What have we learnt from five years of paludiculture in Mediterranean peatland (Tuscany, IT)?

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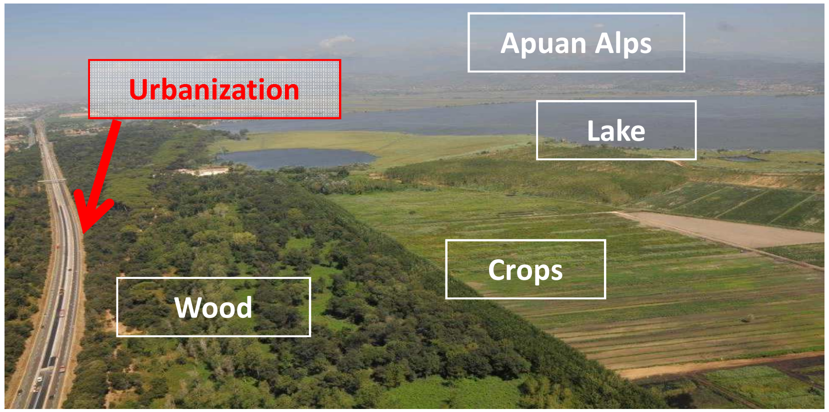
Problem description
- MASSACIUCCOLI LAKE BASIN-



ENVIRONMENTAL ASPECTS

- Catchment area: 11430 ha
- San Rossore, Migliarino and Massaciuccoli Regional Park
- Nature 2000
- Ramsar site
- NVZ area

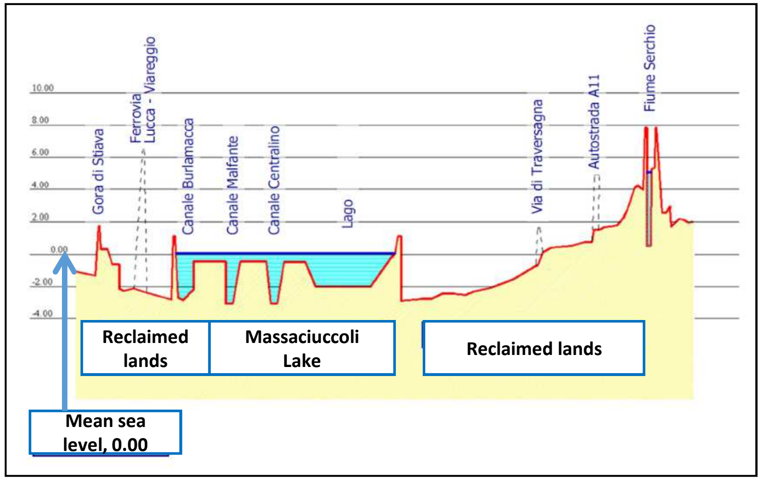
SOCIO-ECONOMICAL ASPECTS

- Populated area (46000 inhabitants)
- Conventional agriculture (5151 ha)[1]

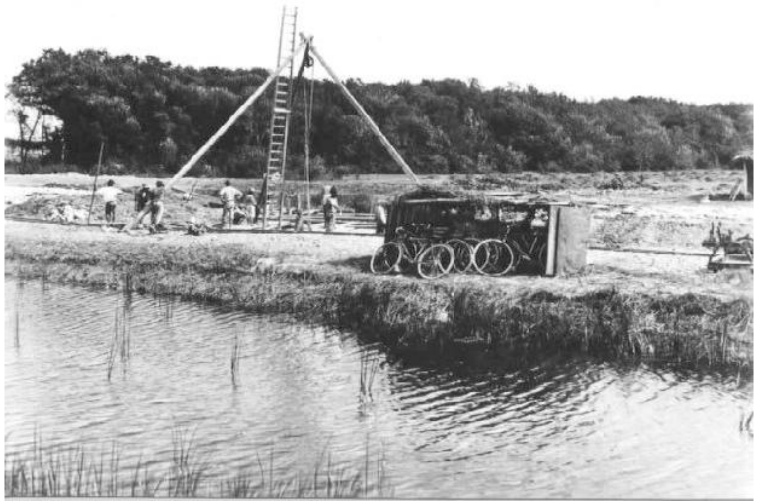
[1] Silvestri, N. *et al*. 'Diachronic analysis of farmers' strategies within a protected area of central Italy.' *Italian Journal of Agronomy* 7.2 (2012): e20.

History

- MASSACIUCCOLI LAKE BASIN-



- Forced drainage since 1920s-30s
- Shallow water table
- Large peaty areas
- Agricultural diffuse pollution
- Urban wastewater
- Lack of buffer areas



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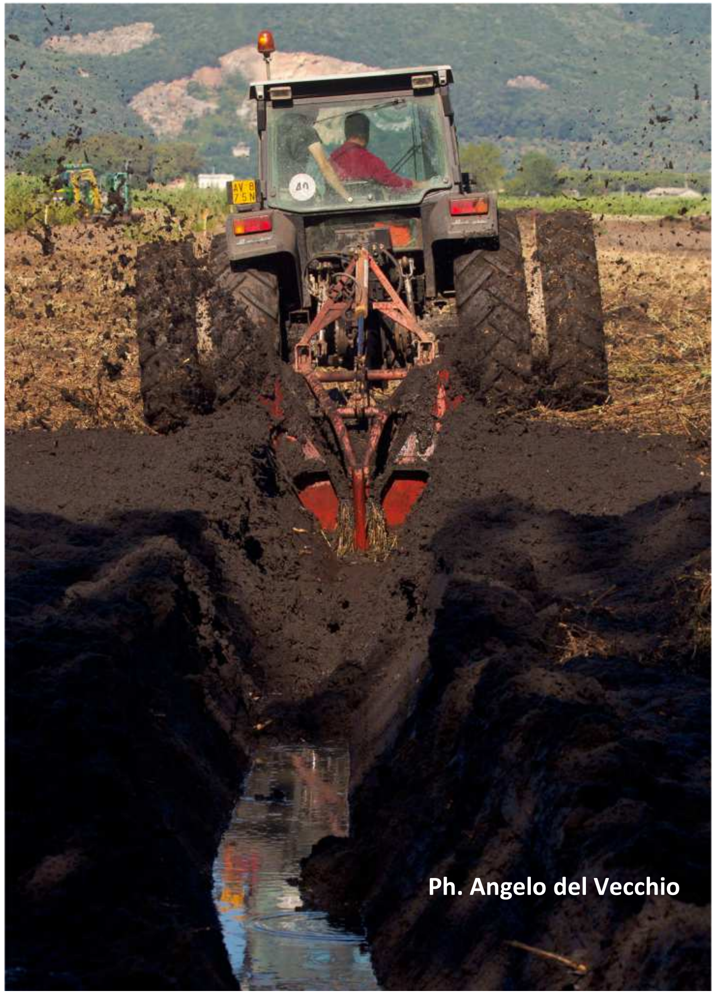


