Report STSM Florence 24-01-2016 to 05-02-2016

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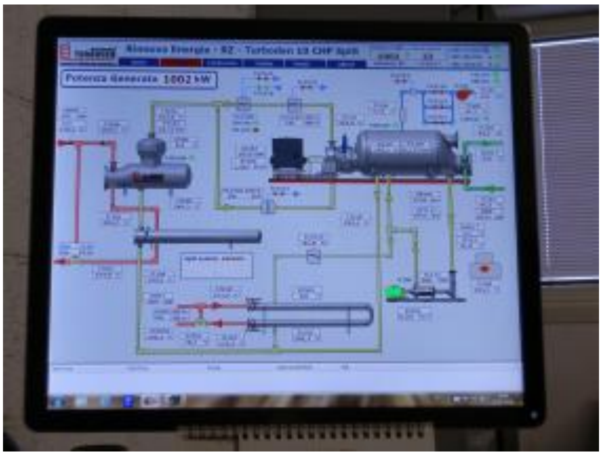
As scheduled this STSM in Italy occurred in the period between 24-01-2016 and 05-02-2016 The STSM was set in four stages. The first stage between Jan. 25 and Jan. 27 aimed to analyze the model of commercial upscaling of poplar SRCs (short rotation coppices, with a maximum three year productive cycle and a plant density of 6700 stumps per hectare) implemented across Italy. Indeed, oppositely to many other countries in Europe, Italy has a lively SRC sector that has reached commercial stage. Currently, there are over 7000 ha of SRC and MRC (medium rotation coppices with a productive cycle of five years and a plant density of about 1200 stumps per hectare) in Italy, and they are managed by contractors. The first operations started in the years 2000-2001, and now there are at least 7 SRC harvesting contractors in Northern Italy. Of course that the applied research for this system began earlier. For example, Dr. Raffaele Spinelli made his first study on SRC in 1985/86. The second stage comprised the period of two days (Jan. 28 and Jan. 29) consisted in the fulfillment of field trials of SRC harvesting. The third stage in the period Feb. 1 to Feb. 4 consisted in the execution of field measurements on hardwood sprouts from coppices which were cut one year ago. The fourth period in Feb. 5 consisted on the analysis and review of the information collected on work visits and field work and also on contacts in the host institution (Ivalsa in Florence) with Italian colleagues working on areas related to poplar SRCs such as field management.

So on Monday 25 we arrived at the Biopoplar facility in Cavallermaggiore, province of Cuneo and we were received by CEO Enrico Allasia. This company owns a 1 MW power plant cogenerating power and heat, corresponding to an investment of 5 M€, and on a total of 7 M€ if we include the greenhouse and drying facilities. The electrical power produced is 1 MW and the heat power is 4 MW. The biomass supply to this unit is on average of 1500 ton/month corresponding to a yearly consumption of about 18000 tons/year. The biomass corresponded to 60 % poplar and 40% chestnut. The heat is used for greenhouse and biomass drying.


1 MW power plant component   Biomass drying with heat from the power plant

The maintenance of the power plant facility is made by 4 days every 6 months. The filtering of flue gas is made through a cyclone and a sleeve filter, while the heavy ash falls by gravity through the grate. The process is the so called organic Rankine cycle (ORC) which consists on a typical closed Rankine cycle where the working fluid is an organic oil instead of hot water. The Rankine cycle is basically an optimization of the theoretical Carnot cycle whereby the compression step occurs with a condensed fluid such as water or an organic silicon fluid, in this case. This result is a upgrading of the work ratio of the power plant. Also the organic fluid enables an operation at relatively low temperatures (70^{o} to $300^{o}C$) The NOx emissions are within a threshold of 100mg /Nm^3 and urea is fed to system to control the NOx emissions. The yearly work rate is about 8200 h per year but a maximum of 8500 h per year is possible. The operational variables of the power unit are permanently monitored by a network of sensors with digital output read by a central software. The heat production of the power plant is directed to the drying of input biomass and to the heating of a plant greenhouse.



