Technical Annex 7.2l - Deliverable Intermediate Report on C.5 Action

Monitoring the environmental and economical sustainability of proposed strategies

Project responsible AGROSELVIT

Responsibilities in case several beneficiaries are implicated:

On farm composting facility and composting process: UNIBAS

Field SOM managements: Tetto Frati, Grandi AGROSELVIT; CastelVolturno CERMANU; Mellone UNIBAS

1 LCA evaluation of on-farm composting plant

1.1 Materials and methods

Composting trial were carried out at "Prima Luce" plant. Particularly, two composting alternatives were taken into account. The alternatives differed for the organic residues used for composting: in one case, lettuce and other similar "light residues", in the other case heavy biomass such as artichokes and cauliflowers residues, tomatoes' stems or walnut husks. The typology of composted materials was very important because the compost yield depended on it. Indeed, in the first case, the production of the so-called "LIGHT COMPOST" (LC) accounted for 7.5 t/week; in the second one, the production of "HEAVY COMPOST" (HC) was around 10 t/week.

1.1.1 Environmental analysis

The environmental analysis was carried out according to LCA methodology from ISO 14040 and 14044 standards (ISO 14040:2006a; ISO 14044:2006b). LCA is a methodology for determining the environmental impacts associated with a product, process or service from cradle to grave. The SimaPro v. 8.04 software (PRé Consultants, 2012) was used to determine the environmental impacts of the examined composting system during a reference period of 20 years (corresponding to the lifespan of the plant). The impact assessment was performed following the CML 2001 methodology guidelines, developed by the Centre of Environmental Science of Leiden University (Guinée, 2001) and the following impact categories were selected: abiotic depletion (AD), acidification (A), eutrophication (E), global warming (GW), ozone layer depletion (OLD) and photochemical oxidation (PO).

The functional unit chosen, namely the reference unit that expressed the function of the system in quantitative terms, was one ton of compost treated.

For the purpose of the current investigation, the system boundary of the model was: the processing of the pruning residues; the transportation of these materials to the plant; the collection of crop residues and its receipt; the construction of the capital equipment and infrastructures; the compost processing and the transport and distribution on the field of the compost produced.

The inventory of the data, associated to the studied systems, was collected in situ at the composting plant. Using a data collection sheet, information on the quantities of machinery, fuel, electricity and other items used were gathered.

During composting process many types of gaseous compounds can be emitted. Direct emissions of CH4, NH3 and N2O were not experimentally measured, but their values were taken from the available considering only researches similar to the present study for both composted materials and technologies used for the process.

<u>1.1.2 Energy analysis</u>

The energy analysis technique was used to calculate the energy involved in the production of 1 t of compost. The energy values, expressed as Mega Joule (MJ), was obtained by multiplying the amounts of each item (machinery, fuel, electricity, labour, etc.) by the relative conversion factors taken from the literature (Monarca et al., 2009; Page, 2009; Pimentel and Pimentel, 1979; Volpi, 1992).

<u>1.1.3 Life Cycle Costing</u>

The production costs of the compost were analyzed according to the Life Cycle Costing (LCC) methodology, through repayment of the capital cost of the facility (annualized over 20 years at an assumed 2% interest rate) plus operating and maintenance costs (van Haaren et al., 2010).

Assuming that the plant had a lifespan of 20 years, the cumulative costs of compost production were evaluated for each year taking into account expenses over the whole life cycle of the plant related to materials, labour, quotas and other duties. Materials included the cost of all non-capital inputs; labour included the cost of workers involved in farm production; quotas include machinery, equipment and depreciation costs (Pappalardo et al., 2013).

