RECOVERY OF PRUNING WASTE FOR ENERGY USE: agronomic, economic and ecological aspects

Silvia Silvestri, Andrea Cristoforetti, Enzo Mescalchin
Fondazione Edmund Mach

Istituto Agrario
di San Michele all'Adige (TN) Italy

Raffaele Spinelli

CNR IVALSA
San Michele all'Adige (TN) Italy

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Introduction

- In Italy about **2 million ha** of surface are dedicated to vine cultivation.
- Vine requires much tending; the yearly pruning produces at least **1 dry ton of biomass per ha**.
- Agriculture generates other kind of wood biomass residuing from the pruning of **olive groves, vineyards** and other **orchards.** It has been estimated to be about **2.85 million tons** every year (Italy).
- Pruning waste is usually cut and left in the field; in some regions they are burnt but this practise is often forbidden due to smoke, dusts and odours. Old plants and roots must be delivered to landfill site; the estimated whole **cost for pruning treatment is 75 € ha^{-1}**
- Pruning wood can play an important role in any analysis of biomass availability conducted in the mediterranean area and agricultural regions.
- This opportunity can be seized only if the biomass is delivered to the end user within set price limits.

Objectives

- To test different types of machines available on the market for the recovery of pruning waste (harvesting and processing).
- To define the best working conditions aimed at reducing the collection costs in the studied area (Northern Italy).
- To verify the quality of biomass for the energy recovery.
- To detect the environmental quality of the agricultural biomass and of the smokes after combustion in small boiler and big boiler.

Materials and methods - Harvesting

4 machines were tested to evaluate the productivity and the variables affecting it:

1) square baler
2) round baler
3) comminuter with drop-down re-usuable container
4) comminuter with built-in dumping bin

System	n.	1	2	3	4
Implement type		Baler	Baler	Comminuter	Comminuter
Bale shape		Square	Round	-	-
Bale Size	cm	40x30x60	40x60	-	-
Container type		-	-	Big bag	Dump bin
Container capacity	m^3	-	-	0.8	1.7
Implement weight	kg	650	498	1,075	1,180
Implement connection		Towed	Carried	Carried	Carried
Implement price *	€	9,900	12,000	9,500	13,450
Tractor power	kW	40	40	77	77
Crew	n°	1	1	1	1

* without VAT

Materials and methods – Biomass quality

The yearly amount of wood produced depends on many factors: the yield, the growing system adopted, the year, the variety (Merlot, Cabernet, Chardonnay etc…)

The Ravaz index is the ratio between the amount of grape produced and the amount of pruning wood.

	Merlot	Lagrein	Pinot nero	Marzem.	Teroldego	Cabernet sauvign.	Mueller thurgau	Pinot grigio	Chardon.	Sauvignon blanc
2002	5,1	3,1	2,2	1,9	1,9	1,5	3			
2003	6,2	6,9	4,8	5,6	4	3,7	4,9	3,3	4,7	6,7
2004	5,5	4,6	4,9	5,2	3,5	3,4	7,8	4,2	6,5	3,5
2005	3,5	3,7	2,7	3,8	1,4	2,5	5,9	4	2,5	2,7
2006	3,2	2,6	4,2	3,1	1,3	2,6	4,2	2,7	3,3	
2007	3,8	3,8	3,7	3,2	2,6	1,6	4,4	5,6	4,7	6
average	**4,55**	**4,12**	**3,75**	**3,80**	**2,45**	**2,55**	**5,03**	**3,96**	**4,34**	**4,73**

(*source: FEM, Project"Il Maso di Cavit"*)

Materials and methods – Combustion tests

100 m³ of pruning waste were collected and stored at the open for 2 months covered with geo-textile; moisture was checked at fixed intervals.

