SUPPLEMENTAL MATERIAL

Table S1. List of the EU project aiming to improve perennial biomass crops cultivation on marginal lands.

Project name	Title	Funding scheme	Year	Crops	Reference
WATBIO	Development of improved perennial non-food biomass and bioproduct crops for water stressed environments	EU FP7	2012-2017	Poplar, Miscanthus, Giant reed	https://cordis.europa.eu/project/id/311929/it
OPTIMA	Optimization of Perennial Grasses for Biomass Production	EU FP7	2011-2015	Miscanthus, Switchgrass, Giant reed	[76]
OPTIMISC	Optimizing Miscanthus Biomass Production	EU FP7	2011-2015	Miscanthus	[8]
GIANT	Genetic improvement of Miscanthus to be a sustainable feedstock for bioenergy in the UK	DEFRA, BBSRC	2011-2016	Miscanthus	http://www.miscanthusbreeding.org/results.html
GRASS MARGINS	Enhancing biomass production from marginal lands with perennial grasses	EU FP7	2011-2015	Miscanthus, C3 grasses	https://cordis.europa.eu/project/id/289461
MISCOMAR	Miscanthus biomass options for contaminated and marginal land: quality, quantity and soil interactions	FACCE SURPLUS ERA-NET	2016-2019	Miscanthus	http://www.miscomar.ietu.pl),
GRACE	Growing Advance industrial Crops for biorEfineries	BBI JU Horizon 2020	2017-2022	Miscanthus, Hemp	https://www.grace-bbi.eu
MAGIC	Marginal lands for Growing Industrial Crops	Horizon 2020	2017-2021	Black locust, Poplar, Willow, Miscanthus, Switchgrass, Giant reed and others	https://magic-h2020.eu [77,78]
PANACEA	Non-Food Crops for a EU bioeconomy	Horizon 2020	2017-2020	Miscanthus, Switchgrass, Giant reed	http://www.panacea-h2020.eu
FORBIO	Fostering sustainable feedstock production for advanced biofuels on underutilized land in Europe	Horizon 2020	2015-2018	Black locust	www.forbio-project.eu
SEEMLA	Sustainable exploitation of biomass for bioenergy from marginal lands	Horizon 2020	2016-2018	Black locust	http://www.seemla.eu/en/home/

Table S2. C source and formulas to estimate the C input from plants (Mg C ha^{-1}) as adapted from Farina et al. [30]

Type of crop	Source of C	Formulas	Crop	Parameters value			Reference	
				HI	R:S	Turn	R:S	Turn
Perennial biomass crops	C from stubble and chaff (*Cs*)	0.1 x (Y/HI) x 0.45	**Black locust**	0.9	0.5	1.00	[79]	[79]
	C in roots (*Cr*)	(Y/HI) x R:S x Turn x 0.45	**Poplar**	0.9	0.2	0.84	[80]	[81]
	C in roots exudates (*Ce*)	0.09 x (Y/HI) x 0.45	**Willow**	0.9	0.2	0.80	[82]	[83]
	Ctot	*Cs* + *Cr* + *Ce*	**Miscanthus**	0.9	0.33	0.50	[84]	[85]
			Switchgrass	0.9	2.5	0.50	[86]	[85]
			Giant reed	0.9	0.2	0.50	[84]	[85]
Annual crops	C from stubble and chaff (*Cs*)	0.1 x (Y/HI) x 0.45	**Sorghum**	0.9	0.20	/	[87]	/
	C in roots (*Cr*)	(Y/HI) x (R:S) x 0.45	**Soybean**	0.50	0.3	/	[88]	/
	C in roots exudates (*Ce*)	0.09 x (Y/HI) x 0.45	**Wheat**	0.45	0.15	/	[89]	/
	C in weeds (*Cw*)	0.07 x (Y/HI) x 0.45						
	Ctot	*Cs* + *Cr* + *Ce* + *Cw*						

Note: Y: Yield of the crop; HI: Harvest Index; R:S: Root to Shoot ratio, Turn: Turnover rate

Table S3. Parameters used to describe the belowground biomass of the perennial biomass crops in ECOSSE.

