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WOOD CHIPPING SERVICE: AN ANALYSIS APPROACH IN NORTHEASTERN ITALY

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Abstract: *With the spread of wood chip boilers and district heating, the chipping service in North-eastern Italy is gradually growing.*
With a GIS based approach is possible to define operative areas of chipping services in relation to the availability of wood biomass that potentially can be chipped. By evaluating the amount of wood that could be chipped, it is possible to check if chippers have the warranty of operating time so that the machine initial investment is justified. Moreover, the possibility to buy and use further chippers, that can work in a sustainable way with the potentially available biomass, can be evaluated.
Wood biomass for chipping service, potentially available from forest and sawmill, is estimated and combined to chipping service headquarters distribution and to road network. Chipping service productivities and costs are considered for two classes of machines: big and medium power class. In the supposed conditions, the study highlights that the current distribution of chippers in the North-eastern Italy require about 70 000 t/y of woody biomass from forest and wood industry. Some more biomass is still available to be chipped, but actually it can be covered with a more far working distance. Moreover not all estimated wood biomass can be technically supplied because of high cost.

1. Introduction

In Northern Italy, regional governments are promoting the use of woody biomass for heating: in particular the exploitation of wood chips in small and medium size heating plant. As consequent, installation of small scale wood chips boilers and development of districts heating are gradually increasing. Therefore chipping service is quickly growing to fuel supply these technologies.

In North-eastern Italian Alps, logging residues represent an important wood source for energy purpose (Spinelli et al., 2007). Both full time chipping service enterprises and small-medium forest enterprises, that want to integrate their income and strengthen and broaden their services, can exploit it.

Chipping service activity is connected to the presence of wood chips heating boilers demand and to the availability of wood biomass resources. Small forest enterprises are interested on wood chips production when chips demand is located nearby their operating area. In this case enterprises wish to integrate their main activity by offering chipping service. On the other side, medium dedicated forest or other related enterprises (such as wood transporting or wood dealer enterprises) find interesting a full time chipping service activity.

1.1. Chipping service and forest enterprises

Chipping service is carried out with different technologies machines, tractor or self-powered, and different cutting systems. Forest enterprises owning a chipper can mainly provide two kinds of service: chipping as a part the forest enterprise practices or exclusively chipping service.

Medium power chippers (within 220 kW) are mainly owned by farmers, small forest enterprises or wood fuel dealers. Usually forest enterprises and wood fuel dealers invest on chippers for a self-use and/or to offer chipping service up to 30 km (rarely up to 45 km). In this way chipping service can become a distinctive aspect of forest enterprises practice. In North-eastern Italy, l chipping service in exchange of material is becoming quite common both in mountainous and in lowland areas: wood chips can be then sold to local wood biomass district heating or to single wood chip boilers.

A professional chipping service is usually carried out with more powerful chippers (over 220 kW). In this case, forest or wood dealers' enterprises offer often their service also beyond regional borders and at unconstrained distance. Chipping services the becomes a full time activity, mainly oriented to provide just chipping operation. Usually, enterprises are paid for the service, but sometimes they can exchange chipping operation with material: this can be realistic only if it is convenient and if the chipping site is located close to the destination.

Professional chipping service enterprises accept to move also far from headquarters in order to achieve the desired annual productive time and thus recovering the initial investment cost.

1.2. Chipping service and working site

Chipping service can work both at sawmill or heating plant storage area and at forest landings or at intermediate terminals. If the work is carried out close to sawmill or heating plant backyards or near to river banks or in a wood biomass platform, it is usually easily reachable with a big chipper machine.

Chipping service in forest condition, as generally for all the forest operation with larger machines, requires particular attention on planning working operations and on evaluating the possible productivity and cost because of the usually limited space to accomplish the operations.

In North-Eastern Italian Alps, medium power chippers (generally mounted on semi-trailers and pulled by tractors) are more suitable for working on forest mountain conditions, since they can easier move along forest road network respect to bigger powerful chippers mounted on trucks. Medium power chippers have usually a lower productivity per hour and limitations on maximum feeding size; thus, even if hourly equipment cost is lower respect to big machines, the chipping cost (€/t) results higher.