	Plant 1 Industrial boiler	**Plant 2 Domestic boiler**
Thermal power (installed)	8 MW (4+4)	55 kW
Grate	mobile	mobile
Feeding	pusher	auger
Smoke treatment	ESP	--
Management of burning parameters	automatic (fixed % O2)	manual

Results - Harvesting

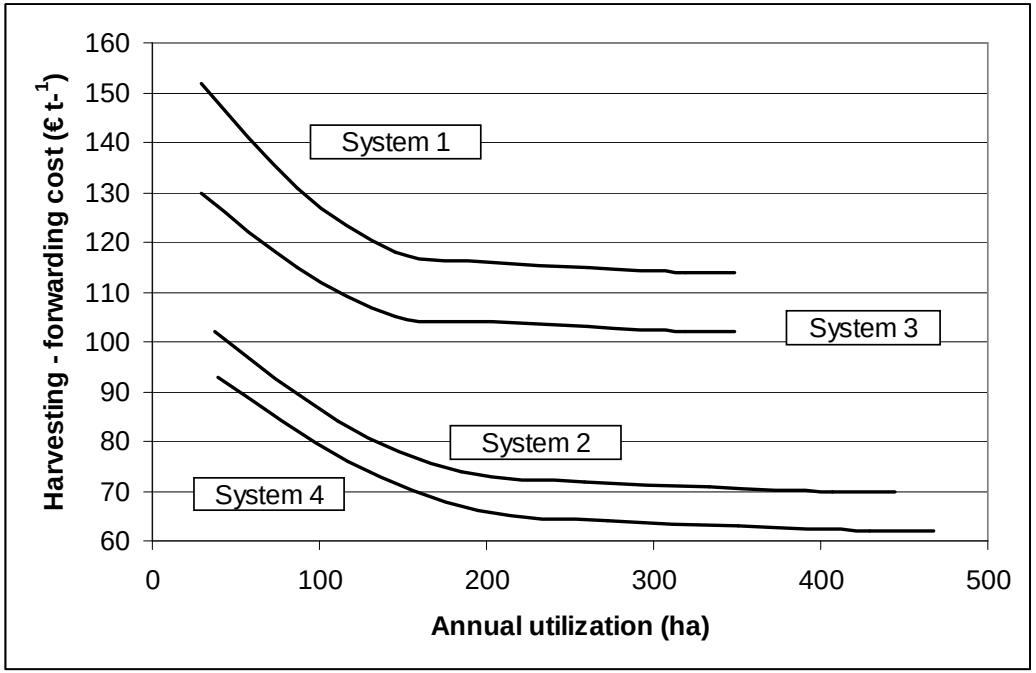
10 ha were harvested producing 21 tons of biomass corresponding to 2.1 tons ha^{-1};

40 hours needed: 15 by harvesting and 25 by forwarding to the collection point

System	**n.**	**1**	**2**	**3**	**4**
Surface area	ha	2.14	3.29	1.79	3.00
Residue mass (water 44%)	tons	4.3	7.5	3.6	5.8
Residue yield	tons ha^{-1}	2.0	2.3	2.0	1.9
Net work time	hours	2.8	3.5	2.6	3.0
Total work time	hours	3.7	4.4	3.1	3.8
Delays	%	25.4	20.2	14.7	23.2
Productivity	tons $hour^{-1}$	**1.15**	**1.68**	**1.18**	**1.50**
Productivity	ha hour-1	0.58	0.74	0.58	0.78
Units **	n°	277	243	22	19
Unit weight	kg	15	31	164	303
Density	kg m^{-3}	215	414	208	203
Hourly cost	€ $hour^{-1}$	32	33	38	40
Unit cost	€ ton^{-1}	27.9	19.7	32.3	26.7

** units are: square bales (1), round bales (2), big bags (3) and bins (4)

Relationship between use and harvesting-forwarding costs



- The harvesting-forwarding cost is drastically reduced when the residues collection implement can be used yearly on at least 150-200 ha.
- Beyond that, cost will not drop much as a result of increased utilization, and 200 ha year^{-1} can be taken as good target utilization level for prospective users.
- System 4 shows the highest overall efficiency.

Results - Agronomical quality of biomass

Pruning wood in Trentino ranges between 1.5-2.5 tons ha^{-1}.

