Marziliano, Menguzzato, Scuderi& Corona, 2012; Proto &Zimbalatti, 2015). Again in Calabria (Southern Italy) the expanse of forest is 40.6% compared to average national coverage of 34.7% (Marziliano, Lafortezza, Medicamento, Lorusso, Giannico, Colangelo&Sanesi, 2015). As a result, the forest in Calabria supplies numerous wood industry sectors in Southern Italy. The annual amount of harvested timber in 2011 was 668 912 m^3(ISTAT 2013), about 8.5% of the national total and 37% of the total amount of timber harvested in Southern Italy, where, according to the National Statistical Database (ISTAT 2013), firewood harvesting has increased more than roundwood harvesting (Proto &Zimbalatti, 2015).

The current increasing dynamism of the firewood market has led thus to the development and improvement of technologies able to extract and process hardwood logs more efficiently by reducing consistently the time and labor required for firewood production (Cavalli, Grigolato, &Sgarbossa, 2014). Despite being such an apparent woodland resource, the most common working method in Calabria is still a traditional one, with many yards in the early stages of mechanization. Such a low level of mechanization can be attributed to location, characteristics of the property, the small scale of many enterprises, limited knowledge of modern machinery, and the scarcity of relevant studies on the use of modern machinery (Zimbalatti& Proto, 2009; Proto, Macrì,Bernardini, Russo &Zimbalatti, 2016).

It is based mainly on the use of agricultural tractors, sometimes equipped with specific forest machines like winches, hydraulic cranes, log grapples but also, the use of animals for gathering and yarding is still widely used. Chainsaws are the most common machinery for timber cutting operations (Verani&Sperandio, 2003; Proto &Zimbalatti, 2015). Wood fromCalabria is mainly destined for the production of energy or forbuilding and packing materials. However some wood productsare sent for processing firms in other regions, where they areconverted into quality products (Zimbalatti, 2005; Proto, Macrì, Russo &Zimbalatti, 2016). Therefore, also in Calabria in the last years some woodchips biomass power plants have been installed. As a consequent wood harvesting for energy wood has been stimulated. Figure 1 highlights in fact an increment of wood energy harvesting from 2002 to 2009.

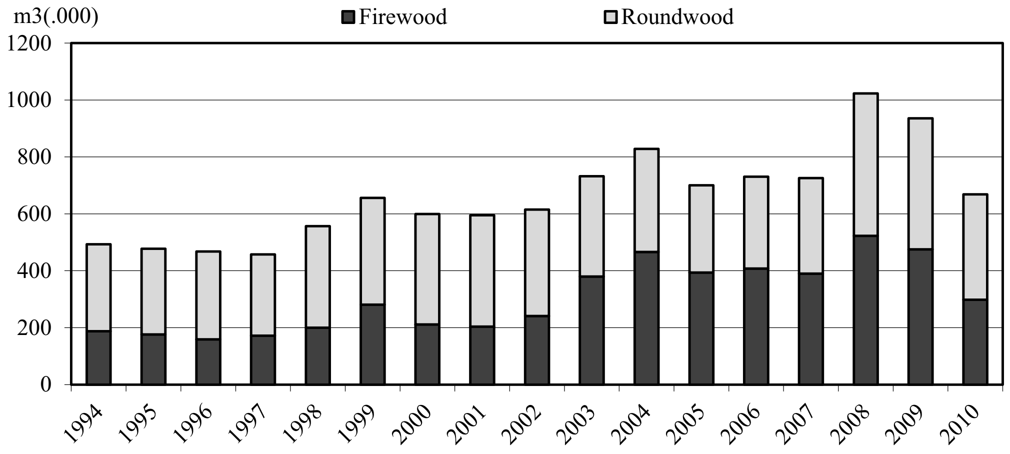

Fig. 1. Harvesting wood in Calabria.