Big truck-mounted chippers move for exploiting service only if an adequate amount of wood is available to be chipped, usually at least 40-50 tons. For lower amount of material moving a big chipper can be more expensive than moving a medium one. Furthermore, for taking advantage, big chippers need a wide enough working site area. A suitable area has to be enough wide to guarantee an adequate space to the machine and at the same time enough quantity of well heaped up logging residues. An amount of 10 tons (moisture content around 45%) of well heaped up logging residue can require approximately between 20 m^2 and 35 m^2, depending on logging residues sort and disposition as well as wood density and residues stack height. Moreover working sites need to be suitable for trucks and trailers or containers where loading chips.

1.3. Objective

Nowadays, chipping service is increasing in North-eastern Italian regions. Different kinds of service are proposed by the enterprises: few of them are willing to work far from headquarters while most of them assert to accept to work only within a specific area, according to wood biomass amount potentially available to be chipped.

This paper wants to define an approach for evaluating how many chippers can work within a specific region in relation to wood biomass potentially available to be chipped.

The main aims is to develop an approach (mainly based on spatial analysis) in order to define the operative area of different chipping services, evaluating if the available amount of biomass is enough to guarantee the minimum amount of operating time. As a secondary aim, the approach wants to point out if there is still space for other chipping services in the studied area.

2. Material and methods

The studied area corresponds to the North-eastern part of Italy and it includes Trento and Bolzano autonomous provinces, Veneto and Friuli Venezia Giulia regions.

2.1. Wood biomass available for chips production

The theoretical availability of forest wood biomass (FWB) [t] for chips production (1) is estimated on different assumptions. Considering cutting volume of every region (CV_i) [m^3] on the forest area (A_i) [ha] (Cavalli, 2004) and potential chip production (CP_i) [t][m^{-3}] for each cubic meter of yield (according to forest silvicultural systems), FWB is estimated. In particular, it is supposed that coppice stands are mainly used for wood fuel production and especially for firewood, but logging residues can be used for wood chips. As well for coniferous stand and high broadleaves forest, where main logs destination is wood industry, while logging residue can be exploited in wood chips production.

Forest wood biomass residues are, here, expressed in tons per hectares. According to the different composition, for each specific region, of the tree species presence, a weighted average of wood density at 45% of moisture contents (wet basis) (Hellrigl, 2006) was calculated for broadleaves forest and for coniferous forest. Consequently wood densities are therefore spatially applied to CV_i value. Forest area and its two main typologies are derived from the second level of *Corine Land Cover* geodatabase (CORINE, 2004).

Potential chips production (CP_i) corresponds to 20% and 15% of cutting volume considering respectively coppice and high forest stands (Pedrolli, 1999). In this case, it is considered that only 80% of these can be used to produce chips. Moreover, trees can be partly pruned in order to make easier extraction operation and in order to reduce damages to standing trees. As a consequence 30% of volume (FWB) is supposed to be left in the forest: thus a reduction coefficient of 0.7 is applied.

$$\mathrm{FWB} = \frac{\sum CV_i \times CP_i}{\sum A_i} \times 0.7 \qquad (1)$$

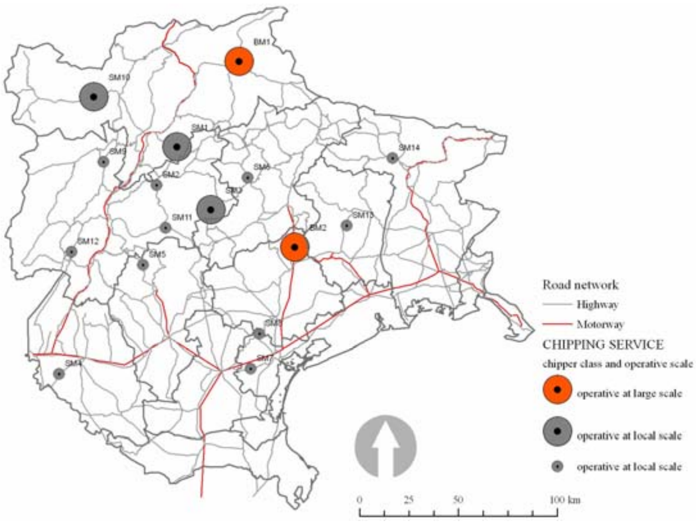
The estimation of wood industry by products results complex because of lack of data or lack of up-to-dated data concerning wood processing. Only for coniferous processing there are some current data at regional scale (Cavalli *et al.* 2006; Pietrogiovanna, 2002). Consequently, wood industry residues are calculated according to data collected from telephone interviews to regional forest service and to other committed regional service (PAT, 2007; Legno Servizi, 2007).