2 tons ha^{-1} pruning wood → 0.35 tons humus (*K1* 30%)

0.35 tons stable humus →
- 0.50 tons of mature manure
- 0.10 tons of manure compost
- 0.65 tons of pelletized manure

Average soil *K2* : 0.10 – 0.20 tons ha^{-1} * year of humus

The organic fertilization is always necessary

K1 = isohumic coefficient

K2 = humus mineralization coefficient (source: Bulletin ERSA FVG, 1/04)

Results - Analytical quality of pruning wood

Moisture at the cutting:	45 - 48 %
- after 3-4 months in the field:	40 % circa
-after storage in pile for several months:	33 - 35 %
	It's OK for burning

Lower calorific value (moisture 35 %):	12 MJ kg^{-1} (3.3 kWh kg^{-1})
LCV of forestry wood chip:	3 - 3.4 kWh kg^{-1} (source: AIEL)
Ash content:	3 - 4% (f.w.)
Ash content of forestry wood chip:	0.2 - 0.5 % t.q. (source: AIEL)

With respect to the environmental quality the analyses showed the presence of pesticide residuals both at the cutting and after the remaining on the ground. Only sulphur and copper are present in the samples from organic farming, while products against the oidium, grape mildew, and botrytis were found in those collected in conventional vineyards.

Results – Combustion tests in the big boiler

All the data are the mean values of three replicates (20'/sample) and refer to 11% O2 concentration:

- all the parameters are within the national limits stated for the biomass combustion;
- the comparison with wood chip showed a higher content of dust in the agricultural waste, which remains below the limit (1/5 of the limit);
- the same consideration is for NO2, higher in the pruning waste but equal to a half of the law limit;
- the small size of pruning wood turned out in a limited O2 diffusion through the biomass and consequently a high CO fluctuations (between 5-263 mg Nm^{-3}).

	Combustion		National limits D.Lgs 152/06 > 6 MW
	Pruning wood	Chipped wood	
Total dust	5.8	0.6	30
Total org.Carbon	< 1	nd	30
CO	148.5	13.7	250
NO_2	208.2	168.3	400
SO_2	8.1	11.02	200

Results – Combustion tests in the domestic boiler

The Italian law distinguishes three class of boilers (and limits) on the basis of the power size: in the studied case (55 kW) only total dust has to be controlled even if TOC, CO, NO2 and SO2 were determined:

- CO seems to be the most problematic parameter due to its relationship with the oxygenation of the mass during the burning;
- the 2nd trial permitted to improve the combustion conditions and to reduce the CO content;
- in any case it remains higher than the limit for the medium size boiler.

	Test 1	Test 2	National limits D.Lgs 152/06		
	55 kW		35-150 kW	150 kW- 3 MW	> 6 MW
Total dust	145.2	169	200	100	30
Total org.Carbon	3.6	< 1	-	-	30
CO	674.9	418.1	-	350	250
NO_2	233.7	345.3	-	500	400
SO_2	5.2	< 1	-	200	200

Conclusions -1

- ✓ On the economics side, the avoided cost of residues management plays a crucial role. Disposing of the pruning wood entails a cost of about 25 € t-1 (50 € ha-1 for 2 t ha-1).
- ✓ If the cost for pruning wood disposal is subtracted from the total harvesting-forwarding cost, processed pruning waste could be obtained at the farm gate at a cost of about 30-40 € t^{-1} under favourable conditions (i.e. short forwarding distance, cheapest recovery system).
- ✓ This cost compares favourable with the price currently offered for energy biomass in Italy, which can reach 50-55 € t^{-1}, delivered to the plant (2009).
- ✓ The chemical analyses on pruning wood sampled in different vineyards on the provincial territory confirmed the presence of PPP residues and heavy metals on the wood, even if in a very low content.
- ✓ The biological management of the vineyard turns into reduced concentration of pollutants but a drift effect was noted too.

Conclusions - 2

- ✓ The mixture between forestry wood chip and pruning waste increased the fluency of the biomass thus the quality of the combustion process.
- ✓ The emissions from the two tested boilers are widely within the law limits.
- ✓ Despite the respect of the law, the absence of the ESP suggests to address pruning waste to a centralized biomass heating plant, at least up to the introduction of ESP systems on the domestic boilers.
- ✓ Finally some considerations on the energy balance: 20 liters of gas oil are needed to collect 2.5 tons of pruning waste. The energy content of wood waste (40% moisture) is equal to 281 kWh, while 1 liter gas oil produces 11 kWh of energy. The final balance is 32:1, so extremely positive for the recovery of pruning wood for energy use.

Thank you for the attention

Silvia Silvestri

silvia.silvestri@iasma.it

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