16th European Biomass Conference and Exhibition. From Research to Industry and Markets
Feria Valencia, 2-6 June 2008
Session Code: VP1.2.13

EVALUATION OF THE REUSE OF BIOMASS PRODUCED BY RIPARIAN VEGETATION MANAGEMENT

L. Recchia (*), E. Cini (*), L. Faggioli (**), S. Corsi (**), F. Piragino (**)
(*) Dipartimento di Ingegneria Agraria e Forestale, Università di Firenze; P.le delle Cascine, 15-Firenze, Italy;
phone +39 055 3288313; fax +39 055 331794; e-mail lucia.recchia@unifi.it
(**) Consorzio di Bonifica per la difesa del suolo e la tutela dell'ambiente della Toscana Centrale; via Verdi, 16-Firenze, Italy

ABSTRACT: With the aim to reduce hydrological risk, it is important to actuate a correct management of riparian vegetation which includes cutting operations of grass, reeds, bushes and trees. Now biomass residues are left shredded along the courses or disposed in landfills as special wastes. This work studies the possibility of the reuse of river vegetation as biomass for energy production and evaluates benefits and drawbacks of economical, environmental and managerial aspects. A specific methodology has been developed for two different hydrological districts: a GIS estimation of biomass distribution and annual residual production along rivers has been carried out; different chains concerning harvesting operation, biomass transport, storage conditions and final utilization in different energy plant, have been defined and compared by multicriteria analysis; for the more interesting agro-energy chains the LCA has been implemented. The application of this methodology allows to compare cost and environmental benefits of the energy use of riparian vegetation, supporting local Authorities involved in environmental management and energy planning: in this way it is possible to compare different alternatives to match the energy demand and meet the energy saving and sustainability issues at the lowest cost for the community.

Keywords: forestry residues, managerial aspects, sustainable use of biomass

1 INTRODUCTION

The river vegetation has an important role for biodiversity, landscape, water quality, natural depuration, bank side stability, etc., but during extraordinary storms can cause bridges occlusion or collapse, destruction of other hydraulic work or creation of natural dams, causing or aggravating floods in urbanized areas.

Therefore, it's important to actuate a correct management of river vegetation which includes cutting operations of grass, reeds, bushes and trees. Now biomass residues are left chipped along the rivers or disposed in landfills as wastes.

The objectives of this work are to study the possibility of the reuse of river vegetation as biomass for energy production and to evaluate benefits and drawbacks of economical, environmental and managerial aspects.

In this paper, a methodology is proposed, to evaluate:

- the river vegetation availability in the Greve-Ema, Pesa and Elsa basins;
- the identification of different scenarios defining harvesting, transport, storage and energetic utilisation steps;
- the evaluation of the economical, logistical and environmental aspects for each identified scenario.

First part the proposed methodology has been applied to the Greve-Ema, Pesa and Elsa basins, affluent of Arno River in Tuscany Region, in order to calculate the energy biomass potential of the territory. For this purpose, an estimation of biomass distribution and annual residual production along rivers has been carried out with GIS software, using data from previous studies and field investigations.

Then, on the basis of the previously assessed energy biomass potentials, different chains concerning harvesting operation, biomass transport, storage conditions and final utilization in different energy plant, have been defined. With the aim to confront different scenarios obtained, a multicriteria analysis has been carried out. Moreover, a network optimization and a detailed environmental analysis through LCA have been realized. A LCA methodology has been developed defining possible energy process chain, fixing carefully the system boundary and using experimental data concerning many operative phases. This analysis will be implemented using commercial software tools for energetic analysis of energy conversion processes, such as GEMIS.

2 GEOGRAPHICAL ANALYSIS: ESTIMATION OF THE LOCAL BIOMASS AVAILABILITY

To estimate the herbaceous and woody biomass locally available, different sites suitable for biomass supply, have been insert in a GIS. The biomass available can be of different types: forestry biomass, biomass from management of forest tree planted, biomass from riparian vegetation management, herbaceous biomass (i.e. arundo donax).