For each region only the 33% of the total amount of wood industry residues (such as raw wood biomass) is considered as available. In fact, sawmill residues that can be chipped by chipping service are in form of slash. Most of wood industries chip residues by their own stationary chippers, so not all the wood industry residues are available to be chipped by external enterprises. As for logging residues, wood industry residues are evaluated with a moisture content of 45% (wet basis).

2.2. Chipping service in North-eastern Italy

Data concerning chipping service were collected interviewing forest enterprises and by collecting data from the Italian Association on Agriculture and Forest Energy (AIEL, 2007) and local forest service (PAT, 2007). Data are classified by considering chipper size, scale of operative area and type of enterprise (Figure 1; Table 1).

Forest enterprises (FE), wood dealers enterprises (WD) and urban green service enterprises (UG) are not considered as full time operating in chipping service. Enterprises classified as chipping service (CS) are full time working in wood chips production. In North-eastern Italy 16 chippers are operative offering full time or as part time chipping service.



CS	Localisation	Operative	Chipper	Enterprise
ID	province	scale	size	
SM1	BZ	local	big	CS
SM2	TN	local	medium	FE
SM3	TN	local	big	WD
SM4	VR	local	medium	UG
SM5	VI	local	medium	FE
SM6	BL	local	medium	FE
SM7	VE	local	medium	UG
SM8	TV	local	medium	UG
SM9	TN	local	medium	FE
SM10	BZ	local	big	CS
SM11	TN	local	medium	FE
SM12	TN	local	medium	FE
SM13	PN	local	medium	FE
SM14	UD	local	medium	FE
BM1	BZ	large	big	CS
BM2	TV	large	big	CS

FIGURE 1 and TABLE 1: chipper distribution on North-eastern Italy according to power size, operative area scale and enterprise typology ***(CS: exclusively chipping service; FE: forest enterprise; WD: wood dealers; UG: urban green service)***

2.3. Chipping service: productivity and cost classification

In order to support spatial analysis, chipping machines are classified in two main classes: medium and big. Therefore, to highlight main characteristics of each class, two machines are considered as representative: a medium-size chipper powered by a 121 kW tractor and a big-size chipper with autonomous engine (361 kW) mounted on a truck. The machine costs were estimated using methodologies well-known in literature (Miyata, 1980; Brinker *et al.*, 2002) and getting specific data from the machine owners.

Different hypothesis of yearly utilization from 300 to 1000 hours were formulated (Figure 2 and Figure 3), which result in different yearly chip output. Considering data from field studies and literature (Spinelli and Mao, 2004; Spinelli *et al.*, 2006a; Spinelli *et al.*, 2006b; Spinelli *et al.* 2007) the hourly productivity was set to 7.0 t/h and 15.5 t/h respectively for the medium and the big-size chipper. On table 2, data for spatial analysis elaboration are presented according to yearly utilization of 300 h/y for a medium class and 600 h/y for a big chipper.

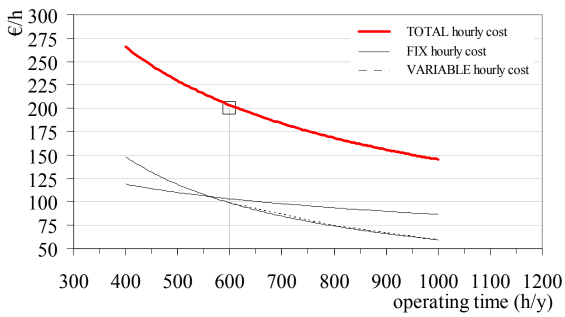


FIGURE 2: hourly cost according to annual operative hour for big chipper class

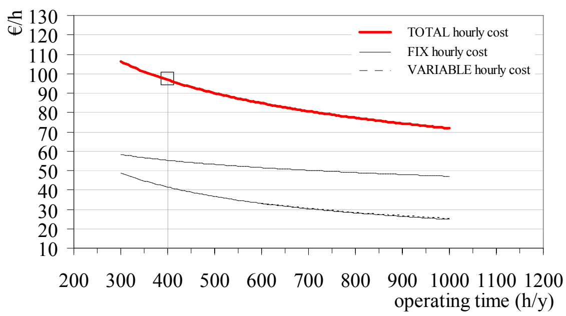


FIGURE 3: hourly cost in relation to annual operative hour for medium chipper class