1.2 Results

<u>1.2.1 Environmental aspects</u>

Table 1 shows the total life cycle impacts in the reference period (20 years) and impacts per ton of compost produced by the two composting alternatives. Under our operative conditions, after 20 years of working, some processing steps (such as the construction of the facility, the collection of the bulking agent and the crop residues, the process, the transport of the compost to the field and its distribution) plus direct emissions produced during the decomposition phases could cause an abiotic depletion (AD) equal to 44 kg of Sb; a global warming potential (GWP) between 1,668,000 and 1,678,000 kg of CO2eq; an average ozone layer depletion (ODP) of 0.13 kg of CFC-11eq; a photochemical oxidation (PO) from 613 to 620 kg of C2H4eq; an air acidification (AA) between 14,558 to 14,581 kg of SO2eq; and an average eutrophication potential (EP) of about 5,965 kg of PO4 eq (Table 1).

The typology of materials composted during the lifespan of the plant will determine the type and the quantity of the compost produced and, consequently, the impacts per ton of compost, as showed in Table 1. The main differences between the two alternatives could be found in the collection of crop residues, in the composting process and in the final transport of the compost produced and in its distribution on the field.

Referring only to global warming (CARBON FOOTPRINT), under our operative conditions, the production of 1 ton of LC caused an emission of 250.02 kg of CO2eq; while the production of 1 ton of HC caused an emission of 198.90 kg of CO2eq. In both composting alternatives, the composting process was the item that emitted the largest amount of CO2eq (about 42%) followed by the construction of the plant (20%).

1.2.2 Energy consumptions

The energy analysis showed that the construction of the facility and its use for a period of 20 years could cause an energy consumption more than 15,500 GJ, that annually it could be approximately equal to 775 GJ (Table 2).

Differently from the environmental analysis, the energy analysis showed that in both composting alternatives the construction of the plant was the item that consumed the largest amount of energy used (38%), followed by the composting process (27%). In the first item, the concrete was the highest energy input representing 53% of the energy involved in the construction of the facility. On the contrary, in the composting process the highest energy input was shown by diesel fuel and lubricants used above all in the mixing of the bulking agent with compostable crop residues, in the creation of the pile and during the screening of the compost obtained.

1.2.3 Cumulative production costs

The cumulative total cost at the 20th year of plant working could be equal to 1,629,840 euro, if the compostable material is light, and equal to 1,314,768 euro if the crop residues are heavy (Table 3). This difference was due to differences in the quantity of crop residues to create piles (200 cubic meters per pile for LC versus 100 cubic meters per pile for HC) and in the transport and distribution of the compost produced (15 cubic meters per pile for LC versus 20 cubic meters per pile for HC).

With regard to the single cost, for LC around 40% of total costs (675,729 €) were related to the collection of crop residues, while for HC these costs were only the 27% (337,865 €). Indeed, for HC there was not a single major cost, but there were three most important costs: the composting process (27%), the collection of crop residues (26%) and the capital costs (20%).

The analysis of the distribution of the production factors in composting production suggested that in both alternatives, the highest cost was provided by labour (more than 40%) followed by electricity (about 30%). In this case, the quantity of the compost produced defined the cost per ton which was equal to 162 € t-1 for LC and 98 € t-1 for HC (Table 3). These results show how HC had a lower rate of overall costs than LC, and appeared to be twice as sustainable due to the lower costs in total and per yield.

Table 1. Results of the total life cycle impact assessment in the reference period (20 years) and per tonne of the Table compost produced