A woodchips production system is a sequence of various steps, including processing, transportation and decision making, with the goal of converting forestry woody biomass into fuel and providing transport of this resource from the forest to conversion plants (Cavalli&Grigolato, 2010). The possibility to use forest biomass for energy production can be realistic only where its supply is economically feasible (Sanesi,Lafortezza, Colangelo, Marziliano& Davies,2013). Cost-efficient woodchips supply in mountainous area depends on chipping and transport interface, transport cost and, where forest biomass for chips production is not considered a by-product, on harvesting and extraction operations (Stampfer&Kanzian, 2006). As the efficiency of forest operations largely depends on forest road network characteristics, therefore chipping and transport interface and biomass transportation also are influenced by forest road network characteristics (Spinelli, Nati&Magagnotti, 2007).

GIS-based analysis results useful also in order to determine the forest biomass woodchips production (Emer, Grigolato, Lubello&Cavalli, 2011). Different approaches have been presented by means of inventory forest data or simply land-use cover data. According to Smeets&Faaij (2007), five types of potential forest biomass quantification can be used: "theoretical", "technical", "economical", "ecological-economical" and "ecological". "Theoretical" quantification represents the maximum availability and it gives just an idea about the potential of an area.

2. Woodchips supply chain in Southern Italy

Overall, Calabria presents 4woodchips big energy plants (< 10 MWe). In this study three of them were considered and their supply chain analyzed. Two of the three woodchips energy plants are located in province of Crotone, properly in Cutro (16 MWe) and Strongoli (46 MWe), along the oriental part of Calabria on the coast of the Ionian sea. The other woodchips energy plant is located in Rende (14 MWe) in the western part of the region.The wood energy plants present different size and annual woodchips demands. Table 1 reports the main data of the wood energy plants. The annual woodchips demand of these three plants reaches 750 000 t (moisture content, w = 50%). The total hourly demand of woodchips is approximately 93 t (w= 50%). Forest woodchips represents the 35-40% of the entire woodchips demand. The remaining amount of woodchips is supply from local wood industries and agriculture residues or by oversea energy wood or agriculture residues importation.

Tab. 1. The main properties of plants case studies.

Plant	Location	Power	wood chips demand	
-	-	MWe	t/h (w = 50%)	t/y (w = 50%)
A	Cutro	16.5	20	160 000
B	Strongoli	46.0	57	460 000
C	Rende	14.0	16	130 000

Therefore, the import of energy wood in Calabria has increased. Mainly energy wood is imported from Latin America because highly competitive. Every year 300 000 tons are imported from these areas to supply wood energy plants. These wood energy plants use also residues from local agricultural practices and these residues cover about the 5% of the demand.This research focuses on the forest supply chain of three wood biomass plants that cover a total power of 70 MWe.

Fig.2.Mobile chipper (a) and wood energy plant at Strongoli (b).

The yearly biomass consumption is estimated in 1 million of green tons. The primary goal of this study is to investigate the local forest “energy wood” (Stampfer&Kanzian, 2006; Marziliano, Coletta, Menguzzato, Nicolaci, Pellicone&Veltri,2015) supply chain in order to describe the realistic use of forest wood biomass for energy production in Calabria.Working systems and wood supply management are thus analyzed in order to highlight the current local forest wood biomass supply chains(Fig. 2.). Three wood biomass power plants were investigated in relation to their supply chains.

3. Material and methods

In the energy wood supply, forest supply represents often the most expensive solution (Ranta, Stampfer&Kanzian,2006; Spinelli, Nati&Magagnotti, 2007). Therefore it is necessary to manage the woodchips production with a cost-efficient supply in order to increase productivity and to reduce costs.

In order to figure the situation in Calabria, the first step is to investigate the current woodchips supply chain. On first, woodchips supply chains were approximately identified. Two different woodchips supply chain were thus highlighted (Fig. 3.). Forest woodchips production can be based on chipping operation location: at yarding closed to forest area or at energy plant. Generally energy plants are used to buy energy wood in form of roundwood and rarely in form of slash. Anyway some forest enterprises are used to chip forest biomass at yarding and thus supply energy plant with woodchips.Thus general figures about supplied woodchips or energy wood were collected for each considered wood biomass power plants: one forest chipping working site at yarding was investigated and the three chipping working sites at each energy plants were analyzed in according to companies data.