First each site potentially suitable for biomass supply has been classified as natural river / course, artificial channel or canalized course.

Particularly, all the artificial channels have been identified using information from data-bases of Consorzio di Bonifica Toscana Centrale (CBTC), whilst canalized courses have been localized analysing the regional technical maps close to urban agglomerations and considering the hydro-morphologic basins' characteristics. In addition, the part of drainage basins sited in non-anthropized areas have not been considered for the GIS implementation because of limited accessibility.

Then spatial data concerning riparian vegetation relief along the river, forest tree planted close to retarding basins or other hydraulic infrastructure, management of riparian bands and selective cuts, etc., have been associated to each supply site.

Finally, with the aim to calculate total quantity of biomass available a specific methodology which allow to integrate all the information collected has been applied.

Particularly, the quantity of stand biomass has been estimated using data supplied by CBTC and references [1; 2; 3], as illustrated in Table I; for each segment of course some technical parameters as the length L_{bio} of the river segment at which a biomass supply site is associated, the width of riparian vegetation band L_{band}

(average value) along this river segment, the areal Q_{bio} and linear density Q_{biolin} (expressed in tons/ha and tons/m respectively) of stand biomass, have been defined. Using this parameters it is possible to estimate the annual biomass supply Q_{supply} (tons/year):

- $Q_{supply} = Q_{biolin} \cdot L_{bio} \cdot 5\% \cdot 45\%$ for natural river or course, considering that an annual sustained yield equal to 7,1 m^3/ha/year (about 5,7% of the stand biomass) and a rate of 45% on the total area interested by selective cuts and vegetation management;
- $Q_{supply} = Q_{biolin} \cdot L_{bio}$ for artificial channel or canalized course.

Therefore, the biomass availability for the different basins has been estimated (see Table II and Fig. 1).

Table I: Values used to estimate the biomass availability.

	Basal area m^2/ha	Stand biomass volume m^3/ha	Stand biomass quantity tons/ha	Wood density kg/m^3
Cane-brake	-	-	15.00	-
Grassland	-	-	7.50	-
Shrubs	-	-	80.00	-
Poplars & Willows	24.41	163.41	89.88	550
Poplars	23.90	162.52	97.51	600
Willows	28.00	168.00	100.80	600
Riparian forest	21.90	129.50	90.65	700
Black locusts	16.10	100.30	65.20	650

Table II: Assessment of the supply biomass available.

Basin	Course typology	Biomass typology	Biomass tons/year
Elsa	Natural river/course	Woody	3670
	Artificial channel	Herbaceous	20
	Canalized course	Herbaceous	130
Pesa, Greve, Ema	Natural river	Woody	980
	Artificial channel	Herbaceous	80
	Canalized course	Herbaceous	70
Total	-	-	4950

3 MULTICRITERIA ANALYSIS TO DEFINE AND OPTIMISE THE AGRO-ENERGY CHAIN

Once the geographical analysis of the local biomass availability carried out, logistical and environmental issues have been considered in order to define the agro-energy chain, including biomass harvesting, transport, storage and utilisation (see Fig. 2). Because of large scenarios' variability, the work has been developed applying a multicriteria analysis.

3.1 Scenarios' definition

Regarding biomass harvesting process several possible yards have been defined taking into account usual vegetation management, typology of operations currently carried out, level of mechanisation, etc..

As reported in Table III, yards are different on the basis of course typology, site accessibility, riparian vegetation typology and dimensions: only four yards sufficiently representative of different realities have been considered. For each yard mechanisation typology and costs have been assessed.

Figure 1: Geographical distribution of biomass quantity available along natural river / course, artificial channel or canalized course. Particularly, two area characterised by higher density level have been indicated.

