Environmental viability of bioethanol derived from the poplar clone Imola

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Why 2G biofuel?

Transport – 30% of energy consumption and 25% of GHG emissions in the EU.

2G biofuel - abundant resources & government mandates.

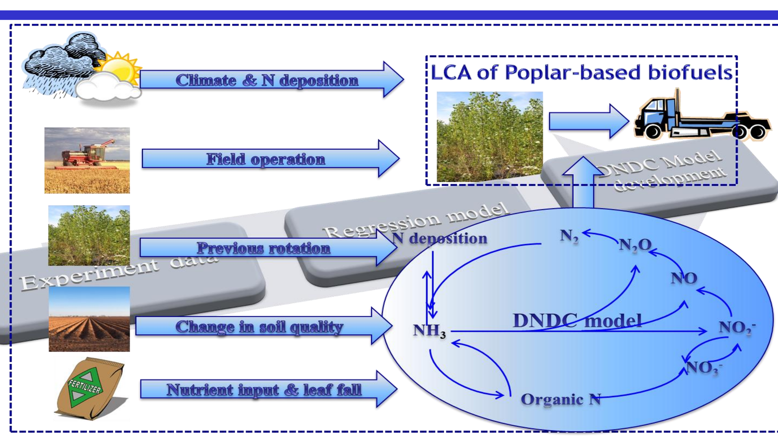
Why environmental modelling?

Bottleneck in biofuel development – controversy regarding biofuel overall environmental sustainability in the EU and globally.

Why Imola?

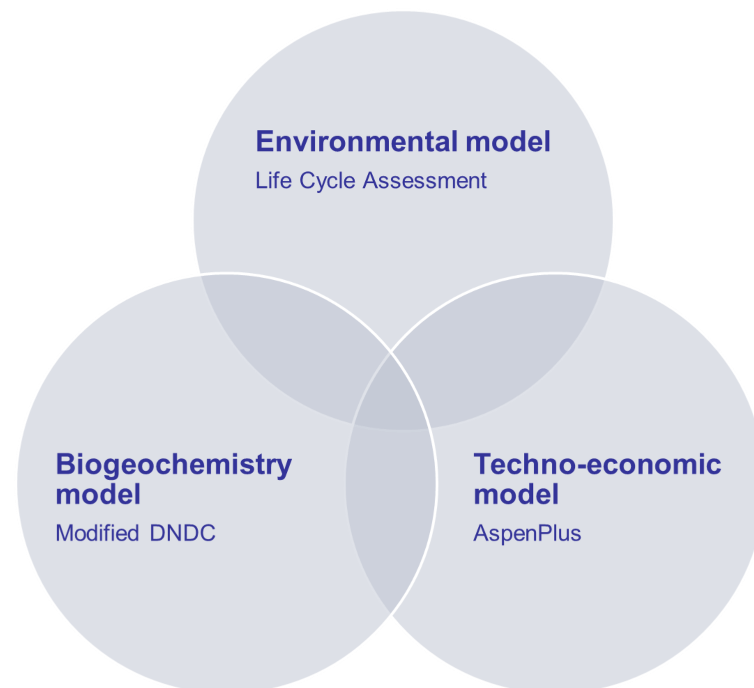
Italian poplar elite clone - a potential biofuel feedstock with high biomass yield, excellent rooting ability and resistance to rust, leaf disease and woolly aphid.

Biogeochemistry model Denitrification-Decomposition (DNDC) was modified for simulation of perennial bioenergy crops. Imola, a hybrid poplar clone, obtained by controlled crossing of *Populus deltoides* Bartr. with *Populus nigra* L. and grown under short or very short rotation coppice (SRC or VSRC) management in a plantation located at Casale Monferrato was modelled (Latitude 45°13'N, Longitude 8°51'E, Mediterranean climate with annual precipitation 600-1100 cm and mean temperature 13.3°C, sandy loam soil).