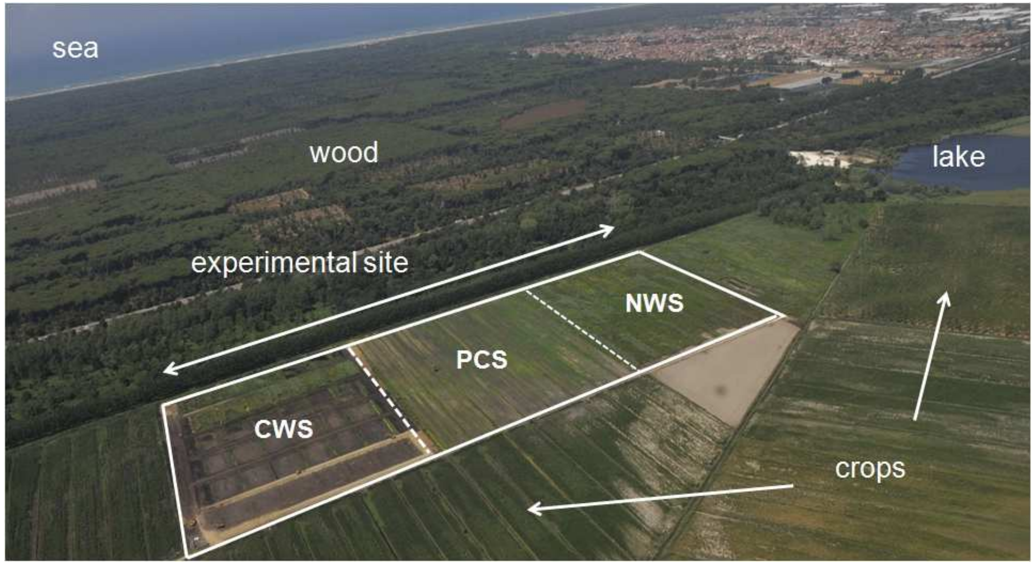
MAIN PROBLEMS:

- **Subsidence (2-3 cm/year)**
- **Peat degradation**
- **Eutrophication of surface- and ground-water[2] (N,P)**
- **Difficulties in land cultivation**

[2] Pistocchi, C. et al. 'A simple model to assess nitrogen and phosphorus contamination in ungauged surface drainage networks: application to the Massaciuccoli Lake Catchment, Italy.' Journal of environmental quality 41.2 (2012): 544-553.

Case study

- OUR INTERVENTION ON THE TERRITORY-



NWS : Natural Wetland System

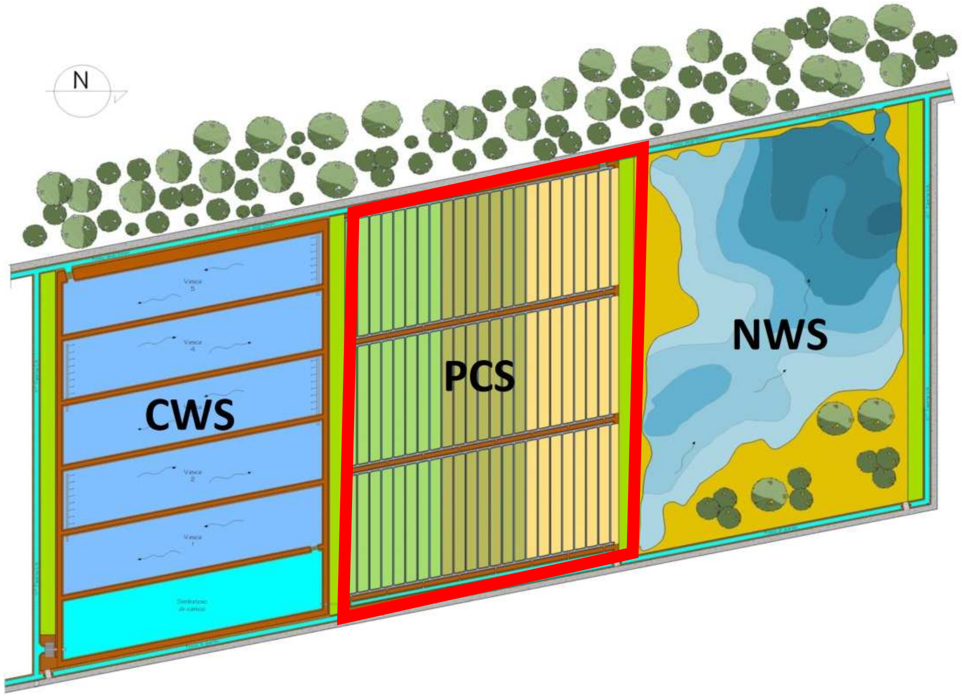
- Re-wetted area
- Spontaneous vegetation

CWS : Constructed Wetland System

- Engineered water flow
- Spontaneous vegetation (helophytes)

PCS : PaludiCulture System

- Grass and wood species watered with drainage water

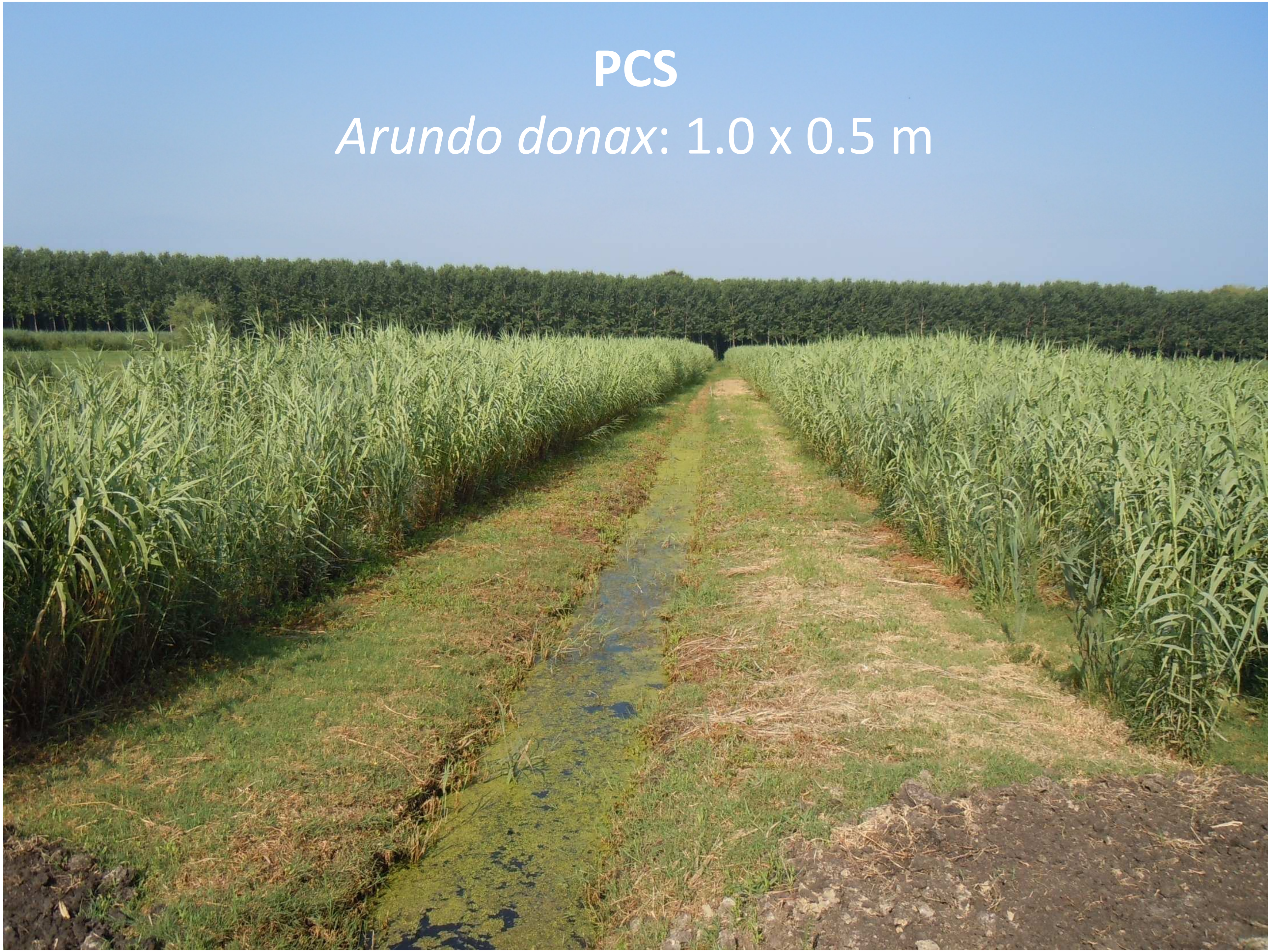


PERENNIAL RHIZOMATOUS GRASSES (PRG)