Central monitoring of the 1 MW power plant

On Monday 25 afternoon and Tuesday 26, we visited the field cultivations of Biopoplar where we were introduced to the complex process of genetic selection of SRC poplar. Hybrid poplar clones are obtained by crossing Populus Nigra male individuals with Populus Deltoides female individuals. The first step in the production of new hybrid poplar clones is parental selection. Biopoplar researchers travelled extensively across Europe and the US to collect a wide range of male and female specimen. Populus Nigra specimens were collected from the basins of the main European rivers, including Rhone, Rhine, Elbe and Oder. *Deltoides* specimens were collected from a transect of 5000 km across the US. These specimens were used to develop a parental material collection in Cavallermaggiore. This collection contains over thousands of individuals. From the collection, promising genotypes are selected among the males in Populus Nigra and among the females in Populus Deltoides. From each promising individual, 4 cuttings are produced, of which 3 are used for comparative trials of parental material and 1 for growing a seed orchard. After 4-5 years, when the seed orchard is in production the results of the parental trials become visible, and so the best individuals are selected for controlled hybridization. Then hybrid clone selection begins. In its first step, 16000 individuals are produced. Of these, 1600 promising individuals are selected in the first stage, which are reduced to 20-25 in the second stage. Biopoplar already sells five patented clones and the aim is to get 5 more. Hybrids are sterile, which makes further hybridization impossible. Plant cuttings with 20cm length are submitted to a two week immersion in water and after that maintained cold for a maximum of two months in a refrigerated environment with 2 ^{o}C to 4 ^{o}C before plantation. We visited also production plots with medium five year rotation agroforestry plantations, where poplar is intercropped with annual farm crops: maize in the first year, sorghum in the second year and triticale in the third year. This annual biomass showed good production and should be directed to syngas production. After the third year the canopy of SRC turned impossible to utilize further annual crops, due to increased covering of the annual plants.

Genetic selection plots for poplar clones

We also performed a demonstrative trial of mechanical planting with one a two row machine of poplar cuttings, estimating a yield of 0.5 $hahr^{-1}$.

Cuttings plantation demonstration trial

In Wednesday 27 Jan. morning we visited the facilities of the company AGRIALL in the town of Borgomanero, province of Novara. We visited the pellet facility of the company with a production of about 700 kg/hour. This unit was installed between August and October 2015, and began operation in November 2015. The company is now installing a 500 kW pyrolysis plant, at a prototype stage.

Pellet unit

We visited also the pavilion with harvesters and tractors of the company. The common used harvester was a Fendt Katana 65, with a dedicated SRC header designed for large size SRC. This head can be adapted to all foragers (Fendt, Krone, JD, CNH) except for Claas units, because these machines have a mechanical power transmission. AGRIALL also designed and produced a replacement chopper for foragers adapted to SRC harvesting. The new chopper is designed for cutting wood and weighs 650 kg, whereas the standard forage chopper weighs 150 kg only, and does not perform as well with large stems.

On Wednesday 27 Jan. at the afternoon we visited another CHP plant operated by Biomasse Europa company in Sospiro, province of Cremona. The plant, with a power of 1MW, was quite similar as the one operated by Biopoplar. In fact, biomass-powered ORC plants are quite common in Italy, where they represent a commercial reality and an interesting market for biomass producer. This kind of intertwined forest and industrial infrastructure is a main feature of the commercial scaling of the SRC cluster in Italy. We were also recommended to consult the website of Turboden, a leading Italian company producing ORC power plants. This power plant would be given a subsidy of 600000 €/year under a condition of full production efficiency, i.e. if all heat could be utilized and not dissipated. The power plant produced 1 MWh electricity all sold into the net, and 5 MWh of heat, of which 3 MWh were delivered to the local hospital and school. The supply of heat to the hospital was made by a 1 km long pipe network, with water at 80°C which was sent back to the unit at 62°C. The hospital paid a flat rate equal to their average heating bill in previous years, which equaled 430000€/year.