TABLE 2: considered chipper classes and parameters employed on GIS-based spatial analysis

Chipper	Power	Operating time	Productivity		Cost	
	kW	h/y	t/h	t/y	€/h	€/t
medium	120-220	400	7.0	2 100	113	18.57
big	220-350	600	15.5	9 300	200	14.40

2.4. GIS analysis approach

GIS based analysis consists in evaluating wood biomass available within a definite distance from chipping service enterprise headquarters. According to the two different forms of chipping service (part time and full time), maximum working distances are fixed to 30 km for local operating scale (SM) and 200 km for large operating scale (BM).

Distance analysis is based on network analysis over main public road: all the road network of the different four administrative districts are merged in order to build a common inter-district network. Highway and motorway are distinguished, considering that chippers working on as local operating scale are not supposed use motorway.

GIS-based network analysis considers a dataset specifically built for the investigation: it includes enterprise headquarters, wood biomass sources and road network as dataset subtypes. All of the previous subtypes are strictly connected with specific rules (ESRI, 2007).

Wood biomass sources consist in points along the main public road network (excluded motorway network) where all the forest wood biomass available for chips production is allocated. Wood sources represent, thus, the working site within a small district where forest wood biomass can be delivered. This approach is based on allocating forest wood biomass (FWB) in one point that represents a site inside a specific area where chipping service can be carried out. In fact, in this approach chipping is supposed as a service and therefore the investigation focus on the evaluation of wood biomass available for more than one machine within the same area.

GIS-based analysis indicates the potential amount of forest wood biomass available for each machine operating in a well defined area. Besides, in this approach analysis considers the different chipping service characteristics as: minimum operating amount (t/y) in relation to chipper class and maximum working distance as fixed by enterprise.

For each chipper, considering the operating area, nearby availability of wood industry residues is added to FWB amount.

3. Results

3.1. Available wood biomass for chipping service

The wood biomass availability from forest operations is considered suitable for chipping service when wood sources present at least 10 t/y of logging residues. According to GIS based analysis, this happens for the 56 % of wood sources. Wood forest biomass available to be chipped is estimated then in 41 282 t/y for all the North-eastern area.

From wood industry, an amount of 77 189 t/y results available to be chipped. Most of these residues are concentrated on the northern part of the investigated area, where the concentration of medium and big class of chippers is higher. Figure 4 summarizes the availability of wood biomass.

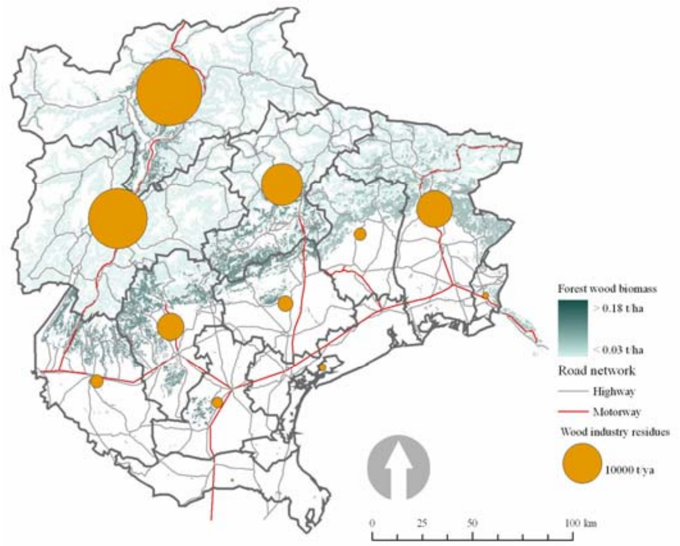


FIGURE 4: raw forest wood biomass and wood industry residues amount useful for wood chips production

3.2. GIS-based results on chipping service operating area

According to network analysis , maps report the operative area for each chipping service (Figure 5 and 6). Figure 7 shows areas where different chipping service are overlapping: there, enterprise has to share FWB and wood industry residues.