- ***Arundo donax:*** local ecotype, micropropagated plants transplanted in June (1.0 x 0.5 m)
- ***Miscanthus x giganteus:*** rhizomes plantation in June (1.0 x 0.5 m)
- ***Phragmites australis:*** rhizomes plantation in June (1.0 x 0.5 m)

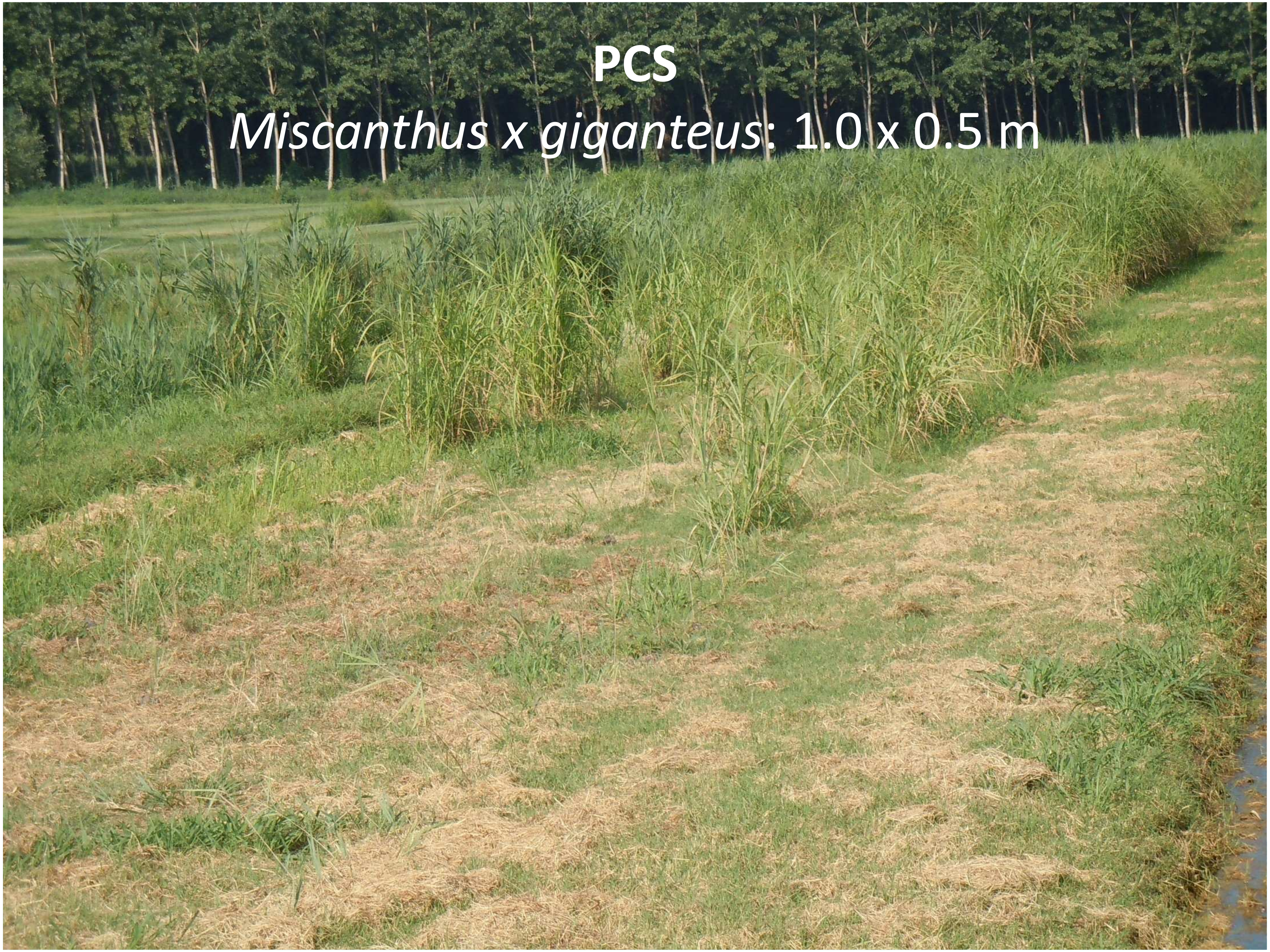
WOODY SPECIES (SRC)

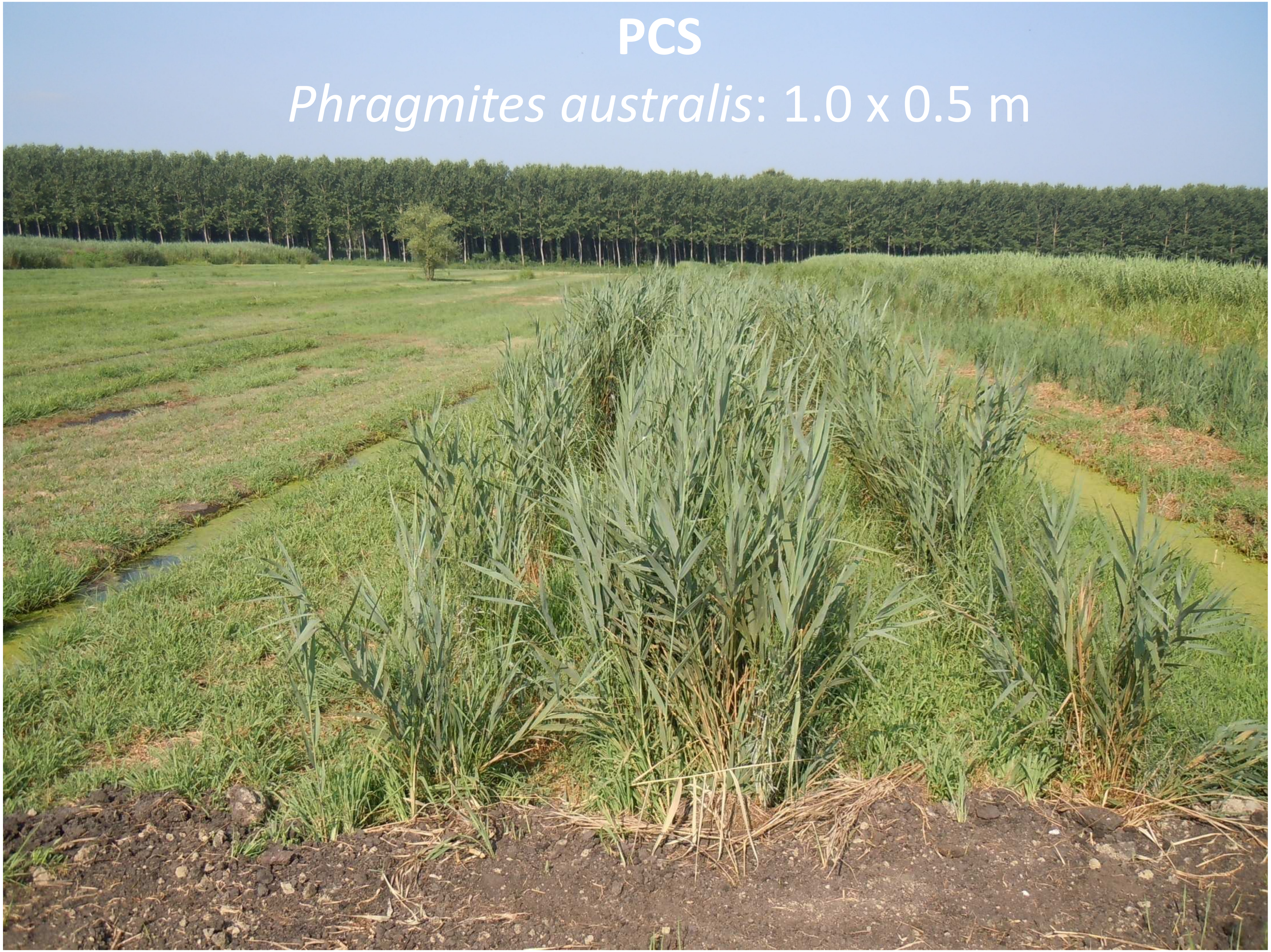
- ***Populus x canadensis nigra 'Oudenberg' :*** cuttings plantation in June (2.0 x 0.7 m)
- ***Salix alba 'Dimitrios':*** cuttings plantation in June (2.0 x 0.7 m)