The biomass input to the power plant was made by 5 rakes, feeding a belt conveyor. The fly ash is stored in big bags and the plant has to pay for its disposal. We visited also the plantation of Biomass Europa (Sozzi plantation) where the management is made under a multicycle multiproduct scheme. This is a modality with an estimated area of a 10000 ha in Lombardia Province.

This is a complex design consisting of a combination of traditional poplar with a 10 year rotation, noble hardwoods (walnut and ash) with a 20 year rotation and intercropped nitrogen-fixing biomass shrubs (hazel and black elder) with a 5 year rotation.

Under the second stage of objectives for this STSM we analyzed and performed some harvesting trials of SRCs in Berra, Province of Ferrara with the support of Veneta Mais Company on Thursday 28 and Friday 29. Our main objective was a full appreciation in the field of the performance of the important operation in the SRC production cycle, which is the plant harvesting.

A first harvesting trial showed a high yield of poplar coppice harvesting, consisting on the cutting of 3ha with 6700 plants ha^{-1} in two hours. The harvesting machine was a Claas Jaguar 890 with 500 Hp. The harvest price is about 400000 €, with a 20000 € yearly cost of maintenance. The tractors John Deere with a power of 105 Hp for biomass trailer transport had a cost of 100000 € with low maintenance costs (mainly lubricating oil and a few more stuff). The harvesting should be made on winter due to the lack of foliage, no physiological activity which could weaken the stump. The harvesting machine works also in summer with maize crops. A thumb rule for the gasoil consumption by harvesters is for example that a consumption of $70lh^{-1}$ is equivalent to a production of 70 t hour (net). The subsidy to electricity producers from biomass is about 140 €/MWh of electricity produced added to a 140 €/MWh of sold electricity on the market.

The harvest was made on blocks of 15 rows of 250 m each, with stumps distanced by 0,68 m away. The average harvest time for one entire row is 1min. 35s and a 200 m row 1minute 12s. The shoots with two years can reach the height of 8m, and 15cm diameter and the root system can reach a depth of 3m and a width of 1m. There are about four stems per stump. Mean yield is 40 tons/ha (50% moist) after two years, but a yield of 60 tons/ha is also possible.

The income for farmer per ton of moist biomass is about 20€ (plants, fertilizing, weeding, irrigation etc.). The transport of the same material to the plant gate costs about 10€ and the harvesting costs between 12 and 15 €, depending on field stocking and extraction distance.

The rental costs of the system are 3x60€/h for tractors with trailers and 1x250 €/h for the harvester. A medium biomass price is of about 42€/ton with 50% moisture.


Harvesting operation

On Thursday 28 Jan., a 3h 40 mins harvest trial in a single row 2.8 ha plot in Berra was performed with the Claas Jaguar machine. The plot was submitted to a two year coppicing cycle with some stumps corresponding to a fourth cycle and the remaining to a second cycle. The field nomenclature attributed to this kind of management is R4F2 or R2F2, where R is the stump followed by the number of its cycle and F is the stem followed by the cutting cycle This trial aimed at quantifying biomass and harvesting productivity, determined according to the methods described in the Good Practice Guideline developed within the scope of COST Action FP0902. The operation was split into time elements including harvesting, turning of the machine to a new row and time stops due to cleanse blockage in cutting knives. The sum of the time durations corresponding to each one these components is the productive machine hour (pmh^{-1}).

If we add to pmh^{-1}other delays related to preparation of the operation, rest, unexpected breakdowns and delays we obtain the so called scheduled machine hour (smh^{-1}). All these time components were recorded with stopwatches. Biomass output was estimated by measuring the volume of all chip containers produced during each test, and by taking sample containers to a certified weighbridge. Row spacing will be measured with a tape, and the length of row harvested for each load with a laser range-finder. This way, it was be possible to calculate the surface actually harvested at each site.