	Abiotic depletion		**Global warming potential**		**Ozone layer depletion**		**Photochemical oxidation**		**Acidification**		**Eutrophication**	
	kg Sb eq		**kg CO_2eq**		**kg CFC-11eq**		**kg C_2H_4eq**		**kg SO_2eq**		**kg PO_4---eq**	
	LC	**HC**	**LC**	**HC**	**LC**	**HC**	**LC**	**HC**	**LC**	**HC**	**LC**	**HC**
Costruction of the facility	2.31	2.31	333391.57	333391	0.01	0.01	77.14	77.14	1408.97	1408.97	325.12	325.12
Collection of bulking agent	1.54	1.54	244771.71	244771	0.02	0.02	69.37	69.37	1431.58	1431.58	411.72	411.72
Collection of crop residues	0.82	0.41	92356.82	46178	0.01	0.01	27.13	13.57	615.89	307.94	208.92	104.46
Composting process	38.21	38.25	724420.44	703937	0.07	0.07	369.60	366.84	9379.57	9213.91	4526.49	4490.34
Transport of the compost and its distribution	1.53	2.03	229458.36	305944	0.01	0.02	69.92	93.23	1489.50	1986.00	410.35	547.13
Direct emissions	0.00	0.00	43430.40	43430	0.00	0.00	0.00	0.00	232.96	232.96	84.66	84.66
Total at the 20th year	**44.41**	**44.54**	**1667829.31**	**1677653**	**0.13**	**0.13**	**613.16**	**620.14**	**14558.47**	**14581.36**	**5967.25**	**5963.43**
Impact per ton	**0.01**	**0.00**	**250.02**	**198**	**0.00**	**0.00**	**0.08**	**0.06**	**2.06**	**1.60**	**0.84**	**0.65**

Table 2. Energy consumption for the examined composting alternatives in the reference period (20 years) and per tonne of the compost.

	Energy consumptions (MJ)	
	LC	**HC**
Costruction of the facility	5,851,605	5,851,605
Collection of bulking agent	2,360,958	2,360,958
Collection of crop residues	1,225,719	612,860
Composting process	4,145,301	4,145,301
Transport of the compost and distribution	1,924,425	2,565,900
Total energy input at the 20 th year	**15,508,008**	**15,536,624**
Annual energy input	**775,400**	**776,831**
Energy consumption per tonne	**1,988**	**1,494**

Table 3. Production costs for the examined composting alternatives in the reference period (20 years) and per tonne of the compost.

	LC	**HC**
Capital costs (€)		
Costruction of the facility	232,772	232,772
Machines	29,934	29,934
Insurance and maintenance fees	928	928
Operation costs (€)		
Collection of bulking agent	230,606	230,606
Collection of crop residues	675,729	337,865
Composting process	364,679	356,635
Transport of the compost and its distribution	95,192	126,029
Total at the 20 th year	**1,629,840**	**1,314,768**
Annual Production Costs	**63,213**	**50,993**
Costs per tonne	**162**	**98**

2 LCA evaluation of field SOM managements

2.1 Methods

The assessment of the environmental and economic sustainability of proposed soil managements is started with the following steps:

- initial acquisition of rough data on field requirements for the different project sites and cropping systems;
- definition and outlining of comprehensive protocol for data collection
- acquisition of software GaBi 6
- data collection and elaboration for the first and second year of field cultivation (in progress).

Two PE INTERNATIONAL GaBi Databases were purchased. They are the largest internally consistent LCA databases on the market today and contain over 7,000 ready-to-use Life Cycle Inventory profiles. The first is “GaBi Professional” database: it is the standard database provided with the GaBi software. The GaBi professional database is regularly updated and is derived from industry sources, scientific knowledge, technical literature, and internal patent information creating a solid foundation for assessing your materials, products, services and processes.

The second is more agricultural oriented and it is called “Renewable raw materials” database. Renewable raw materials contains 140 processes: fertilizers, pesticides, tractors, agricultural equipment, industrial intermediate products, and different crops (corn, wheat, hemp, flax, rape seat, soybean, etc.)

System boundaries of the different crops were designed for each of the following productions: lettuce and Brassicacee on Grandi farm (Grugliasco TO), Grain maize on Tetto Frati UNITO experimental farm (Carmagnola TO), Maize on UNINA experimental farm (Castel Volturno) and BLA orchard system at Mellone farm.

As example on Figure 4, System boundaries of lettuce and Brassicacee contivated on Grandi farm was reported. Inside the boundaries were counted all the field operations, and all the impact generated to produce the input: fertilizer (PK), pesticide, seeds, fuel and lubrficants, bioplastic end one of the three fertilizer that characterizes the three different production technique: compost (humus anenzy®), digestate soild fraction or traditional fertilization (urea). Crop yield represent the output of the system.