Crop	Dry matter in fresh biomass (%)	N in dry matter (%)	C in dry matter (%)	N that is NH_4^+	Percent of biomass that is lost as gas (%)	Critical level of rainfall below which volatilisation occurs (mm)	N in biomass that is decomposed organic matter (%) -i.e Organic N	Percent of biomass added in top 25 cm (%)	Liquid? (0=no; 1=yes)
Poplar	45	0.9	39.2	0.01	0.1	5	99	100	0
Willow	48	0.7	37.8	0.01	0.1	5	99	100	0
Black locust	50	2.0	35.7	0.01	0.1	5	99	100	0
Switchgrass	45	0.8	38.0	0.01	0.1	5	99	100	0
Giant reed	45	0.8	38.3	0.01	0.1	5	99	100	0
Miscanthus	45	0.9	38.5	0.01	0.1	5	99	100	0

Table S4. Annual biomass production (Mg DM ha^{-1}) of six different perennial biomass crops in the experimental trial of Gariga. Values from year 2007 to 2014 are taken from Amaducci et al. [3]. Data from 2015 to 2017 are unpublished data. Herbaceous perennial crops were harvested every year, while woody perennial crops were harvested every 2 or 3 years.

Perennial Biomass Crops		Biomass production (Mg DM ha^{-1})										
		2007	2008*	2009	2010*	2011	2012	2013*	2014	2015	2016*	2017
Woody PBCs	Black locust	3.6	3.6	9.2	9.2	10.8	10.8	10.8	17.7	17.7	17.7	10.1
	Poplar	3.5	3.5	15.1	15.1	12.3	12.3	12.3	15.7	15.7	15.7	11.0
	Willow	2.7	2.7	14.4	14.4	13.4	13.4	13.4	11.3	11.3	11.3	11.0
Herbaceous PBCs	Miscanthus	< 1	7.00	14.0	17.5	16.9	12.8	19.4	15.3	15.4	14.5	18.0
	Switchgrass	1.9	12.1	15.4	14.4	14.8	11.4	14.7	14.4	9.0	12.8	19.4
	Giant reed	3.29	14.9	20.1	24.0	21.2	13.7	21.5	15.3	13.4	17.6	19.9

Note: years with * represent the years in which woody crop biomass was harvested. Total biomass production was divided according to the number of years from the previous harvest

Table S5. Biomass production (Mg DM ha^{-1}) and C inputs (Mg C ha^{-1}) of annual crops cultivated in the experimental trial of Gariga, after the reversion of six perennial biomass crops. Different letters within the same column indicate significant differences ($p < 0.05$) among crops, according to Tukey's test.

PEC		Biomass production (Mg DM ha^{-1})									C input for ECOSSE model				
		PBC average	Sorghum		Fallow		Soybean		Wheat		PECs	Sorghum	Fallow	Soybean	Wheat
Woody PBCs	Black locust	10.10	15.1	d	5.3	b	6.3		10.4	b	2.2	3.4	3.0	1.6	1.9
	Poplar	11.00	13.4	cd	3.7	b	6.5		8.1	ab	0.7	3.0	2.1	1.6	1.5
	Willow	11.00	10.7	b	4.5	b	6.6		7.7	a	0.7	2.4	2.5	1.6	1.4
Herbaceous PBCs	Miscanthus	13.89	4.6	a	0.9	a	5.6		7.0	a	1.2	1.0	0.5	1.4	1.3
	Switchgrass	11.49	7.8	a	0.4	a	6.0		8.0	ab	6.3	1.8	0.2	1.4	1.5
	Giant reed	16.82	11.4	bc	1.8	a	5.6		7.4	a	1.1	2.6	1.0	1.4	1.4
Anova Table	Factor		F	P	F	P	F	P	F	P					
	CROP		29.26	***	21.03	***	0.58	ns	5.12	**					
Sign: * = < 0.001, ** = <0.01, * =< 0.05**															

Table S6. Soil organic carbon stock (Mg C ha^{-1}) in the first 30 cm of the soil before and after the reversion of six different perennial biomass crops in Gariga. Different letters within the same column indicate significant differences ($p < 0.05$) among crops, according to Tukey's test. Different letters in the timeline indicate differences (P<0.05) between sampling time according to Tukey's test.