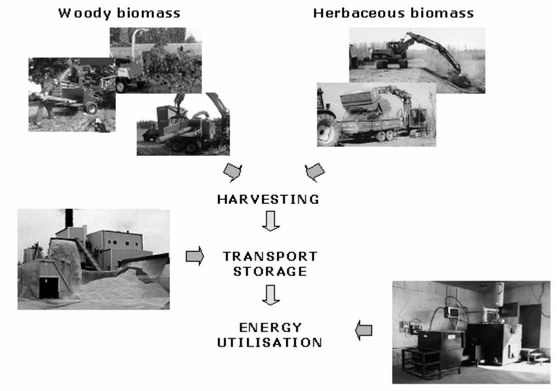

Figure 2: Main phases of the agro-energy chain.

Concerning logistics (biomass transport and storage) different scenarios are projected. At this moment the assumptions carried out are completely generic because any decision about energy conversion plant has been taken in term of typology, size and localisation.

Particularly, following scenarios have been defining:

1. storage of the wood, previously reduced into small pieces, close to the harvesting yard, and transport to the small-sized private plants. It is important to highlight that this solution does not insure anything about the effective wood utilisation in appropriate plants (high efficiency; low atmospheric emissions; short distance between yard and final plan; etc.);
2. first storage at an average distance of 15km from the harvesting yard (maybe close to some retarding basin or in some dedicated areas) for a limited period, from the cut until September, and transport to the final energy conversion plant. The transport distance between first storage and energy plant has been hypothesised equal to 20km for the low-medium sized plants and to 50km for the high sized ones;
3. storage close to the harvesting yard and transport to the final energy conversion plant, taking into account the assumptions reported above concerning the

distance between storage area and plant. This solution is better than the previous one but somewhere it is impossible leaving the biomass close to the courses because of law regulations.

In Table IV all the logistical scenarios are illustrated.

Table III: Definition of harvesting yards (Y) at the current (C) and future (F) status.
Yards n.1, 2 and 3 are referred to natural river/course; yards n.3 and 4 to canalised course and artificial channel, respectively. Yards n.1 an 2 are characterised by high accessibility; yard n.3 by low accessibility. In addition, yard n.1 supposes an average diameter of the woody biomass ≤15cm, yard n.2 ≧30cm and yard n.3 equal to 20cm.

	Mechanisation	Cost
Y1C	shredder without harvesting	70 €/tons
Y1F	feller buncher; chipper; truck trailer	89 €/tons
Y2C	feller buncher; chainsaw	122 €/tons
Y2F	feller buncher; chipper; truck trailer	91 €/tons
Y3C	chainsaw; winch	111 €/tons
Y3F	chainsaw; winch; chipper; truck trailer	144 €/tons
Y4C.1 Y4C.2	shredder without harvesting	26 €/t
Y4F.1 Y4F.2	shredder with harvesting; truck trailer	77 €/t

Table IV: Definition of logistical yards along different course typology.

	1st transport	1st storage	2nd transport	2nd storage (near the plant)
L1	0 km	harvesting yard	-	small-sized
L2	15 km	dedicated areas	50 km	high-sized
L3	15 km	dedicated areas	20 km	medium-sized
L4	0 km	harvesting yard	50 km	high-sized
L5	0 km	harvesting yard	20 km	medium-sized

Concerning the energy utilisation scenarios, different plant typologies have been considered:

1. medium and high sized direct combustion plants using wood chips;
2. small sized direct combustion plants using wood in pieces;
3. anaerobic digesters that use wood chips and sewage,
4. medium sized gasifiers using wood chips and producing gas for a micro gas turbine;
5. composting plants.

All different scenarios are described in Tab. V.

3.2 Decision criteria definition

For each scenario of biomass harvesting, logistics and energy utilisation, some decision criteria concerning organisation, environmental impact and economic sustainability, have been defined as reported in Table VI.

