land

MDPI

Supplementary Materials

Supplementary S3: Data used in LCI

Table S5. Inventory for the production of 1 t of packed biochar – Feedstock production and logistic

Process/Flow	Unit	Amount	Data quality	Comment
Input				
Woodchips, hardwood_production mix_at plant_EU-28+3_S	kg	15641.09	Primary	Deciduous tree in the database was represented by hardwood.
Woodchips, softwood_production mix_at plant_EU-28+3_S	kg	3910.27	Primary	Coniferous tree in the database was represented by softwood.
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}	t*km	531.8	Primary	Deciduous woodchips transportation. Supplier distance = 17 km; number of discharges = 87; tare weight = 12689,65 kg.
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}	t*km	391.03	Primary	Coniferous woodchips transportation. Supplier distance = 50 km; number of discharges = 17; tare weight = 12545,45 kg.
Woodchips, hardwood_production mix_at plant_EU-28+3_S	kg	15641.09	Primary	Deciduous tree in the database was represented by hardwood.
Output				
Wet unscreened woodchips	kg	19551.36	Primary	

Table S6. Inventory for the production of 1 t of packed biochar –Screening and drying

Process/Flow	Unit	Amount	Data quality	Comment
Input				
Wet unscreened woodchips	kg	19551.36	Primary	
Output				
Sawdust	kg	1841.79	Primary	Outside system boundaries.
Water vapour	kg	2709.56	Primary derived	Calculations summarized in Table S11.
Screened and dried woodchips	kg	15000.0	Primary	

Table S7. Inventory for the production of 1 t of packed biochar – Gasification, syngas combustion and energy production

Process/Flow	Unit	Amount	Data quality	Comment
Input				
Screened and dried woodchips	kg	15000.0	Primary	Refers to the energy consumed by the whole process (by all machinery).
Electricity, medium voltage {IT}| market for	kWh	1610.7	Primary	
Lubricating oil {RER}| market for lubricating oil	kg	9.92	Primary	
Output				
Biochar	kg	750.0	Primary	

Electricity, medium voltage {IT}| market for | Cut-off, S - Copied from Ecoinvent	kWh	-10066.87	Primary	
Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at boiler modulating >100kW | Cut-off, S - Copied from Ecoinvent	kWh	-12750.89	Primary	This process was chosen as the conventional heat generation technology for the evaluation of the avoided impacts.
Carbon monoxide	kg	16.14	Primary	
PAH, polycyclic aromatic hydrocarbons	kg	3.0E-4	Primary	
Particulates, < 10 um	kg	0.18	Primary	
TOC, Total Organic Carbon	kg	0.68	Primary	
Benzene	kg	0.0028	Primary	
Chlorine	kg	0.11	Primary	
Nitrogen dioxide	kg	10.33	Primary	
Sulfur dioxide	kg	0.22	Primary	
Disposal, ordinary industrial waste, to municipal waste treatment/FR U (ACYVIA) [lubricating oil]	kg	9.92	Primary	
Disposal, ordinary industrial waste, to municipal waste treatment/FR U (ACYVIA) [other waste (Filters, absorbent materials, rags etc.)]	kg	8.5	Primary	

Table S8. Inventory for the production of 1 t of packed biochar – Quenching, packaging and sale of biochar

Process/Flow	Unit	Amount	Data quality	Comment
Input				
Big Bag 1t, polypropylene, production/FR U	kg	5.0	Secondary	The weight of a bag was assumed equal to 1 kg.
Biochar	kg	750.0	Primary	
Tap water {Europe without Switzerland}| market for | Cut-off, S - Copied from Ecoinvent	kg	250.0	Secondary	
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, S - Copied from Ecoinvent	t*km	3.55	Primary	Supplier distance = 355 km. Number of bags needed each year = 353.
Output				
Big-Bag	kg	5.0	Secondary	
Packed Biochar	kg	1000.0	Secondary	

Table S9. Inventory for the production of 1 t of packed biochar – Biochar application to soil

Process/Flow	Unit	Amount	Data quality	Comment
Input				
Fertilizing, with spreader on bed/FR U	h	0.28	Secondary	Calculations summarized in Table S11.
Hoeing, with 4-6m hoe (standard)/FR U	h	0.03	Secondary	Calculations summarized in Table S12.
Packed Biochar	kg	1,000.0	Secondary	
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, S - Copied from Ecoinvent	t*km	20.1	Secondary	
Output				
Applied to soil biochar	kg	1000.0	Secondary	
CO_2 sequestration	kg	-1,513.07	Secondary	
N_2O reduction	kg	-0.017	Secondary	
Irrigation {ES}| market for | Cut-off, S - Copied from Ecoinvent	m^3	-13.01	Secondary	
Ammonium nitrate (AN) (with 33.5% N), at plant (WFLDB 3.5)/RER U	kg	-0.21	Secondary	Production process of a N fertilizer chosen from the database.
Phosphoric acid, as P_2O_5, at plant (WFLDB 3.5)/RER U	kg	-0.09	Secondary	Production process of a P fertilizer chosen from the database.
Potassium chloride, as K_2O, at plant (WFLDB 3.5)/RER U	kg	-0.03	Secondary	Production process of a K fertilizer chosen from the database.

Table S10. Evaporated water data.

Tree species	Mass	Mass	Moisture content	Water content	Screened dried woodchips	Evaporated water	Moisture content for gasification	Water (10%)
	%	kg	%	kg	kg	kg	%	kg
Deciduous	0.80	14,167.65	0.20	2,833.53	12,467.53	1,700.12	0.10	1,246.75
Coniferous	0.20	3,541.91	0.35	1,239.67	2,532.47	1,009.45	0.10	253.25
Total	1.00	17,709.56	0.23	4,073.20	15,000.00	2,709.56	0.10	1,500.00

Table S11. Fertilizing with spreader data.

Activity/characteristic	Unit	Amount
Packed biochar density	kg m^{-3}	645.25
Spreader capacity	m^3	4.00
Biochar mass spreader capacity	kg	2,581.00
Number of loads	-	1.00
1 Loading time	h	0.20
Total loading time	h	0.20
Tractor speed	m h^{-1}	2,000.00
Spreader swath	m	10.00
Fertilizing rate	m^2 h^{-1}	20,000.00
Max fertilizer flow rate	kg min^{-1}	520.00
Assumed fertilizer flow rate	kg min^{-1}	200.00
Total time without loads (for a F.U. of biochar applied to soil)	h	0.08
Total time (with loads) (for a F.U. of biochar applied to soil)	h	0.28

Table S12. Hoeing, with rotary hoe data.

Activity/characteristic	Unit	Amount
Tractor speed	m h^{-1}	2,000.00
Hoeing width	m	6.00
Hoeing rate	ha h^{-1}	1.20
Area on which 1 F.U. is applied	ha	0.04
Hoeing time (for a F.U. of biochar applied to soil)	h	0.03

Table S13. Italian energy mix (2018) [1].

Primary sources used	%
Renewables	40.80
Coal	12.34
Natural gas	39.19
Petroleum Products	4.14
Nuclear	0.53
Other	3.00

References

1. GSE *Mix iniziale nazionale anno 2018*; 2019;