System boundaries of compost production on new plant was also planned in order to calculate the impacts of the different process phases.

The scenarios and impact assessments were modelled and computed by GaBi 6 software by using ILCD (International Reference Life Cycle Data System), EDIP (Environmental Design of Industrial Products) method of impact assessment.

Impact assessment category selected are: Global Warming Potential (IPCC), Acidification Potential (EDIP), Freshwater Eutrophication Potential (RECIPE) and Terrestrial Eutrophication Potential (RECIPE).

In order to assess and compare the sustainability of different crops production three Function Units were selected. The impacts were reported per harvested production (product oriented), per cultivated land (surface oriented) and finally per crop revenues, in order to add the impact of different crops cultivated on the same land, during the same year.

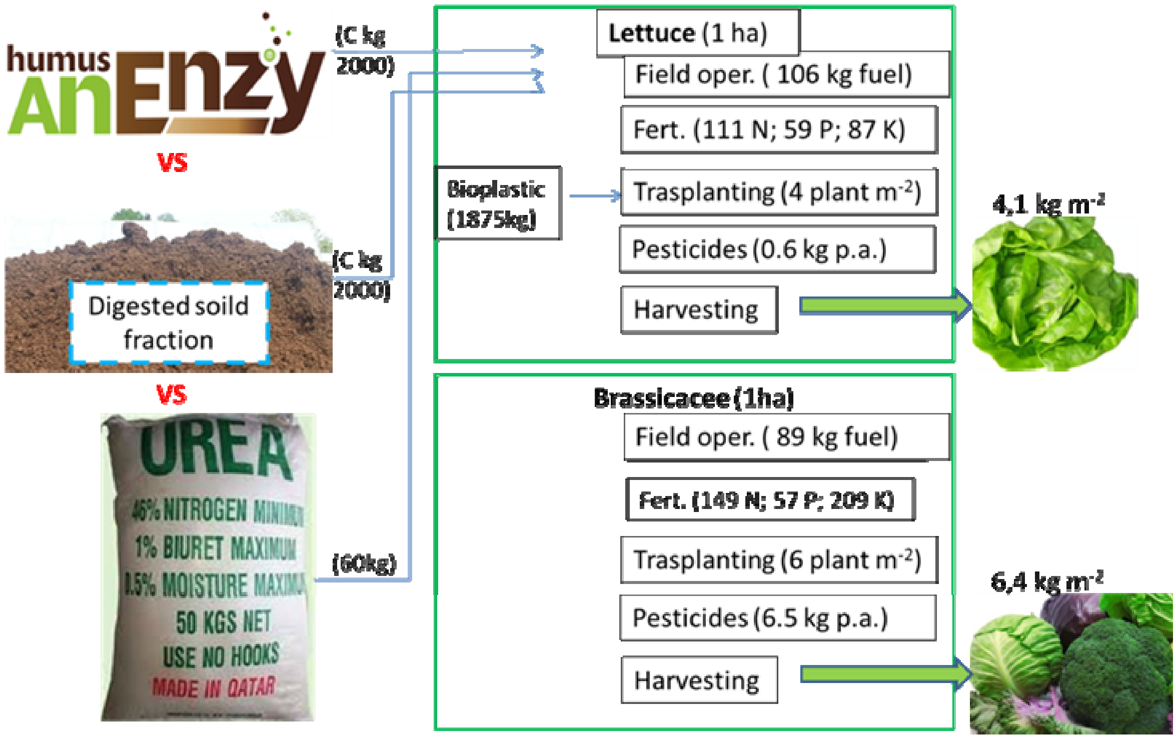

Figure 19. System boundaries for LCA calculations of lattuce and brassicacee production in Grandi farm.