The recorded time allowing calculating pmh^{-1} is shown in the following Table. With the recorded time components, a trailer volume of 34 m^3 , an average lab result of $293.5kgm^{-3}$ for poplar biomass density (50% moisture) we calculated values of 2.5h pmh^{-1}, 3.6h smh^{-1}, $174m^3$ pmh^{-1}, and 124 m^3 pmh^{-1}. The corresponding values for weight of biomass were 51 tons pmh^{-1}, and 36 tons smh^{-1}. The productivity, in terms of weight per hect. was 47 $tonsha^{-1}$ and 24 $tonsha^{-1}year^{-1}$. The following table gives the values of time components (centiminutes) allowing to calculate productive machine hour (pmh^{-1}), with average and standart deviation times needed for the calculation of the filling of the trailers.

Harvest	Turn	Blockage	Other work		% full trailer
284	71	0	0		
245	40	0	0		
297	90	0	0		
104	0	0	0	Aver. 232.5	100
67	50	0	0	Std. 88.5	
309	75	0	0		
208	65	0	0		

129	204	0	0	Aver.178.3	100
211	85	0	0	Std.104.5	
157	174	0	0		
144	157	0	0		
193	87	0	0		
91	237	0	79		
68	53	0	0		
40	0	0	0	Aver.129.1	90
106	70	0	0	Std.64.4	
63	36	0	0		
86	71	0	52		
79	45	53	31		
113	107	0	0		
84	0	0	0	Aver.88.5	110
213	45	0	0	Std.18.3	
138	38	0	0		
247	75	0	0		
197	83	32	21		
167	0	24	0	Aver.192.4	100
198	49	0	0	Std.41.9	
109	63	0	0		
118	0	12	0		
112	35	0	0		
82	0	0	0	Aver.123.8	60
515	60	637	194	Std.43.7	
1013	138	197	42	Aver.764.0	100
571	188	166	213	Std.352.1	
1008	95	33	0	Aver.789.5	100
135	83	0	0	Std.309.0	
125	31	0	0	Aver.130.0	100
119	50	0	0	Std.7.1	
119	28	0	0		
117	49	0	0		
143	33	0	0		
121	26	0	0		
121	38	0	0		
134	49	0	0	Aver.124.9	100
167	67	0	0	Std.9.8	
116	36	0	0		
124	51	0	0		
121	47	0	0	Aver.132.0	100
134	41	0	0	Std.23.6	
143	59	0	0		
133	33	0	0		
151	68	0	0		
82	53	0	0	Aver.128.6	100
Aver. 190,0	Aver. 64,7	Aver. 21,8	Aver. 11,9	Std.27.1	

On Wednesday 29 Jan. a second 4h30m harvesting trial was performed on a 1.84 ha plot and the main results were 100 m^3 smh^{-1} and 164 m^3 pmh^{-1}. In weight the productivities calculated were 46.7 $tonpmh^{-1}$ and 28.5 $tonsmh^{-1}$. In terms of productivity par area unit and year the results were 69.3 $tonsha^{-1}$ and 34.6 tonsha-1$year^{-1}$, respectively. This last trial gave lower productivities given the higher average times (centiminutes) spent on e.g. operations such as turning the machine (128.26 cmin vs 64.7 cmin), blockage repair times (40.3cmin vs 21.8 cmin) total delays (1.75h vs 1.02h). Anyway these two trials gave yields according with the literature and mainly allowed to a relevant field analysis of the important and determinant operation for SRC management which is the harvesting.