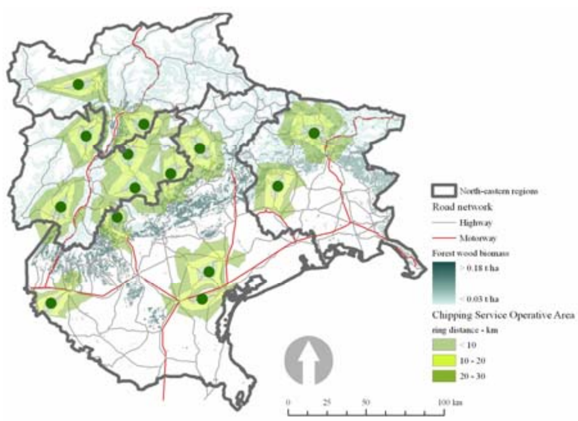


FIGURE 5: chipping service operating at local scale (SM)

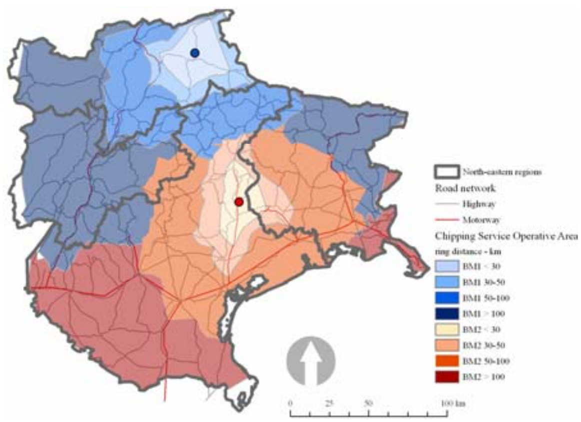


FIGURE 6: chipping service operating at large scale (BM)

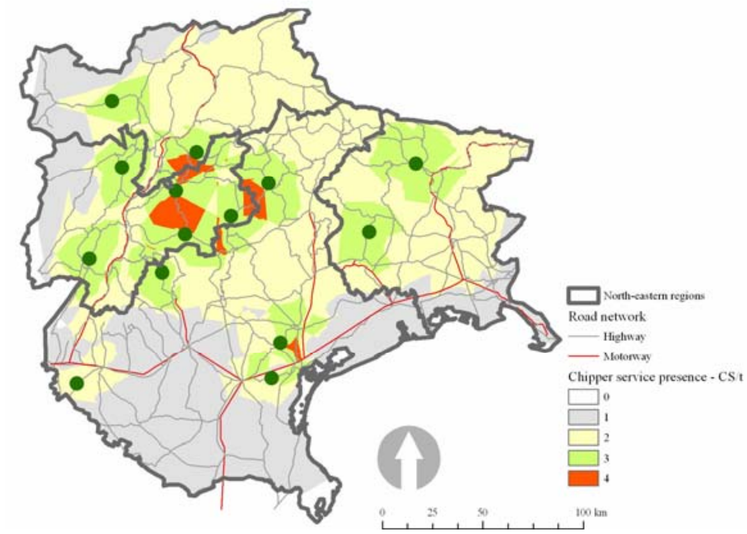


FIGURE 7: number of chipping service (CS) exploiting wood biomass availability (t/y) as CS/t

3.3. Availability of wood biomass for chips production in relation to the actual number of chipping service

Overlaying results about operative area of chipping services and availability of wood biomass (FWB and wood industry residues), it is possible to observe that in North-eastern Italy 48 871 t/y of wood biomass from forest operations and wood industry are still available to be chipped (Table 3).

TABLE 3: wood biomass from forest operation and wood industry available to be chipped

		A	B	C	(B+C)-A
Operative area	CS ID	minimum amount*	from forest**	from industry***	±Δ
SMALL SCALE	-	t/y	t/y	t/y	t/y
forest	SM1	9300	263	6250	-2787
forest	SM2	2100	281	2935	1116
forest	SM3	9300	218	2935	-6147
rural and urban	SM4	2100	357	500	-1243
forest	SM5	2100	291	1699	-110
forest	SM6	2100	853	3745	2498
rural and urban	SM7	2100	251	500	-1349
rural and urban	SM8	2100	381	667	-1052
forest	SM9	2100	220	2935	1055
forest	SM10	9300	366	6250	-2684
forest	SM11	2100	317	2935	1152
forest	SM12	2100	1	2935	836
forest	SM13	2100	0	450	-1650
forest	SM14	2100	416	2987	1303
-	*subtotal*	51 000	4215	37 723	-9062
LARGE SCALE	-	t/y	t/y	t/y	t/y
all	BM1	9300	19 839	19 733	30 272
all	BM2	9300	17 228	19 733	27 661
-	*subtotal*	18 600	37 067	39 466	57 933
		A	B	C	(B+C)-A
		minimum amount*	**from forest****	**from industry*****	**±Δ**
		t/y	**t/y**	**t/y**	**t/y**
-	**TOTAL**	**69 600**	**41 282**	**77 189**	**48 871**