	SRC											VSRC									
	0	1	2	3	4	5	6	7	8	9	10	0	1	2	3	4	5	6	7	8	9
Ploughing																					
Harrowing																					
Planting																					
Herbicide application	1	1					1						2	2	2	2	2	2	2	2	2
Pesticide application	3	2	2	2			2	2	2			3	3	3	3	3	3	3	3	3	3
Mechenical weeds control		2	2	1	1	1	2	2	1	1	1	1	2	1	1	1	1	1	1	1	1
Fertilizer application	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Irrigation																					
Cut-back																					
Harvesting and chipping																					
Combine harvesting																					

Three modelling platforms were applied in this study. An attibutional LCA approach was undertaken to model potential Imola-derived bioethanol supply chains (combinations of various cultivation methods and processing technologies) and to compare bioethanol with gasoline. The DNDC-modelled soil carbon sequestration and C and N fluxes together with the processing technologies simulated using AspenPlus were integrated into LCA model.



Experimental Results

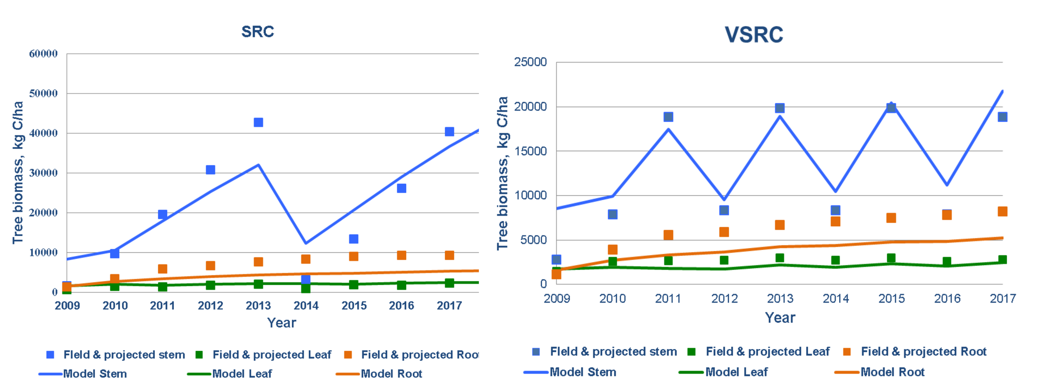
- The elemental analysis results were used to develop C/N partitioning models for DNDC and LCA modelling.

Data range for year 1-3	N % ODW	C % ODW	H % ODW
Stem	0.07-0.19%	49.42-49.61%	7.04-7.25%
Branch	0.17-0.5%	49.26-50.96%	6.82-7.19%
Leaf	2.33-2.65%	46.36-47.16%	6.38-6.58%
Corse/fine root	1.07-1.38%	47.78-48.23	6.42-6.57%

***Notes:** 1g samples ground using Retsch Cutting Mill (M200) and CryoMill (Model 20.748.0001), analysed by OEA Laboratories Ltd using a Thermoquest EA1110 elemental analyse.*