Particularly, the decision criteria have been determined taking into account the following aspects:

a) logistic scenarios can be preferred if the number of machines involved for harvesting is lower, if the transport distance is shorter, and if the energy plant management is easier;

Table V: Definition of energetic scenarios for wood biomass utilisation.
E1: high sized (10MW$_t$ e 3,6MW$_e$) direct combustion power plants using wood chips for electricity production
E2: medium sized (1MW$_t$ e 150kW$_e$) direct combustion power plants using wood chips for electricity production
E3: small sized (20-60 kW$_t$) direct combustion private plants using wood logs for heat production
E4: medium sized (<1MW$_t$) direct combustion plants using wood chips for heat production
E5: anaerobic digesters
E6: medium sized (1MW$_e$) gasifiers and MGT
E7: composting plants

	Fuel demand t/MW/year	Operating time h/year	Efficiency %	Investment k€/kW
E1	11100	7000	20	?
E2	41300	5000	15	3,50-5,00 [1]
E3	600	2200	70	0.35-0.40 [2]
E4	0.50	2200	85	0.15-0.20 [2]
E5	30000 (tons/year)	-	-	2,50-7,50 [3]
E6	1000	7000	20	3,50-5,00 [4]
E7	-	-	-	150-600 (€/t/year)

b) environmental impacts are reduced simplifying forestry mechanisation, limiting transport distances and adopting energy plant with high conversion efficiency. All these assumptions have been confirmed by LCA. Considering wood chips utilisation in heat boiler of 1MW, it is possible to affirm that the agro-energy chain characterised by an easier forestry mechanisation permits lower GHG and atmospheric emissions, and significant reduction for non renewable part of CER (Cumulated Energy Requirement). The LCA results are summarised in Fig. 3;

c) economic benefits are possible if biofuel production costs, storage operations and investment costs are minimised.

To combine all these criteria a specific decision rank has been realised.

Table VI: Definition of evaluation criteria for agro-energy scenarios.
The weights from A to D classify the agro-energy chains from high to low sustainability respectively. In addition, DC=direct combustion; G = gasifier; MGT=micro-gas turbine; AD=anaerobic digester; C=composting plant.

	Weights			
	A	B	C	D
Logistic Aspect:				
1. n° machines	1 – 2	3	4	> 4
2. n° transport	0	1	2	> 2
3. plant	DC (<1MW)	DC (>1MW)	G+MGT DC logs	AD C
Environmental Aspects:				
1. n° of machines	1 – 2	3	4	> 4
2. distance (km)	0	1 – 20	20 – 40	> 40
3. efficiency (%)	> 80	50 – 80	20 – 50	< 20
Economic Aspects:				
1. cost difference (€/t)	0 – 10	10 – 20	20 – 30	30 – 50
2. storage	no	outdoor	outdoor	indoor
3. investment (k€/kW)	< 0,3	0,3 - 1	1 – 4,5	> 4,5

3.3 Agro-energy chains' identification

Combining all the scenarios identified for each part of the agro-energy chain, 19 different solutions have been obtained, as indicated in the Table VII.

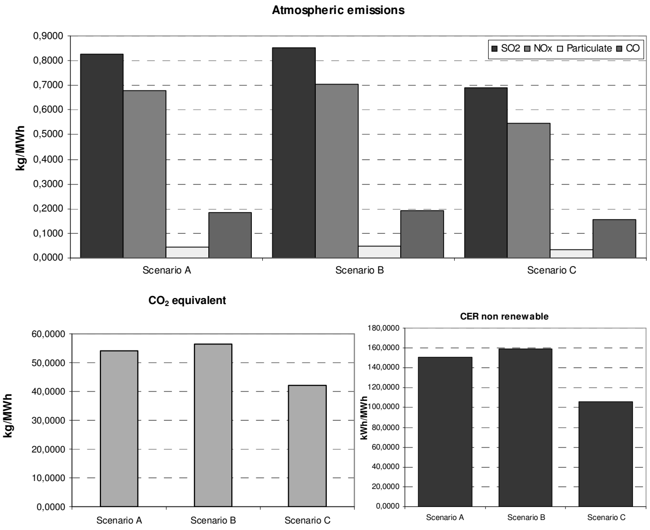

Figure 3: LCA applied to different scenarios obtained as combination as harvesting, logistics and energy utilisation possibilities (see Tables III, IV and V): Scenario A = Y1F+L4+E4; Scenario B = Y2F+L4+E4; Scenario C = Y3F+L4+E4. Particularly, some results (GHG and atmospheric emissions, CER non renewable) are illustrated.