*Note: * minimum workable amount per year; ** by estimation on potential logging residues; *** by estimation of raw wood industry residues available in form of wood slash*

Table 3 evidence that 57% of chipping services operating at local scale present, within their operative area, an insufficient exploiting wood biomass; some of these enterprise have declared that, as they are not full time chipping service, in actual fact they make use of machines less than 400 h/y in the case of medium chippers and less than 600 h/y in the case of big chippers.

Chipping service based on large scale operative area present, still within a exploiting distance of 200 km, an adequate amount of wood biomass to warranty the minimum operating hour fix from the same enterprise in order to get machines recovering.

4. Discussion

Results evidence that chipping services can face problems to achieve the desired number of machine operative hours per year if they are oriented to work exclusively at a local level. In fact, a maximum working distance of 30 km is not always enough to reach 400 h/y, corresponding, for a medium class chipper, to a production of 2100 t/y. It is also worse for a big chipper, which, working within this distance, can never reach the 800 h/y. In fact, the three big chippers operating at a local level (Figure 1) actually do almost exclusively stationary chipping at headquarters, being part of wood fuel processing platforms.

Chipping services working at large scale level, on the other side, can more easily work the minimum yearly amount of operating hours, since they can exploit larger areas. Anyway the machine moves from headquarter only if a minimum amount of wood biomass is available (at least 40-50 tons when it requires one day of work in proximity to headquarter).

If more large scale chipping services are working in proximity and local scale chipping services are quite widespread, for big chippers the minimum working distance will have to increase. Figure 8 and 9 compare, for chipping services BM1 and BM2, two minimum working distances: potential working distance (WDp) and current working distance (WDc). WDp represents the potential distance supposing that only the considered chipper is working in the area of study, while WDc corresponds to the distance in the real situation, with another large scale chipping service and other 14 local scale chipping services operating in the considered area.

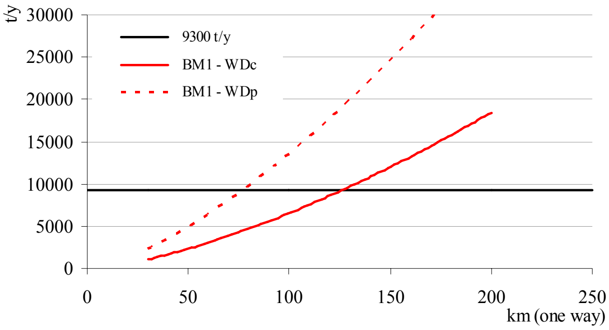


FIGURE 6: WDc and WDp for chipping service BM1 (according to GIS based analysis on the area of study)

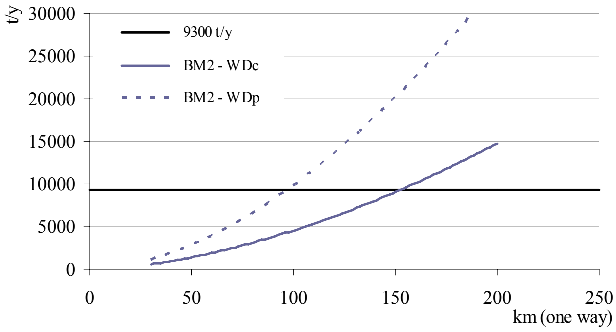


FIGURE 7: WDc and WDp for chipping service BM2 (according to GIS based analysis on the area of study)

5. Conclusion

With the present work, in order to understand if the current number of chipper machines can increase, the existing distribution and characteristics of chipping service over a specific area is observed,. In the same time, the study focuses on evaluating how chipping services influence each other.