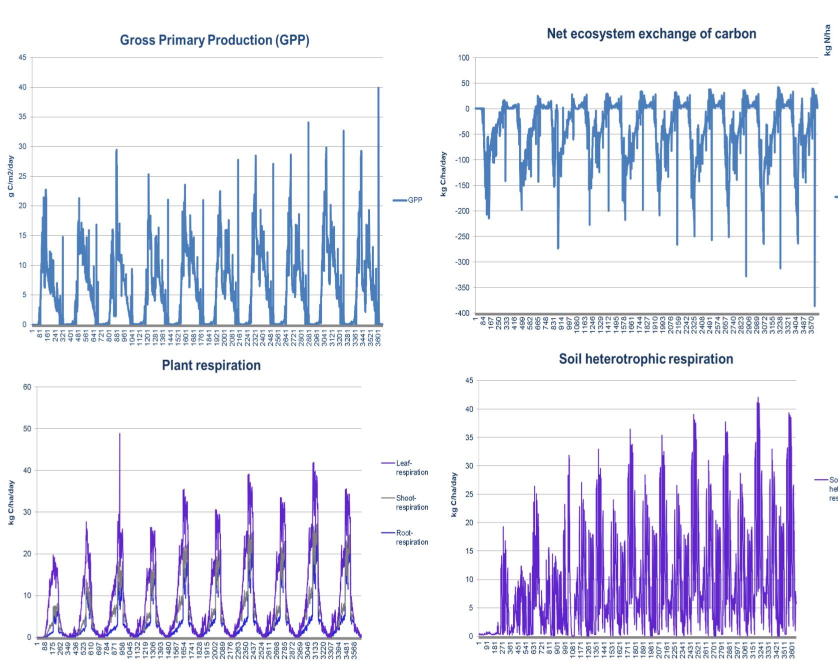
DNDC simulation vs. observation

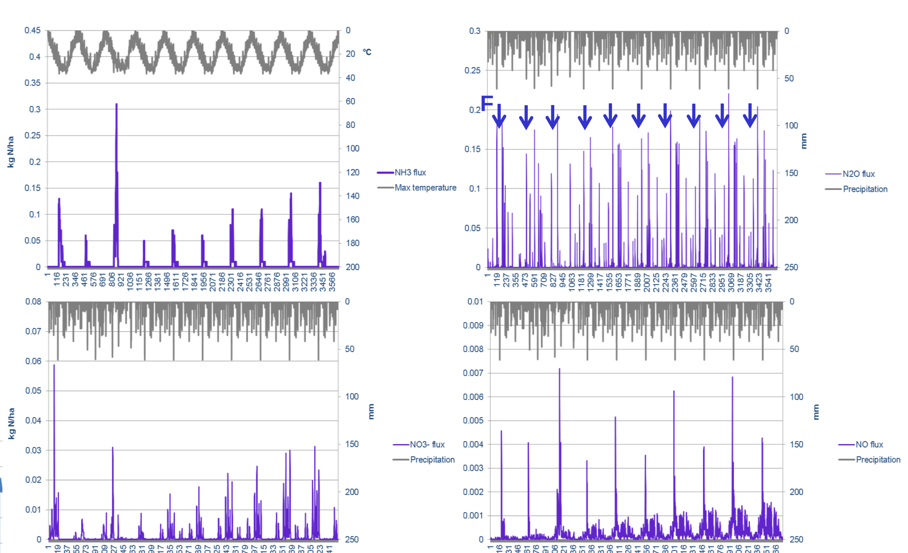
- The biomass yield and C pool derived from DNDC simulations were consistent with the experimental observations.



DNDC simulated daily C/N fluxes

- The NEE (net ecosystem exchange of carbon) simulation shows the carbon sequestered in poplar biomass and soil.