CROP		11th year a	Reversion b	Sorghum ab	Fallow c	Soybean c	Wheat c	Factor	F	P
Woody PBCs	Black locust	39.04 a	40.84 b	41.91 ab	49.95 bc	48.11 b	47.87 a	CROP	4.16	0.002
	Poplar	35.74 a	40.77 ab	40.13 ab	46.19 ab	48.66 b	45.73 a	TIME	86.49	0.001
	Willow	38.19 a	39.73 ab	40.48 b	48.36 ab	49.71 b	48.28 a	CROP x TIME	2.78	0.001
Herbaceous PBCs	Miscanthus	37.85 a	42.75 b	39.90 ab	44.62 a	47.31 ab	46.82 a			
	Switchgrass	35.62 a	41.99 ab	38.99 ab	46.99 ab	42.96 a	45.33 a			
	Giant reed	38 .76 a	37.11 a	35.47 a	52.26 c	45.71 ab	45.62 a			

Table S7. Soil organic carbon stock (Mg C ha^{-1}) based on an equivalent soil mass procedure (4000 Mg ha^{-1} of soil) before and after the reversion of six different perennial biomass crops in Gariga. Different letters within the same column indicate significant differences ($p < 0.05$) among crops, according to Tukey's test. Different letters in the timeline indicate differences (P<0.05) between sampling time according to Tukey's test.

CROP		11th year a	Reversion bc	Sorghum b	Fallow c	Soybean c	Wheat bc	Factor	F	P
Woody PBCs	Black locust	38.00 a	47.35 a	44.19 a	49.67 a	45.30 a	45.51 a	CROP	3.86	0.003
	Poplar	35.26 a	44.21 a	41.73 a	51.45 a	46.15 a	45.42 a	TIME	64.31	0.001
	Willow	37.70 a	48.37 a	47.39 a	47.06 a	49.50 ab	49.42 a	CROP x TIME	1.53	ns
Herbaceous PBCs	Miscanthus	36.14 a	47.72 a	45.87 a	48.83 a	47.26 ab	46.06 a			
	Switchgrass	33.48 a	47.02 a	44.96 a	46.93 a	48.38 ab	47.20 a			
	Giant reed	36.20 a	45.80 a	47.30 a	51.21 a	53.14 b	48.92 a			