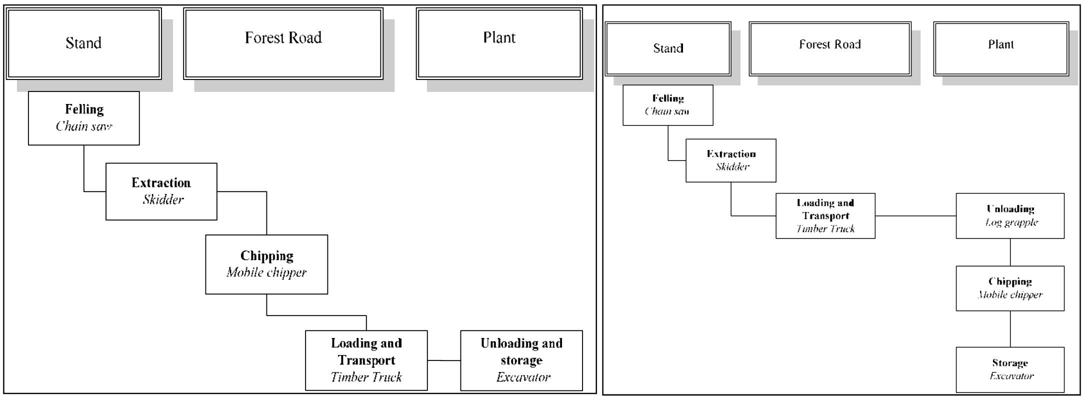

Fig.3. Forestbiomassproduction: two different supplychain.

Above all the “theoretical” amount of forest wood (Smeets&Faaij, 2007) from local area was estimated within a supply distance of 150 km. In fact the “theoretical” forest biomass quantification was consequently used for estimating energy wood (roundwood or woodchips) availability supply curves. One of the most common approach used for supply analysis is to evaluate the annual offer in relation to the supply distance. Costs of transportation highly depend on travel time, which is a function of distance and road properties.Supply investigations are commonly supported by GIS-based analysis: the cumulative “theoretical” mass for woodchips production in relation to the distance of the plant from forest resource area can be used thus for this purpose (Macrì, Zimbalatti, Russo& Proto, 2016). Therefore in this study after the estimation on the availability of forest biomass, the supply analysis considered a transport distance up to 150 km. The analysis was based on network GIS based analysis and land use cover data. For each productive forest hectare an average availability of 2.7 t (w = 50%) was considered.

Woodchips operations have been analyzed both at yarding and at wood biomass energy plant. Working system productivities are related to machine types and power, feeding systems, energy wood material type (roundwood, slash, logging residues).For the chipping site at yarding, working time was analyzed by time studied surveys. The method study was based on stop-watch study in according to Olsen&Kellogg (1983).

4. Results

In order to calculate the hourly cost of chipping operations at yarding as for the chipping at plant, Ackerman et al. (2014) approaches were applied. According to the data and information collected, Table2 reports the hourly costs for two mobile chippers working at energy plant (Rende and Cutro) and for one mobile chipper at yarding. In one energy plant (Strongoli), chipping operation is based on a stationary chipper (BruksKlockner, 1200 kW). For this machine the hourly cost is determined by the company at 160 €/h while productivity is estimated at 94 t/h (w = 50%).

Tab.2.Calculation of mobile chippers hourly costs.

				Jenz 560D	Brucks 803CT	Jenz 561D
			mounted on	trailer	truck	trailer
			working at	energy plant	energy plant	yarding
Description and data	Symbol	Unit	Formula	At plant	At plant	At forest
Purchase price	P	€		230 000	400 000	280 000
Salvage value	S	€	20% P	46 000	80 000	56 000
Estimated life	n	Year	-	8	8	8
Power	Pt	kW	-	205	320	340
Daily utilization	DSH	hr	-	16	8	8
Yearly utilization	DY	Days		240	238	200
Scheduled operating time	SH	hr	DSH*DY	3840	1904	1600
Average fixed investment	AI	€/year	(P-S)*(n+1)/2n+S	149 500	260 000	182 000
Machine maintenance rate	RMr	%	%Depr	13.8	24.0	16.8
Knives maintenance rate	RMc	€/hr	/hr	5.3	6.5	6.0
Interest rate	R	%	-	5	5	5