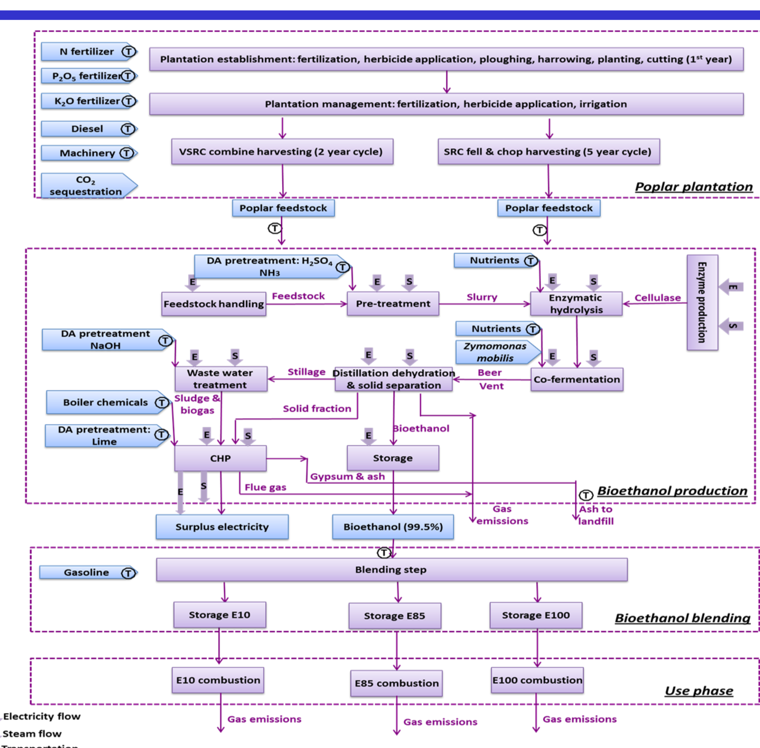




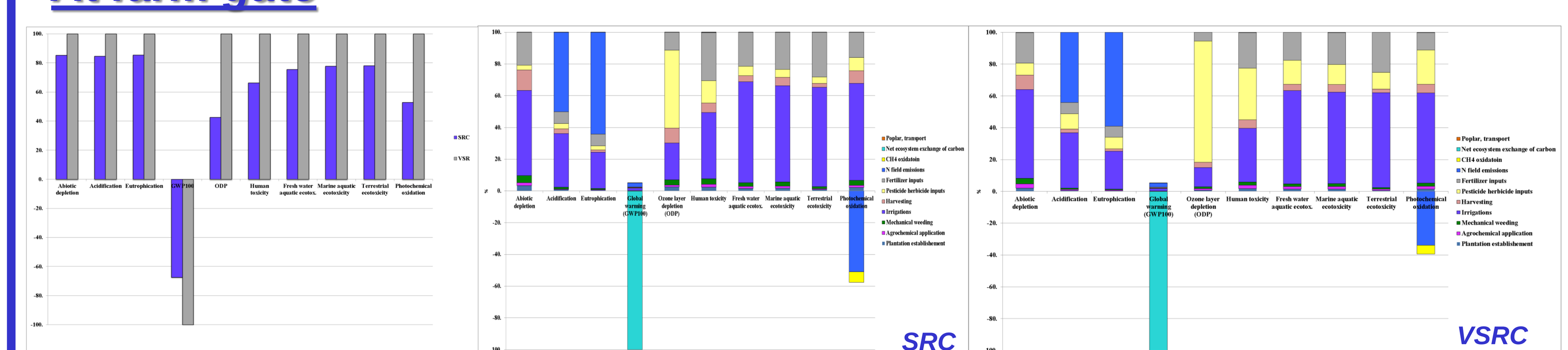
- N_2O emission peaks and N leaching are strongly related to N fertilizer inputs and rainfall events(which triggered the anaerobic zones developed in the soil).
- NH_3 emission peaks (by volatilization) roughly match the daily maximum temperature trends.

Supply chains modelled

- Hypothetical bio-refinery - 2,000 oven-dry tonne of Poplar biomass per day.
- Two pre-treatment technologies - dilute-acid (DA) & liquid hot water (LHW).
- Enzymatic saccharification with Cellic Ctec 1; co-fermentation of C5 and C6 sugars by *Zymomonas mobilis.*
- Combined heat and power (CHP) & wastewater treatment (WWT).
- Co-products - E10/E85/E100 bioethanol and surplus electricity.