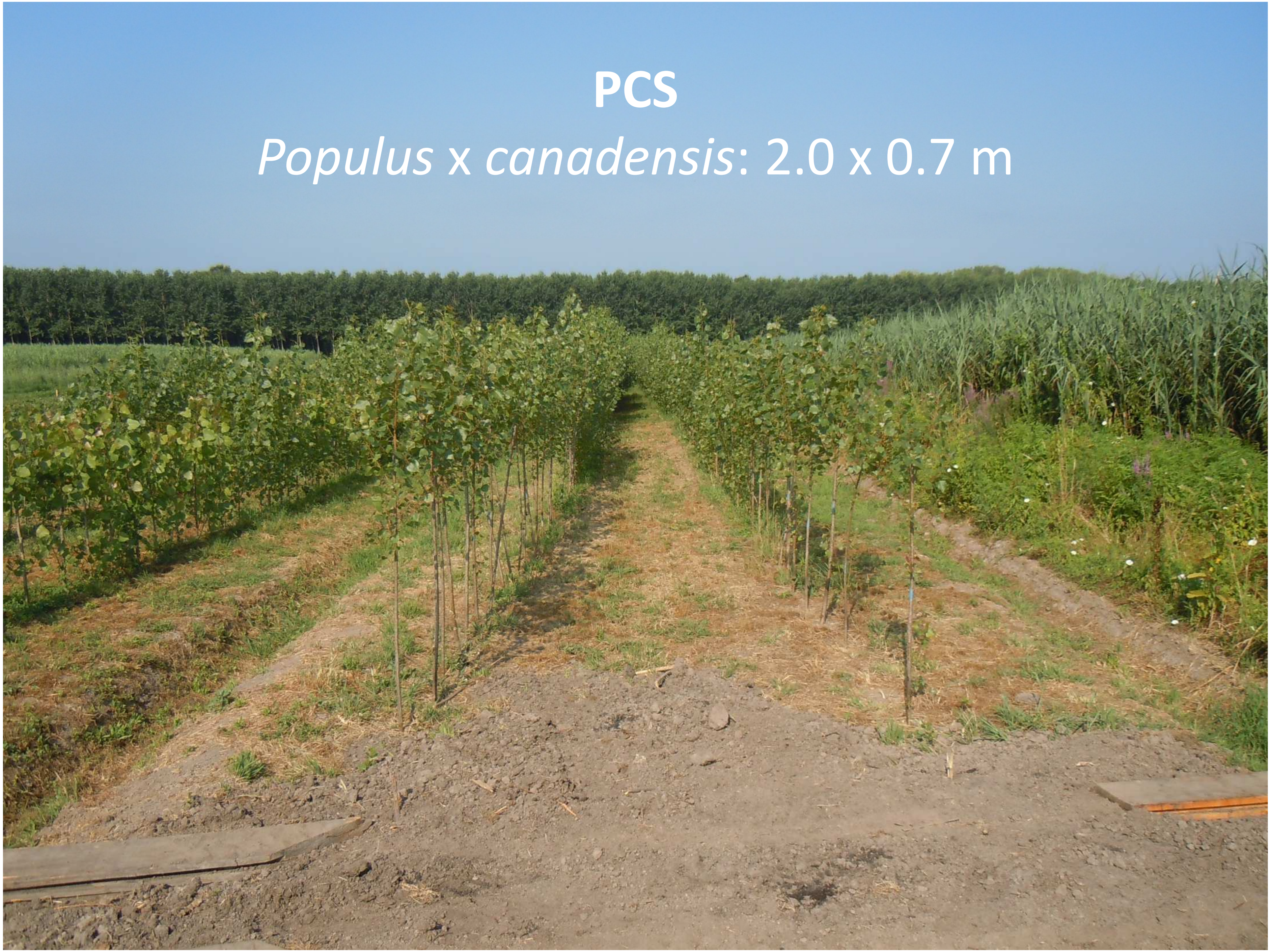

PCS
Arundo donax: 1.0 x 0.5 m

PCS

Miscanthus x giganteus: 1.0 x 0.5 m



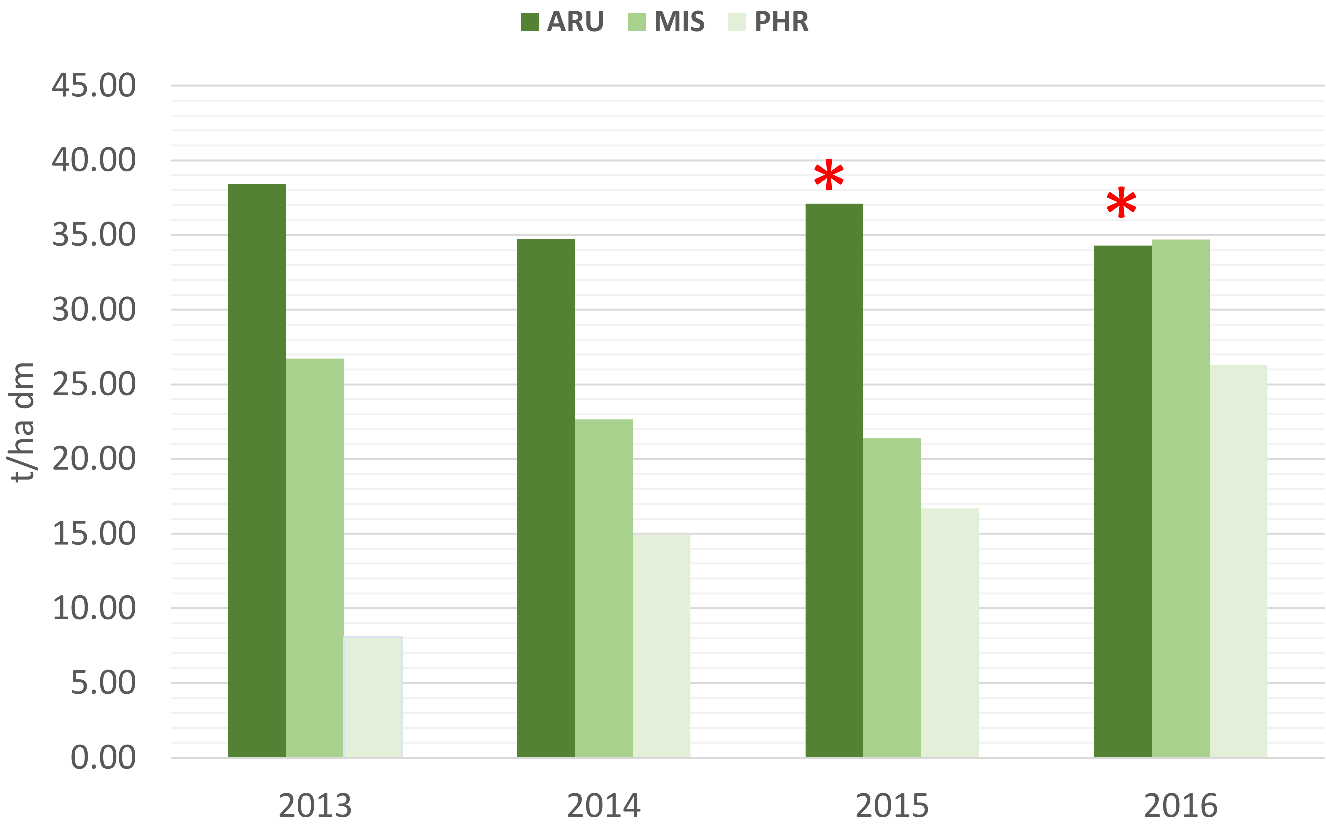

PCS
Phragmites australis: 1.0 x 0.5 m


PCS
Populus x *canadensis*: 2.0 x 0.7 m


PCS
Salix alba: 2.0 x 0.7 m

Main results

Yields – Perennial Rhizomatous Grasses

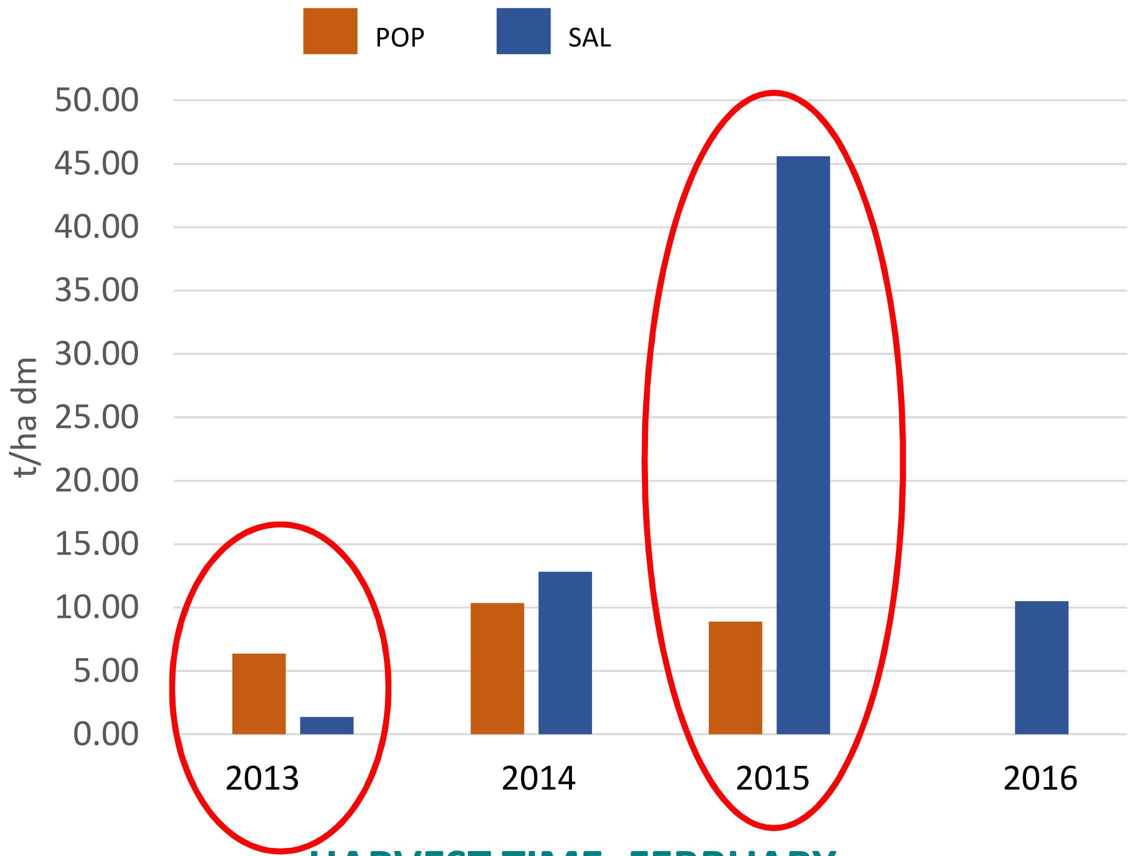


HARVEST TIME: SEPTEMBER

