FloroBaSco Project

Analysis of alternative production chains for the nursery sector designed to reduce pollution and produce renewable energy

OBJECTIVES

The objective of the project is to determine the phytoremediation capacity that specialized plantations for woody biomass production have with respect to reducing the nitrogen content of digestates and liquid manure. In addition, two other lines of research were developed: using solid digestate to prepare cultivation substrates in nurseries and using woody biomass as a fuel to meet energy needs to produce protected crops.

PROJECT DESCRIPTION

Over the course of the project, the following aspects were analysed:

1. phytoremediation capacity of a poplar short rotation forestry (SRF) plantation with a 5-year rotation for biomass production with respect to reducing the nitrogen and phosphorous content of the liquid fraction of cattle manure digestate and liquid swine manure;
2. the efficacy of deep injection of the liquid fraction of cattle manure digestate and liquid swine manure in the containment of greenhouse gas emissions;
3. the production increase in woody biomass resulting from the distribution of liquid swine manure and the liquid fraction of cattle manure digestate;
4. the use of the solid fraction of cattle manure digestate to prepare potting soil for the cultivation of certain ornamental container plants (*Rosa spp*, *Photinia x fraseri*, *Cupressocyparis leylandii*) in order to establish the quantitative limits of its use and evaluate the economic advantages;
5. analysis of the energy needs of particular nurseries to provide them with valid alternatives to fossil fuels, study of the technical/economic feasibility of a short, closed wood energy production chain to produce fuel for woodchip biomass systems at nurseries, and determination of the minimum threshold of thermal output required to make conversion of the heating system advantageous.

RESULTS

1. PHYTOREMEDIATION ASPECTS

The experiments pertaining to phytoremediation were conducted on a plot that was recently planted with Poplar (Baldo clone) having a total area of approximately 1.3 ha. Several scenarios involving the application of different amounts of liquid swine manure and the liquid fraction of cattle manure digestate on five similar plots were tested, as shown in Table 1.

Table 1 – Test scenarios monitored in the experiment.

Type of crop	Description	Code	Theoretical load of applied digestate (kg N/ha/year)
Poplar plantation with 5-year rotation (*Baldo* clone)	Control	A0	0
	Application of liquid fraction of cattle manure digestate	A1	170
	Application of liquid fraction of cattle manure digestate	A2	340
	Application of liquid swine manure	B1	170
	Application of liquid swine manure	B2	340

The manure was spread using subsurface banding along the rows, producing a furrow approximately 20-25 cm deep that generally closed immediately afterwards.

In order to better understand the nitrogen and phosphorous dynamics, a series of analyses were conducted to determine the hydrology of the soil in the experimental area. These analyses indicated that the soil in the plots is extremely protective and has a high clay content to a depth of approximately 125 cm, where an artesian aquifer is located. In addition, the silty-clay nature of the underlying soil layers impedes the formation of suspended saturated zones that connect to the drainage channel, as has occurred in locations where the soil has a lower clay content. Direct inflow from the aquifer to the channel is therefore negligible and the only water flowing into the channels originates from two sources:

- surface runoff from the field (rather limited, given the average slope of 2% from the centre of the test site to the edge of the channel);
- subsurface flow through fractures and macroporosity, which only develop in the summer and have a negligible overall contribution.

Analysis of the nitrogen content in the application areas (furrows) and other areas (outside of the furrows) demonstrates that the manure remains almost completely in the unsaturated zone within the application furrow, without coming into contact with the groundwater or surface runoff due to the notable tendency of the furrow to close after passage of the spreader.

Unlike experiences in other settings, the results clearly demonstrated that, both in the case of swine manure and cattle manure digestate, the applied nitrogen tends to remain inside the application furrow, where it is degraded by bacterial processes (denitrification) or absorbed by trees. Under these conditions, no significant nitrogen leaching was observed in the scenarios in which the waste was applied in accordance with the current limits for Nitrate Vulnerable Zones (A1 and B1), or for the scenarios in which the applied amount was doubled, which is typical for non-vulnerable zones (A2 and B2). The only differences between swine manure and cattle manure digestate derive from the higher amount of phosphorous applied (equal to the amount of nitrogen) in the swine manure scenarios, which exceeded the quantity used by the vegetation and led to a greater accumulation of phosphorous in the application furrow. As with nitrogen, there was no risk of phosphorous leaching into the aquifer or surface water bodies.

2. GASEOUS EMISSIONS

The gaseous emissions deriving from spreading swine manure and cattle manure digestate according to the methods and quantities described above were monitored for three annual applications. The monitoring method adopted was based on using a dynamic chamber (Figure 1). The primary objective was to determine the NH_3 and N_2O emissions, however greenhouse gases including carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) were also monitored.

Figura 1 – Camera chiusa posta sul solco di distribuzione.