Taxes and insurance rate	ITGr	%	-	8	8	8
Fuel consumption rate	Fc	l/hr	-	32	40	45
Oil consumption rate	Lc	l/hr	-	0.7	0.9	1
Hydraulic oil consumption rate	Lci	l/hr	-	0.3	0.4	0.5
Fuel cost	Fp	€/l	-	1.3	1.3	1.3
Oil cost	Lpm	€/l	-	2.40	2.4	2.4
Hydraulic oil cost	Lpi	€/l	-	2.40	2.4	2.4
Operators cost	WB	€/hr	-	45.0	45.0	45.0
Fixed Costs						
Annual depreciation	Depr	€/year	(P-S)/n	23 000	40 000	28 000
Interest cost	In	€/year	Al*R	7 475	13 000	9 100
Taxes and insurance	ITG	€/year	Al*ITGr	11 960	20 800	14 560
Total	OC	€/hr	Depr+In+ITG/SH	11.05	38.8	32.0
Operating Costs						
Maintenance and repair cost	RM	€/hr	RMr+RMc	19.1	30.1	22.8
Fuel consumption cost	FC	€/hr	Fc*Fp	41.6	52.0	58.5
Oil and lubricants cost	LC	€/hr	Lc*Lp	2.4	3.1	3.6
Operators cost	Pc	€/hr	= WB	45.0	45.0	45.0
Total	OpC	€/hr	RM + FC+LC+Pc	108.1	130.6	129.9
	TOTAL	**€/hr**	**OC + OpC**	**119.1**	**169.4**	**161.9**

The investigated mobile chipper in forest yarding is a Jenz 561D (340 kW). Time studies concerned the chipping of forest residues and roundwood. The energy wood material was distributed in pile along the forest yarding. Piles had an average dimension: length of35 meters, width from 3 to 4 meters and height up to 2.5 meters. The chipper proceeded along the piles and loaded woodchips directly into woodchips trucks (in average with a capacity of78 m^3). From work time study analysis, the chipping operations presented a productivity of 15 t/h.For what it concerns productivities of chippers working at plants, they were estimated on the data collected by interviews to the companies.

Supply cost was estimated in according to companies indications on transport type and costs. Transport cost by truck and trailer was fixed in 90 €/h. The transport cost (one way) was thus fixed at 0.14 €/km per ton (w = 50%) for energy wood and in the case of woodchips transport at 0.18 €/km per ton (w = 50%).

Supply cost was also related to supply distances and energy plant chipping characteristics. Energy wood biomass price was defined at 26 €/t (w = 50%) at forest yarding. At the yarding energy wood can be chipped or load to truck and trailer (cost was estimated in 0.59 €/t) and transported to energy plant. In this case chipping operations is performed at plant. In Figure 6 forest biomass supply curve for the three power plants is presented. The supply-curves (Fig. 4.) are calculated according to the distribution of forest area and the location of the power plants in relation to road network. The forest potential amount is supposed in 2.8 t/ha per year (moisture content, w=50%).

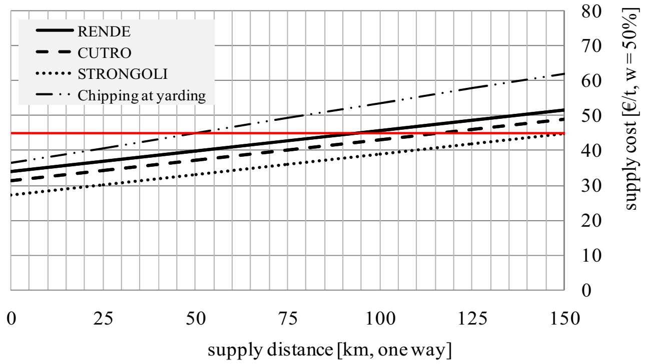

Fig.4. Supply cost for wood chipping process at plant (Rende, Cutro, Strongoli) and at yarding (energy wood cost at yarding = 25 €/t).