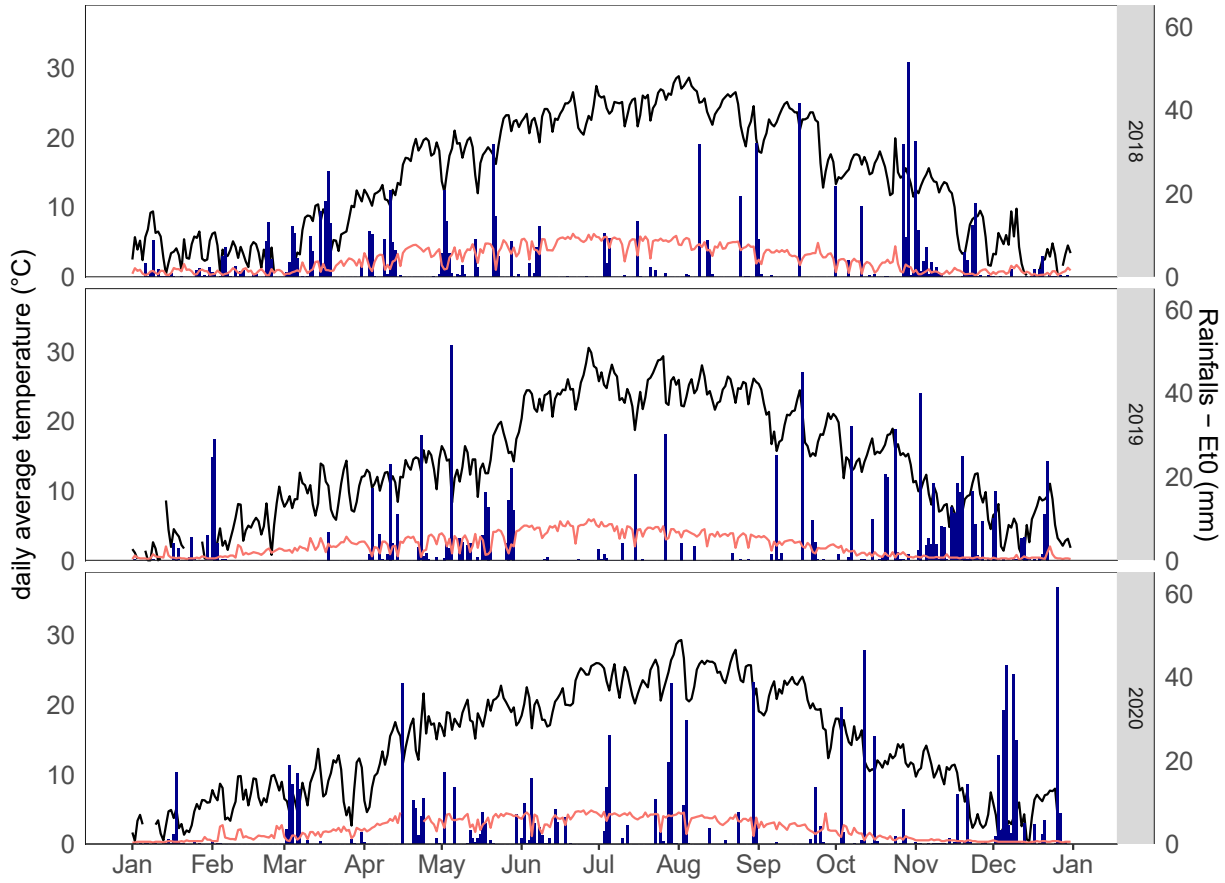

Figure S1: Daily mean temperature (°C, black line), rainfalls (mm, blue bars) and potential evapotranspiration (Et0, mm, red line) in 2018, 2019 and 2020 in the field experiment of Gariga (Piacenza, NW Italy).