The N emissions measured from the subsurface application of digestate (A1 and A2) and liquid swine manure (B1 and B2) were very low (<0.025 kg/ha/24h) if an event that occurred on 22/05/2014 is excluded. On that day, in scenarios A1 and A2, the digestate was unintentionally spread closer to the surface and without furrow closure because the spreader failed to penetrate the soil deeply, probably due to the presence of a more compact soil layer.

However, the higher N emission level (particularly in the form of NH_3) resulting from this event provided confirmation that subsurface application, with proper closure of the furrows, almost completely eliminates NH_3 emissions. If the anomaly that occurred on 22/05/2014 is excluded, the N emissions were composed predominantly of N_2O, with extremely low maximum values (Table 2).

The total annual N emissions measured for the subsurface application of liquid manure were very low for all of the scenarios studied and ranged from 0.011 to 0.424 kg N/ha/24h, equal to 0.01 to 0.13% of the applied N respectively (Table 2). Emissions from scenarios having larger amounts of N (A2 and B2) were higher compared to those with lower amounts (A1 and B1), however the ratio of N emitted to N applied was slightly lower for the scenarios having larger amounts of N.

Table 2 – Annual N emissions.

Scenarios	$N\text{-}NH_3$ (kg/ha)	$N\text{-}N_2O$ (kg/ha)	Total N (kg/ha)	N em./N app. (%)
A1	0.219	0.022	0.242	0.127
A2	0.411	0.013	0.424	0.112
B1	0.007	0.004	0.011	0.012
B2	0.006	0.010	0.016	0.008

The predominant greenhouse gas (GHG) emitted was CO_2 and ranged from 54.9 to 101.8 kg CO_2 eq./ha, with the higher levels corresponding to the application of digestate (scenarios A1 and A2) and the lower levels to liquid swine manure (scenarios B1 and B2). The emissions fluctuated significantly depending on the volume of material applied and the season, with higher emissions after summer application (25/07/2013).

Although limited in comparison with CO_2 emissions in terms of mass, CH_4 and N_2O emissions provided a considerable contribution to the global warming potential (GWP) (Table 3). However, the results clearly demonstrated that the total emissions detected for subsurface application were significantly lower than those for other application methods.

Table 3 – Greenhouse gas emissions and Global Warming Potential (GWP) calculation. The values represent total emissions during the first 24 hours after application of digestate (A1, A2) or liquid swine manure (B1, B2).

Scenarios	CO_2 (kg CO_2 eq./ha)	CH_4 (kg CO_2 eq./ha)	N_2O (kg CO_2 eq./ha)	Total GWP (kg CO_2 eq./ha)
A1	65.3	14.7	10.5	90.5
A2	101.8	45.8	6.1	153.7
B1	54.9	7.0	1.8	63.7
B2	57.0	10.0	4.6	71.6

3. WOODY BIOMASS

Tables 4 and 5 report estimates of the biomass produced by the plantation at the end of the second and third growing years.

Analysis of the data indicates no strict correlation exists between the methods used to apply the cattle manure digestate and liquid swine manure and the estimated woody biomass production for each scenario. In the different cases analysed, the estimated productivity of the clones was inconsistent, making it impossible to draw conclusions after only three years of study.

The estimated woody biomass produced in the second and third growing years was determined using the following formula:
W = 0.0989xDBH2.3574
W = dry weight of the aboveground portions of the plant
DBH = diameter measured at 1.30 m above ground level

Figure 2 – Experimental poplar stand after three years.

The clones were grown in similar areas and no nutrients were applied, making it easier to compare the diameters. At the end of the third growing year, clone AF2 had the highest average diameter while clone ORION had the lowest average diameter. In this case as well, however, the measurements were taken after an extremely short period. The data may be more meaningful if taken after at least a 5- to 6-year rotation. In fact, 5 to 6 years is the rotation normally used in these types of plantations, enabling the trees to maximize their growth.

4. POTTING SOIL PREPARATION

The solid phase fraction of cattle manure digestate was used to prepare potting soil for the cultivation of certain ornamental container plants, specifically *Rosa spp.*, *Photinia x fraseri* and *Cupressocyparis leylandii*. The tests, which were conducted over an entire cultivation cycle, provided good results. No significant differences were observed in the overall development of the aboveground portions and root systems of the test plants and the two test scenarios (one with 20% and the other with 40% digestate in relation to the peat composing the potting soil). The intermediate pH and salinity parameters were measured, final visual examinations of the root system were conducted and the plants' development, habit and leaf colour were monitored during the second year of the test. These examinations demonstrated that the plants showed no signs of distress. The incorporation of up to a maximum of 40% digestate in potting soil is therefore deemed suitable. It should be mentioned that these good results were achieved partly due to the type of digestate used, which displayed a consistent, uniform composition throughout the year. When applying this to other species and using digestate having a different origin and composition, the nursery should perform

Table 4 – Estimates of the woody biomass produced in each scenario – Area 1 – Baldo clone.