In the studied area, results are exclusively based on forest wood biomass in form of logging residues and on wood industry residues in form of slash. The study sorts out that current chipping services could use no more than 59% of total available biomass, meaning that the number of chipping services in the considered area can increase. Moreover other wood biomass sources can be considered, such as urban and orchard pruning, so that a bigger wood biomass amount could be adsorbed by the higher number of chipping services.

Even if wood biomass is enough to guarantee other chipping services, it has to be considered that a part of wood biomass could not be easily exploitable; additional chipping service then, both at local and large operating scale, require a precise evaluation.

Spatial evaluation on chipping service and wood biomass availability shows that, even if the raw material is enough, when more chipping services cover the same area the minimum working distance must increase: hence, chipping service will present higher cost due to the higher distances to be covered.

The main limit of this study is about FWB and wood sawmill residues evaluation: the actual yearly amount to be chipped results hard to calculate and consequently to validate.

The present approach on evaluating chipping service is just on its first developing phase: next steps will require an improvement in data quality and archiving methods on chipping service in order to develop *geodatabase*. It could include complete georeferenced information for each chipping service and their main customers. This would result in a useful dataset to support planning and management of wood fuel supply chain at a regional scale, while forest enterprises could find it helpful to clear up the possibility to deal with this chain.

6. References

AIEL (2007). Associazione Italiana Energie Agroforestali. Legnaro (PD). *Personal communication*

Avena V. (2006). *Valutazione della funzionalitá e della produttivitá delle macchine impiegate per la sminuzzatura del legname.* Dendronatura. 1: 53-58

Brinker R.W., Kinard J., Rummer B. and Lanford B. (2002). *Machine rates for selected forest harvesting machines.* Circular 296 (revised). Auburn, AL: Alabama Agricultural Experiment Station, Auburn University

Cavalli R. (2004). *Le utilizzazioni forestali nell'Italia nord-orientale.* L'Italia Forestale e Montana. 59 (6): 453-465

Cavalli R., Grigolato S., Redigolo N. (2006). *Impiego dei residui di lavorazione delle segherie. Risultati di un'indagine condotta in Veneto.* Sherwood. 12 (2): 37-41.

CORINE (2004). *Corine Land Cover Project*. APAT: Roma. Available on line: http://dataservice.eea.europa.eu

ESRI (2007). *ArcGIS Desktop Help*. Environmental Systems Research Institute. Redland, CA. Available on line: http://webhelp.esri.com/arcgisdesktop/9.1/

Hellrigl, B. (2006). *Elementi di xiloenergetica.* AIEL, Associazione Italiana Energie Agroforestali. Legnaro (PD)

Legno Servizi (2007). Cooperativa Legno Servizi. Amaro (UD). *Personal communication.*

Miyata E.S. (1980). *Determining fixed and operative costs of logging equipment*. USDA Forest Service, General Technical Report nc-55 USDA. St Pail, Minnesota: North Central Forest Experiment Station.

PAT (2007). Servizio Foreste e Fauna, Provincia Autonoma di Trento. Trento. *Personal communication*.

Pedrolli M. (1999). *Disponibilità e costi di raccolta delle biomasse per usi energetici.* Servizio Foreste e Fauna. Provincia Autonoma di Trento. Trento

Pietrogiovanna M. (2002). *Studio sulla disponibilità di biomassa per la produzione di energia termica in Alto-Adige.* Provincia Autonoma di Bolzano. Bolzano. Available on line: http//:pro-lignum.it/

Spinelli R., Mao G. (2004). *Approvvigionamento degli impianti di teleriscaldamento. Quale strategia?* Sherwood. 10 (7): 21-27

Spinelli R., Magagnotti N., Hartsough B. (2006a). *Raccolta integrata di tondame e biomassa nel taglio a gruppi di fustaie alpine.* L'Italia Forestale e Montana. 61 (4): 303-316

Spinelli R., Nati C. and Magagnotti N. (2006b). *Recupero di biomassa, alcune utilizzazioni di boschi alpini.* Sherwood, 12 (2): 21-27

Spinelli R., Nati C., Magagnotti N. (2005). *Recupero di biomassa residua nel taglio a gruppi in fustaia alpina.* Dendronatura. 4: 49-59

Spinelli R., Nati C., Magagnotti N. (2007). *Recovering logging residues: experiences from the Italian Eastern Alps.* Croatian Journal of Forest Engineering. 1(28):1-9