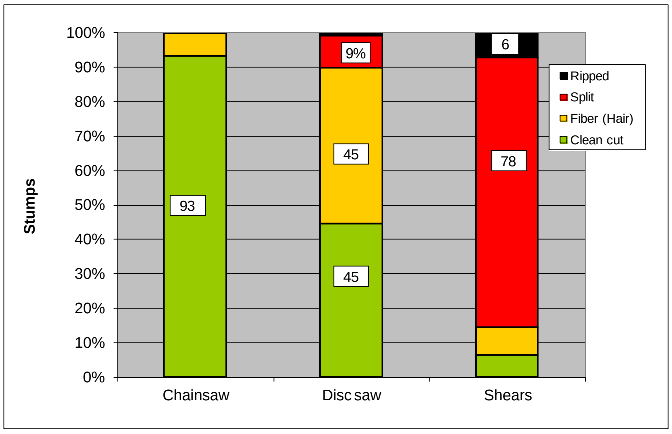
The third stage in the period Feb. 1 to Feb. 4 consisted in the execution of field measurements on hardwood sprouts from coppices which was performed one year ago in Tarquinia, province of Viterbo. Basically the field trial consisted in three blocks with five random plots each and aimed to analyze the impact of three kinds of coppice harvesting, manual chain saw, disc saw and shear cutting on the growing vitality of the emerging sprouts from each stump. The plots included 81 stumps of Acer campestris, 54 stumps of Fraxinus Augustifolia, 15 stumps of Fraxinus Ornus, 130 stumps of Quercus Serris, 16 stumps of Quercus Pubescens and 21 dead stumps. Of these 108 stumps corresponded to a chain saw 107 to disk harvesting and 102 to shear harvesting. Fraxinus Ornus was submitted to eight shear cuttings, five chainsaw cuttings and two disc cuttings. Acer Campestris was submitted to 34 manual chain saw cuttings, 22 disk sawings and 25 shear sawing harvestings. Fraxinus Augustifolia was submitted to 23 chainsaw cuttings, 16 disk sawings, and 15 shear cuttings. Quercus Cerris was submitted to 37 chainsaw cuttings, 53 disk sawings and 40 shear cuttings. And lastly Quercus Pubescens was submitted to five shear cuttings, eight disk cuttings and three chainsaw cuttings.

Stems cutting by disk (left) and shear (right)

The measurements of height with a 2.5 m mast and diameter with a caliper were made for the five dominant stems in each stump, the number of stems per stump was also counted and the damage on the stumps due to each kind of treatment was also recorded (clear cut, fiber, split which is a vertical split with no loss of matter from the plant, and ripped corresponding to a situation when matter which is a cut when matter has been lost). All measurements report only results concerning the first year after cutting and the growing in further years should be monitored in order to give consolidated results.

Field measurements in Tarquinia

The following table provides the results in percentage of the damage inputted by each treatment allowing concluding that, under this point of view, the cutting with chainsaw well performed is the better option.



Damages caused in the stumps by each treatment

On the other hand, the average height of stumps after cutting ranged between a minimum of 4.93cm and a maximum of 11.03 cm for the disc cutting, a minimum of 7.85 cm and 15.24cm for shear cutting and from a minimum of 4.17 cm and maximum of 9.42 cm for chainsaw. Some of the variability of the height of stumps is due to the unevenness of the flatness of the terrain. The threshold of 7 cm to 10 cm, considered as adequate for the vitality of resprouting, was thereby achievable with the three cutting modalities.

In Feb. 5, in Florence an analysis of the work made during the STSM was made. For concluding, I can say that this STSM visit was very important for contacting the commercial reality of SRC cultivation in Italy and for a detailed analysis of field work on operations such as coppice planting, harvesting and allometric measurements. This cooperation with Italian colleagues was very useful, and some of the experience obtained was incorporated on a 4 ha demonstration project for poplar SRC in Portugal, counting with the cooperation of Italian partners, already submitted. I can't finish my report without thanking to the Italian colleagues and especially to Dr. Raffaele Spinelli the support given to the accomplishment of this STSM.

Signed for acceptance

The host – Dr. Raffaele Spinelli