Table VII: Agro-energy chains' evaluation: the chains more interesting identified are n. 4, 8 and 15 for the woody biomass and n. 18 and 19 for the herbaceous biomass.

The weights from A to D classify the agro-energy chains from high to low sustainability respectively. In addition, DC=direct combustion; G = gasifier; MGT=micro-gas turbine; AD=anaerobic digester; C=composting plant.

Chain	Scenarios			Characteristics		
				Logistic	Environmental	Economic
1	Y1C	-	-	no energetic reuse of biomass		
2	Y1F	L4	E1	C	D	C
3	Y1F	L5	E2	B	D	C
4	Y1F	L5	E4	B	B	C
5	Y2C	L1	E3	B	C	C
6	Y2F	L4	E1	C	D	C
7	Y2F	L5	E2	B	C	C
8	Y2F	L5	E4	B	B	B
9	Y2F	L5	E5	C	C	C
10	Y2F	L5	E6	C	C	C
11	Y2F	L5	E7	C	C	C
12	Y3C	L1	E3	C	B	B
13	Y3F	L4	E1	C	D	D
14	Y3F	L5	E2	B	C	D
15	Y3F	L5	E4	B	B	C
16	Y4C	-	-	no energetic reuse of biomass		
17	Y4F	L5	E5	C	C	D
18	Y4F	L5	E6	B	B	D
19	Y4F	L5	E7	B	B	D

It is possible to highlight that

- two scenarios provide no re-use of biomass energy, assuming to leave on the ground shredded biomass;
- two scenarios expect to produce wood into smaller pieces to leave close to harvesting yard;
- twelve scenarios of various kinds involving the use of wood chips;
- three scenarios expect to collect herbaceous biomass and use it in facilities more appropriate than direct combustion, as anaerobic digester, gasifier, composting plant.

Assuming the results obtained through multicriteria analysis, these following agro-energy chains have been identified as more interesting:

1. concerning woody biomass, chains that provide a temporary storage close to the harvesting yard and further transport at the medium sized energy plant (private or public), based on the direct combustion technology and located within a distance of about 20 km from the supply biomass area;
2. concerning herbaceous biomass, chains that hypothesise a gasifier with micro-gas turbine or composting plant.

4 CONCLUSIONS

The work has permitted to evaluate the riparian vegetation availability in a total area of 1700 km2 located in Tuscany. In addition, a specific methodology for the assessment of logistical, economical and environmental aspects, has been carried out. This methodology allows a multidisciplinary approach: collecting many different data it helps to identify sustainable agro-energy chains.

The results obtained have highlighted that

- the area can be classified as a biomass supply site, with an average quantity of 4650 and 300 tons/year of woody and herbaceous biomass (i.e. 16250 MWh_t/year and 540 MWh_t/year respectively);
- analyzing possible agro-energy chains, the most interesting ones have been identified. Particularly, chains that require limited forestry mechanization, short transport distance and medium sized plants basing on direct combustion technology, have been preferred.

5 REFERENCES

[1] IPLA, I Tipi forestali delle Marche, Inventario e Carta Forestale della Regione Marche (2001).
[2] Costa G., La Mantia T. Il ruolo della macchia mediterranea nel sequestro del carbonio, Forest@, 2 (2005).
[3] Tagliaferro F., Ebone A. (2007). Tecniche selvicolturali e agronomiche per il miglioramento dell'habitat di Tuber magnatum in tartufaie spontanee di boschi naturali, Forest@ n.4
[4] ENEA, Le fonti rinnovabili - Lo sviluppo delle rinnovabili in Italia tra necessità e opportunità, 2005
[5] ITABIA, Rapporto sullo stato della bioenergia in Italia al 2002, giugno 2003
[6] AA.VV., Energia dalle biomasse, Ministero dell'Economia e delle Finanze – Regione Autonoma Friuli Venezia Giulia, aprile 2006
[7] www.rete.toscana.it/ sett/agric/p_a_forestale