*** These value are to be referred to the part of the field in which the crop is still present**

Main results

Yields – Short Rotation Coppice

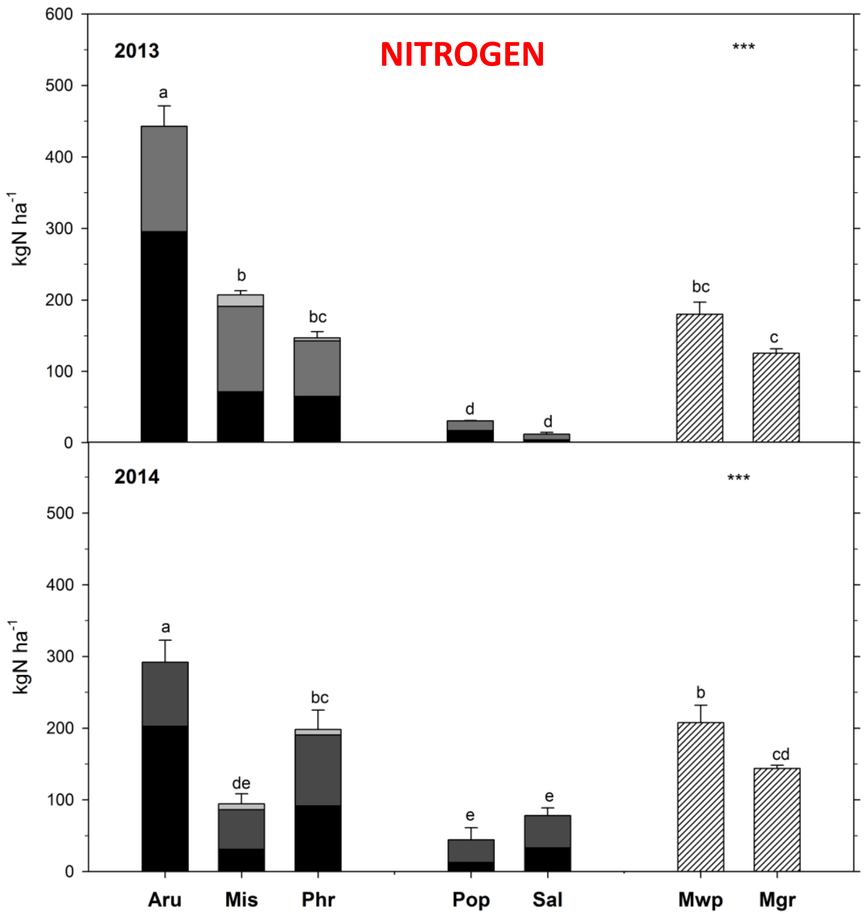


HARVEST TIME: FEBRUARY

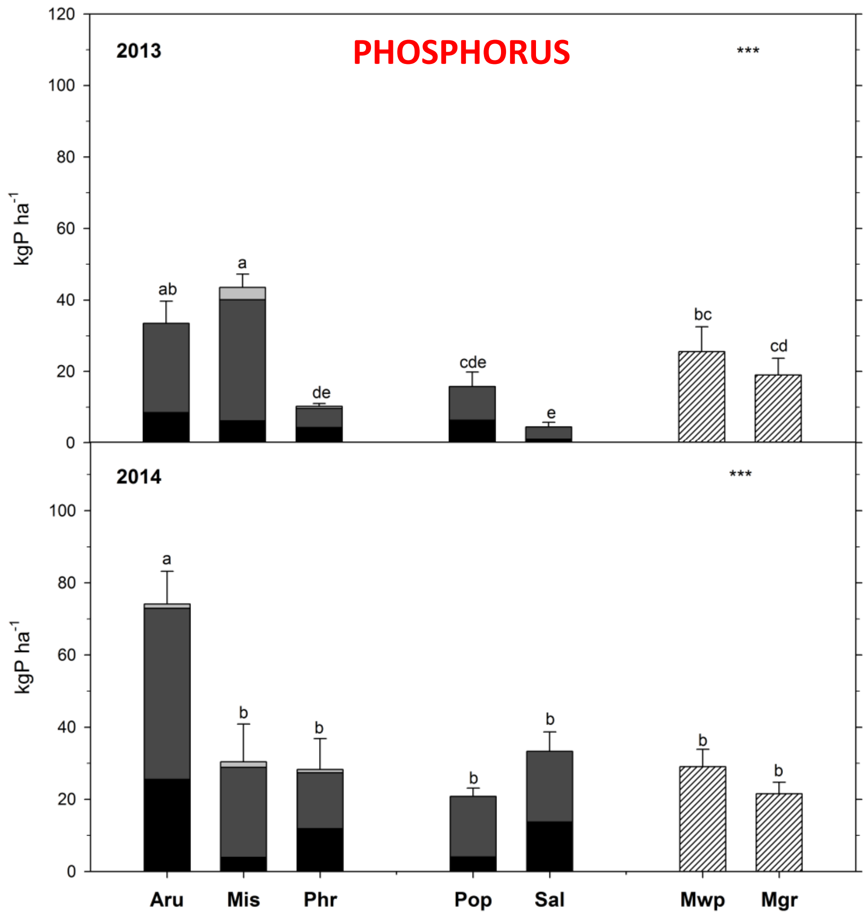
- **In 2013 and 2015, the real harvest was performed, while in 2014 and 2016 only destructive sampling was carried out**
- **All the values reported are actual yields**

Main results

A focus on nutrient uptakes