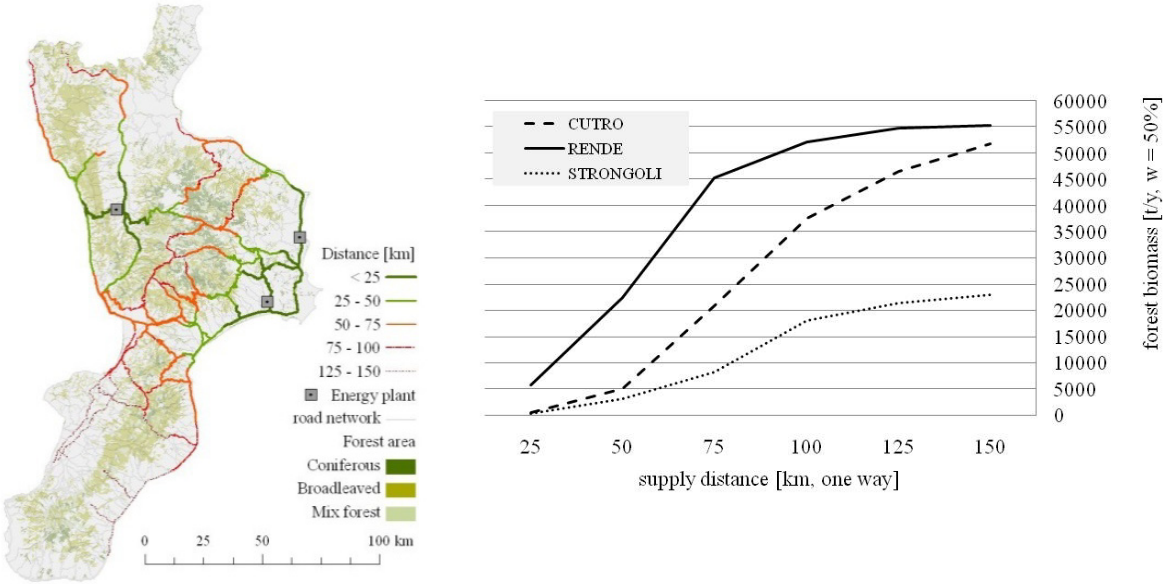

Fig.5. Potential forest biomass amount in relation to supply distance (a: supply distance analysis by GIS; b: supply-curves).

5. Conclusions

The case studies described in this paper show that all aspects of biomass supply chain are evolving. In Calabria, the woodchips demand for energy use is high and it is met partially by local forest enterprises. The current supply chains are nearly to be cost-efficient relating to the oversea importation of woodchips (at harbor 42 €/t, w = 50 %). Increasing local biomass productivity allows for an increasing scale of the entire system. The highest price for local woodchips is justified to promote local economies and social development.In this study, by using geographical resource mapping and cost distance analysis, the costs of woodchips supply from forests to energy plants were analyzed for three selected sites in Calabria. In fact, large amounts of biomass are transported for long distances in the area.The supply analysis highlighted that within a distance of 150 km (Fig. 4.), the offer of forest energy wood is not enough. In fact a part of the residual energy wood come from other part of the region, wood industry or oversea import. For what it concerns the supply cost, the supply chain with chipping operation at yarding result less cost-efficient in respect of the supply with chipping at energy plant. The maximum cost-efficient supply distance, in fact, results 50 km. When chipping is performed at energy plant and the supply considers round wood, the cost-efficient supply distance increase also up to 160 km. That depends on chipping cost: stationary chipping operation at energy plant presents generally a lower hourly cost and higher productivities. In the same time the supply chain shows an advantage when the transport concerns energy wood in form of round wood in respect of woodchips.

The presented model could be improved by adding precision to geographical data on forest production and by investigating the productivity and transport cost. By collecting all the information and integrating them by time studies, the analysis could be complete with an optimization study.Anyway, the improvement of forest resource in Calabria cannot be attained only through a general increment in terms of woodchips supply but should be rather based on a re-arrangement of the management of the same productive forest area likely to result in a steady productive supply of timber that responds to the needs of the woodchips market.The increase of productivity, both for the forest firms and for all the wood row companies, is due to a constant search of production efficiency, a proper selection of machinery and integration among the different sections of the row.

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