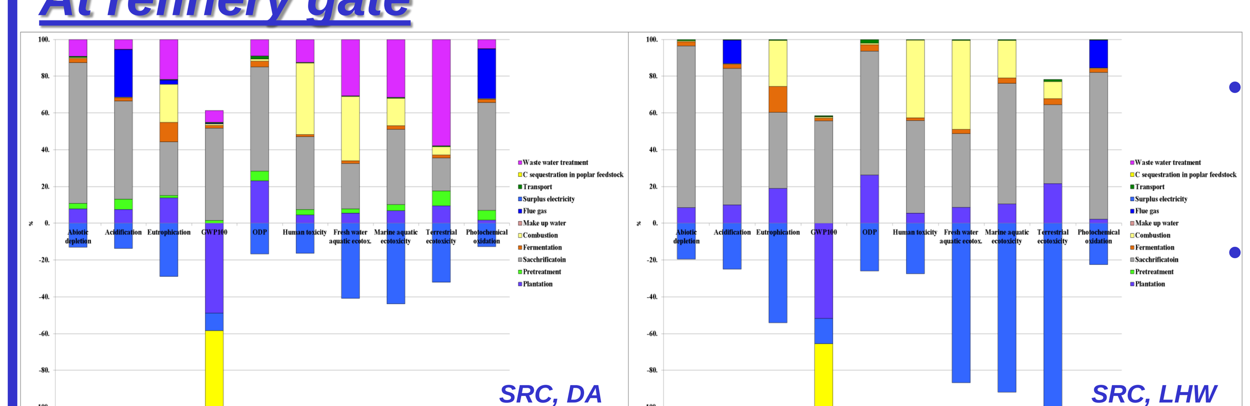


At farm gate



Characterized LCIA profiles of Imola at farm gate (unit: 1 ton poplar harvested (ODW); method: CML 2 baseline 2000)

At refinery gate

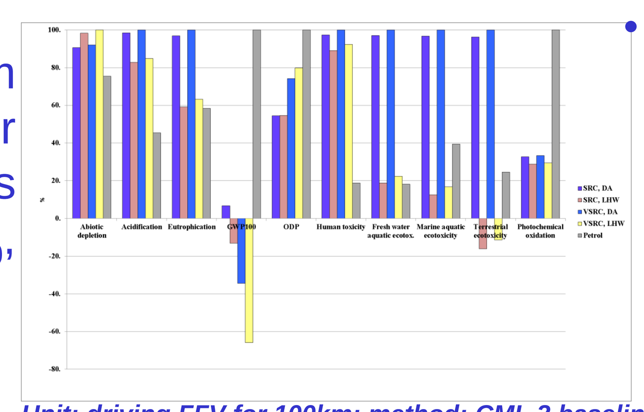


Unit: per ton Imola-derived bioethanol at refinery gate; method: CML 2 baseline 2000

- Hotspots: enzyme, chemical inputs and ash disposal .
- Biogenic carbon sequestered into poplar biomass and C absorption in soil bring GHGs 'savings'
- Higher chemical inputs and induced emissions in DA process than LHW.

Bioethanol vs. petrol

- Bioethanol derived from Imola delivers lower environmental impacts than petrol in GWP_{100}, ODP and POCP.



Unit: driving FFV for 100km; method: CML 2 baseline 2000

- An integrated modelling platform - advance the understanding of the biogeochemical processes in perennial bioenergy crop agro-ecosystems and their influences on the overall environmental profiles of biofuels.
- VSRC and SRC show similar N flux patterns - N_2O (>30%) NH_3 (>24%) and N leaching (>21%) - imply low soil buffering effects ; VSRC shows higher C & N fixation.
- Over life cycle, LHW shows environmental advantages over DA on most impact categories except for the abiotic depletion, and ODP.
- SRC is environmentally superior to VSRC on most impact categories except for GWP_{100} where higher C fixation by VSRC crops are more favourable.
- Imola-derived bio-etahnol offers life cycle GWP_{100} savings over petrol of 90% or more, placing it well within the most desirable categories being targeted by policymakers internationally.
- A particular aspect that warrants further research is the contribution that soil carbon accumulation can make to achieving low-GHG fuels in the future.

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