Nitrogen uptakes and allocation in different plant parts of the paludicultural species grown for bioenergy purposes and of the conventional annual species (i.e. maize, considered under two different scenarios).



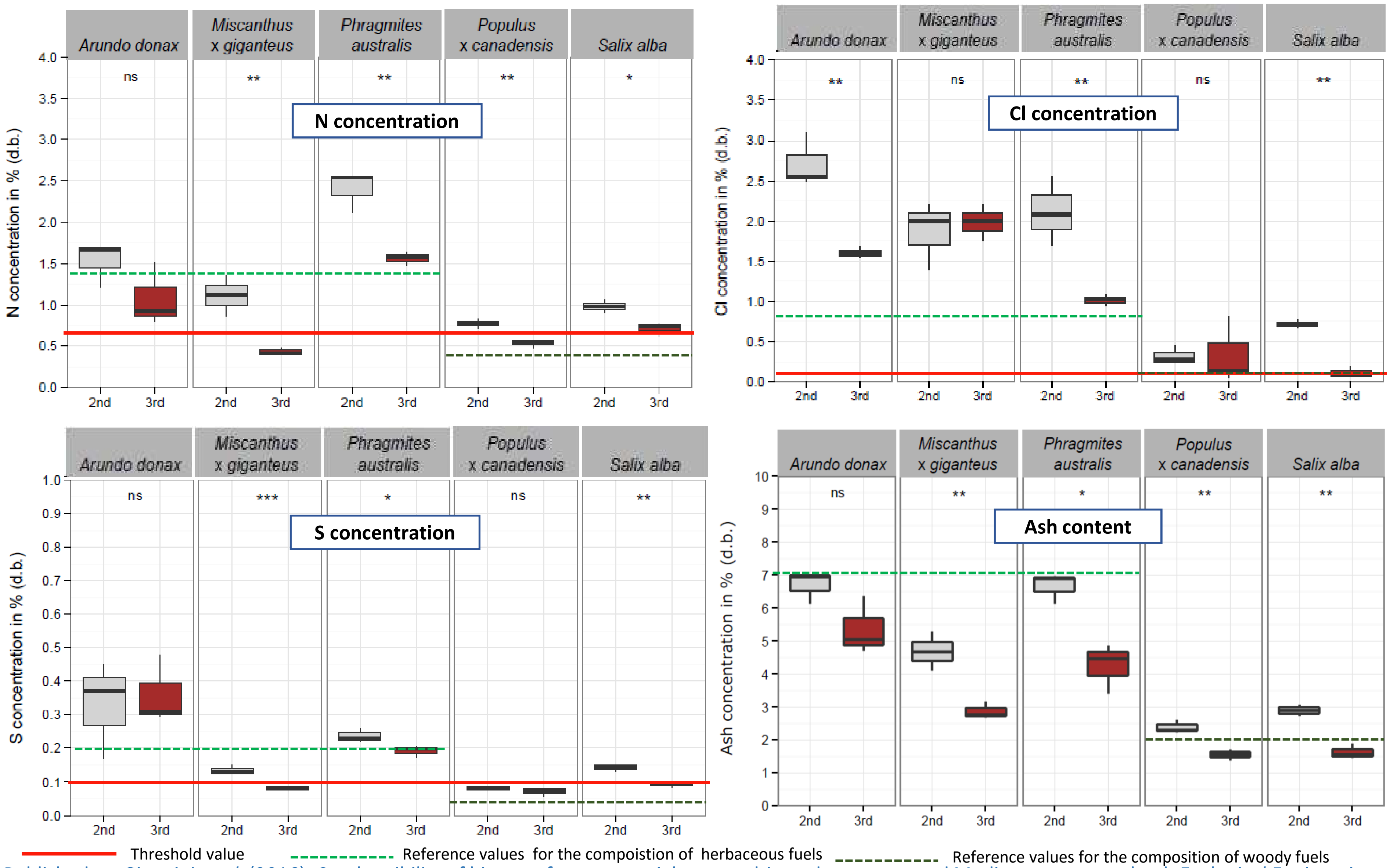
Phosphorus uptakes and allocation in different plant parts of the paludicultural species grown for bioenergy purposes and of the conventional annual species (i.e. maize, considered under two different scenarios).