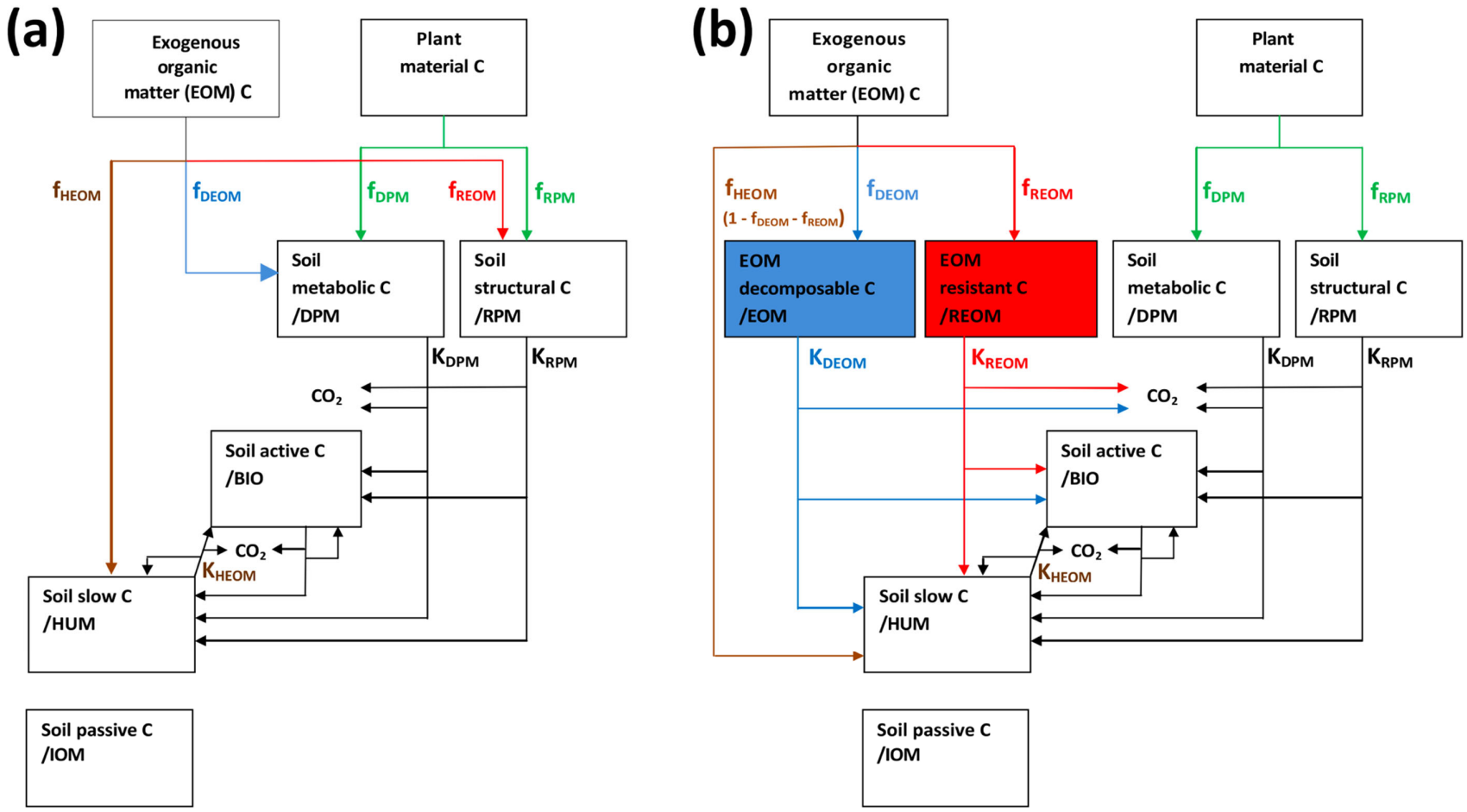

Figure S2: Structure of the original (a) and modified (b) version of the Rothamsted Carbon model. The original version (a) is used in ECOSSE, while the modified version (b) used in Ferrarini et al. [22] to derive *f* and *k* of EOM pool.

Table S8. Soil Bulk Density (g cm^{-3}) of the 0-30 cm soil layer from the beginning of Gariga experimental trial. Data of the time zero soil characterization (year 2007) were taken from Chimento et al., [47] and Amaducci et al., [3], while data of the 11th year of perennial biomass crops cultivation were taken from Martani et al., [17]. Bulk density after the reversion is the average of n=36 samples (2 per plots).

CROP		Time zero	11th year	Reversion	Sorghum	Fallow	Soybean	Wheat
Woody PBCs	Black locust	1.43	1.38	1.09	1.10	1.30	1.28	1.33
	Poplar		1.36					
	Willow		1.36					
Herbaceous PBCs	Miscanthus		1.42					
	Switchgrass		1.43					
	Giant reed		1.45					

Table S9. Input parameters used for the calibration of the ECOSSE model. Arable was common for all the six PBCs, while e for the reversion phase, specific data for each species were used.

Land use	Phase	Year	ECOSSE input parameters							
			Nitrogen deposition rate (kg N ha^{-1} y^{-1})	Soil pH	Clay content	Total organic C stock in top 50 cm of soil [Mg C ha^{-1}]	Inert organic C content	Soil available water at field capacity [mm/ 0-25 cm]	Soil available water at wilting point [mm/ 0-25 cm]	Depth to impermeable layer (cm)
Arable	PBC	2007	20	6.9	24	45.40	0.0	99	33	150
Black locust	Reversion	2018				52.45		109	28	
Poplar						53.22		103	32	
Willow						51.28		102	35	
Miscanthus						53.70		101	31	
Switchgrass						51.35		107	32	
Giant reed						54.50		104	29	
References			[90]	[19]	[3]	[17]				