BALDO clone scenarios	Avg. Ø (cm)	Estimated avg. weight of one plant (kg d.w)	No. plants	Surface area occupied (ha)	Total avg. weight (kg d.w)	Total avg. weight (kg d.w./ha)	Total avg. weight (kg f.m./ha)
DECEMBER 2014 (2nd growing year)							
A1 170 kg/N/ha cattle manure digestate	6.06	6.92	225	0.256	1,555.89	6,077.71	15,194.27
A2 340 kg/N/ha cattle manure digestate	5.83	6.31	225	0.256	1,420.25	5,547.87	13,869.66
B1 170 kg/N/ha liquid swine manure	6.15	7.16	225	0.256	1,610.92	6,292.64	15,731.61
B2 340 kg/N/ha liquid swine manure	6.86	9.26	225	0.256	2,084.15	8,141.22	20,353.04
0 Control (0 kg/N/ha)	5.77	6.16	225	0.256	1,386.04	5,414.21	13,535.51
DECEMBER 2015 (3rd growing year)							
A1 170 kg/N/ha cattle manure digestate	8.67	16.09	225	0.256	3.619.64	14,139.21	35,348.02
A2 340 kg/N/ha cattle manure digestate	8.79	16.62	225	0.256	3,738.85	14,604.89	36,512.22
B1 170 kg/N/ha liquid swine manure	8.99	17.52	225	0.256	3,942.50	15,400.40	38,500.99
B2 340 kg/N/ha liquid swine manure	9.94	22.20	225	0.256	4,995.94	19,515.40	48,788.51
0 Control (0 kg/N/ha)	9.2	18.50	225	0.256	4,163.06	16,261.94	40,654.84

Table 5 – Estimates of the woody biomass produced by the different clones present in Areas 2, 3 and 4.

Clone	Avg. Ø (cm)	Estimated avg. weight of one plant (kg d.w.)	No. plants	Surface area occupied (ha)	Total avg. weight (kg d.w.)	Total avg. weight (kg d.w./ha)	Total avg. weight (kg f.m./ha)
DECEMBER 2014 (2nd growing year)							
ORION	4.93	4.25	1198	1.28	5,092.96	3,978.88	9,947.19
SIRIO	5.66	5.89	902	0.86	5,309.97	6,174.39	15,435.97
AF8	5.19	4.80	925	0.87	4,438.88	5,102.16	12,755.41
AF2	4.94	4.27	932	0.86	3.981.11	4,629.20	11,572.99
DECEMBER 2015 (3rd growing year)							
ORION	6.79	9.04	1198	1.28	10,831.86	8,462.39	21,155.97
SIRIO	8.02	13.39	902	0.86	12,075.45	14,041.23	35,103.07
AF8	7.78	12.46	925	0.87	11,527.45	13,249.94	33,124.86
AF2	8.61	15.83	932	0.86	14,749.88	17,151.03	42,877.57

Figure 3 – Root system development in *Rosa spp.*, in scenario C (with 40% digestate).

tests before adopting the use of this type of potting soil on a large scale.

5. ANALYSIS OF ENERGY NEEDS

Analysis of the energy needs of ten different nurseries demonstrated the technical feasibility of conversion from fossil fuel boilers to woodchip boilers. However, careful evaluation of each individual business showed that, depending on the company's characteristics (areas heated, annual consumption, etc.), in some cases the woodchip heating system would reduce the heating costs of the greenhouses considerably and the investment recovery period would be quite brief, while in other cases a reduction in costs is possible but the investment recovery period is too long. For the cases studied, calculations were made to determine the threshold of thermal output and the approximate useful energy suppled to heat a greenhouse, ensuring the economic sustainability of conversion from an oil-fired system to a woodchips system. Considering the current market prices of woodchips and fuel oil and excluding any incentives, the calculations revealed that the investment becomes economically advantageous (meaning recovery of the investment within 7 years at most) at a thermal output of approximately 1,000 kW (1,300 useful MWh supplied annually). If it is possible to take advantage of the current 5-year Conto Termico incentive, the investment begins to be economically advantageous (recovery of the investment within 7 years at most) for outputs of less than 500 kW (650 useful MWH supplied annually), down to a minimum output of approximately 350 kW. Cases that are significantly different from those analysed will required detailed calculations using the specific data for each individual case.

Figure 4 – Example of a woodchip boiler for heating greenhouses.

This document is an informative summary of the activities and results of the "FLOROBASCO – Analysis of alternative production chains for the nursery sector designed to reduce pollutants and produce renewable energy" project

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For further information on the project, see the publication "Valorizzare i nutrienti, produrre biomassa da energia – Report di sintesi dei Progetti REDAFI e FLOROBASCO" published by Veneto Agriculture and the publication "Progetto FLOROBASCO" published by FlorVeneto. Both publications are available at www.venetoagricoltura.org (Formazione, convegnistica, editoria / catalogo editoriale / agricoltura sostenibile) and the website http://riducareflui.venetoagricoltura.org/

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