leaves stems panicles maize

* Published as: Giannini *et al*. (2017). Growth and nutrient uptake of perennial crops in a paludicultural approach in a drained Mediterranean peatland. *Ecologica Engineering* 103: 478-487

Main results

Biomass conversion – Combustion



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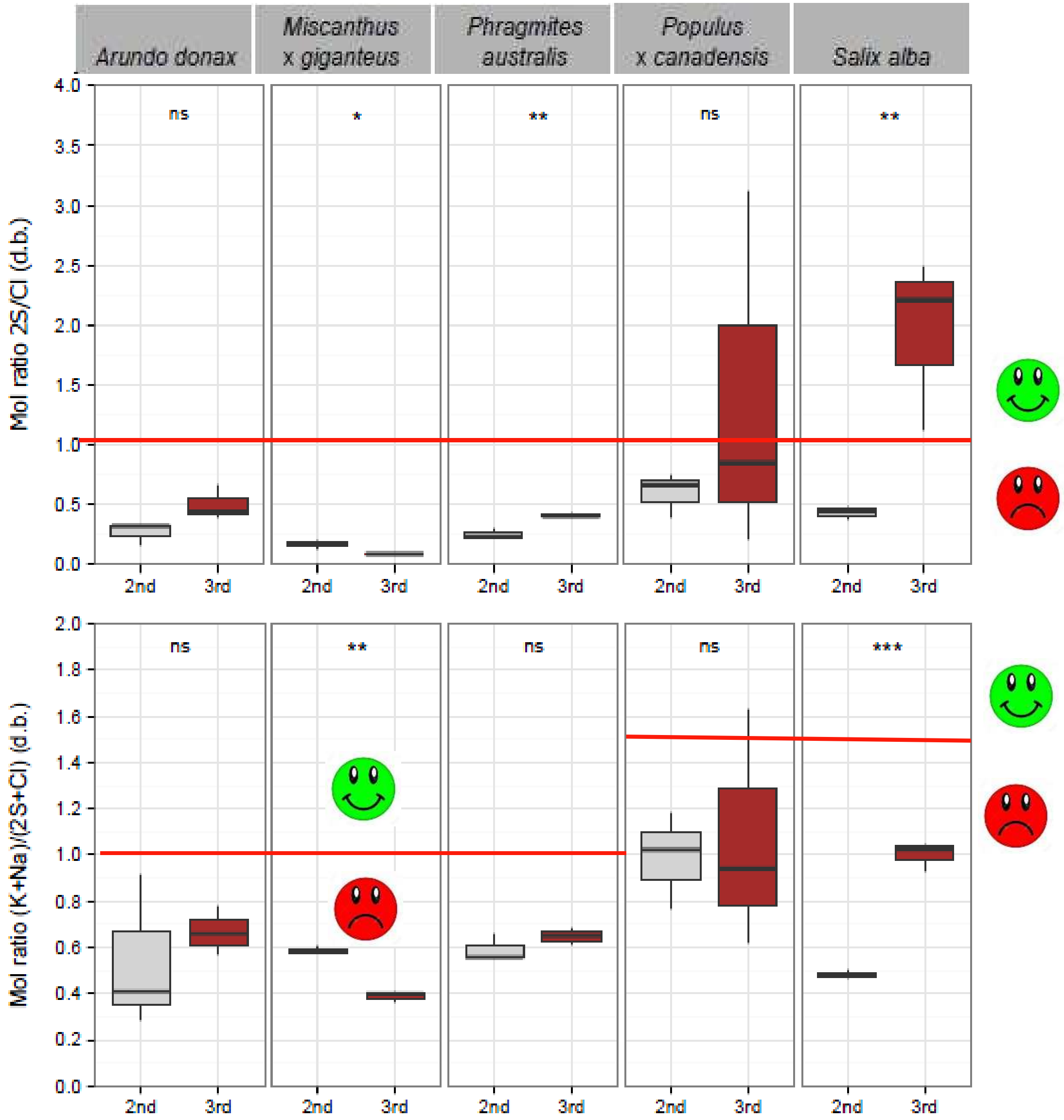
Main results

Biomass conversion – Combustion



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Main results

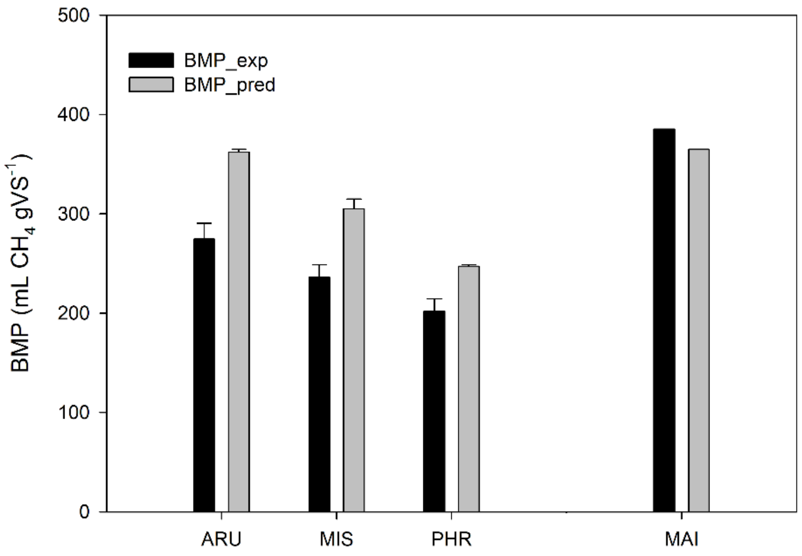
Biomass conversion – Anaerobic digestion

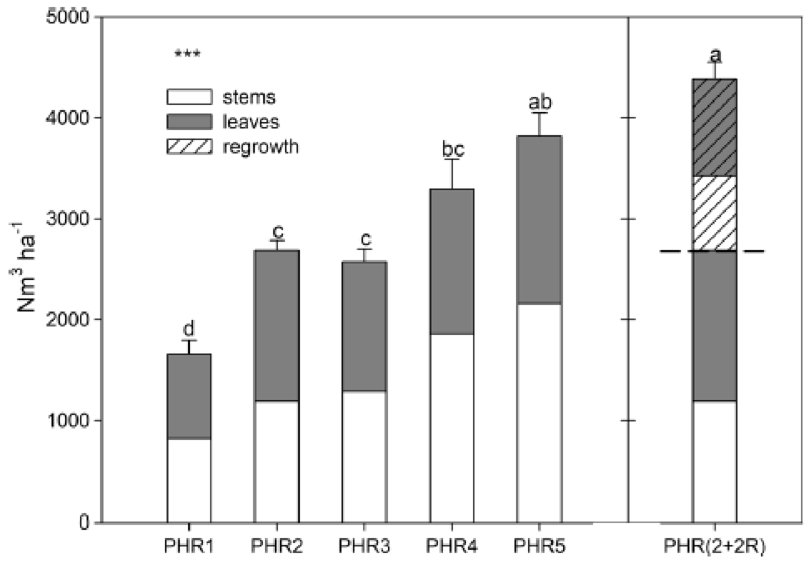
Experiment 1

Comparison among the digestibility of the biomass of the rhizomatous grasses harvested in September

Experiment 2

Analysis of the anaerobic digestion in Phragmites, comparing 5 harvest times and the hypothesis of a double cut



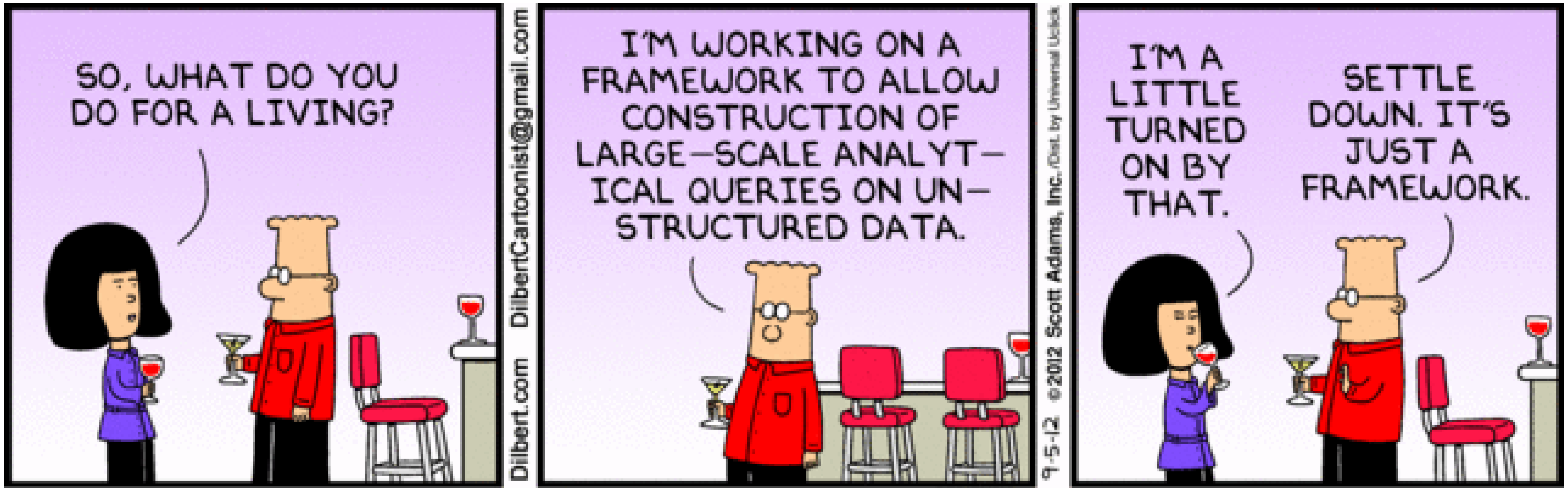


Methane yields per hectare obtained at different harvest times from May toSeptember (PHR1–PHR5) and combining a first harvest in June with a second harvest in September (PHR2 + PHR-2R). Standard errors and significance level of ANOVA are reported (***, $p < 0.001$). Values with the same letter are not significantly different ($p < 0.05$)

Published as Dragoni et al. (in press). Effect of Harvest Time and Frequency on Biomass Quality and Biomethane Potential of Common Reed (Phragmites australis) Under Paludiculture Conditions. Bioenergy Research. DOI 10.1007/s12155-017-9866-z

How can we summarize these results?

A multi-adaptive framework for the crop choice in paludicultural cropping systems



* Published as Silvestri et al. (2017) A multi-adaptive framework for the crop choice in paludicultural systems. *Italian Journal of Agronomy 12: 734 : 69-76*

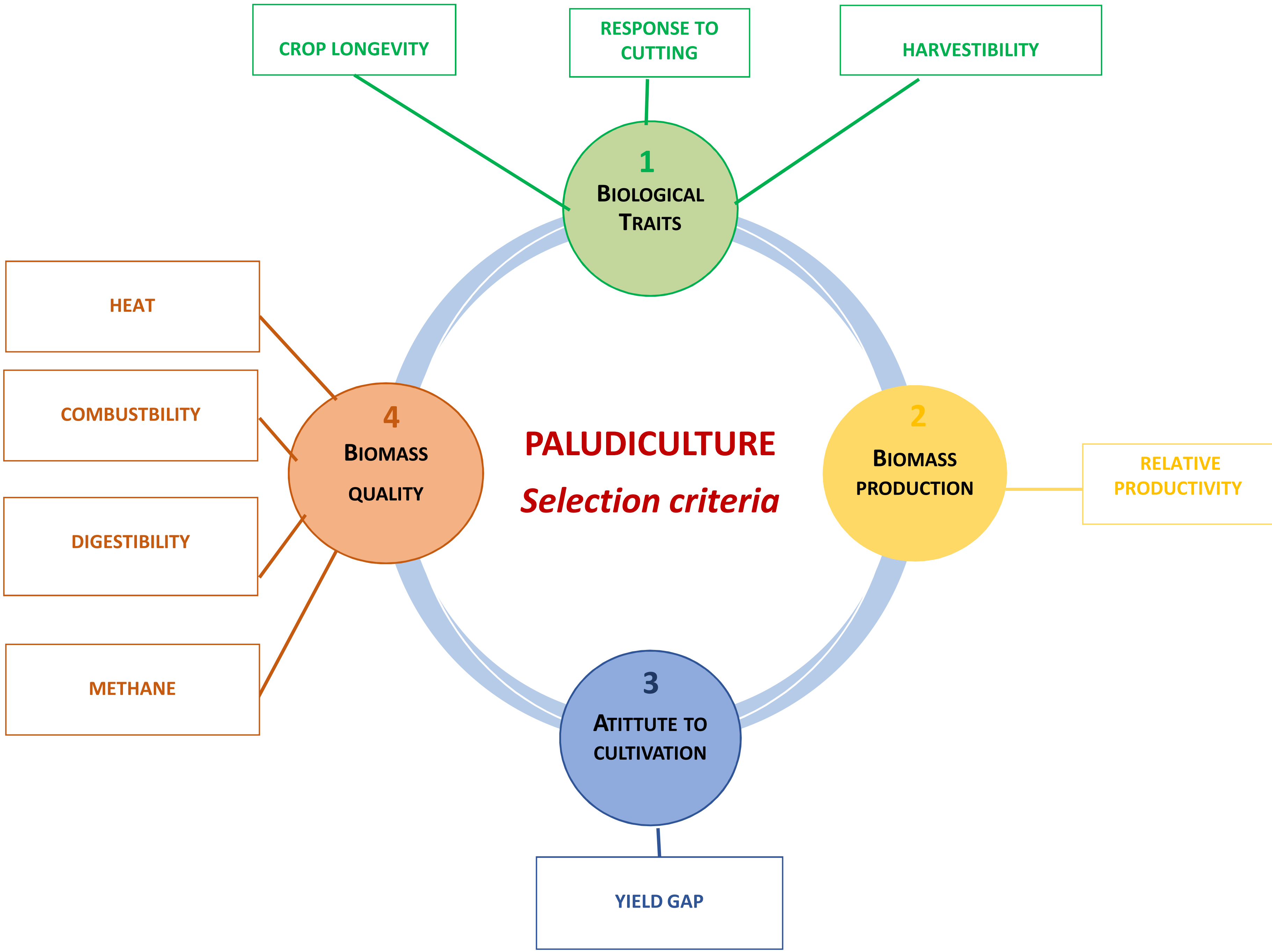
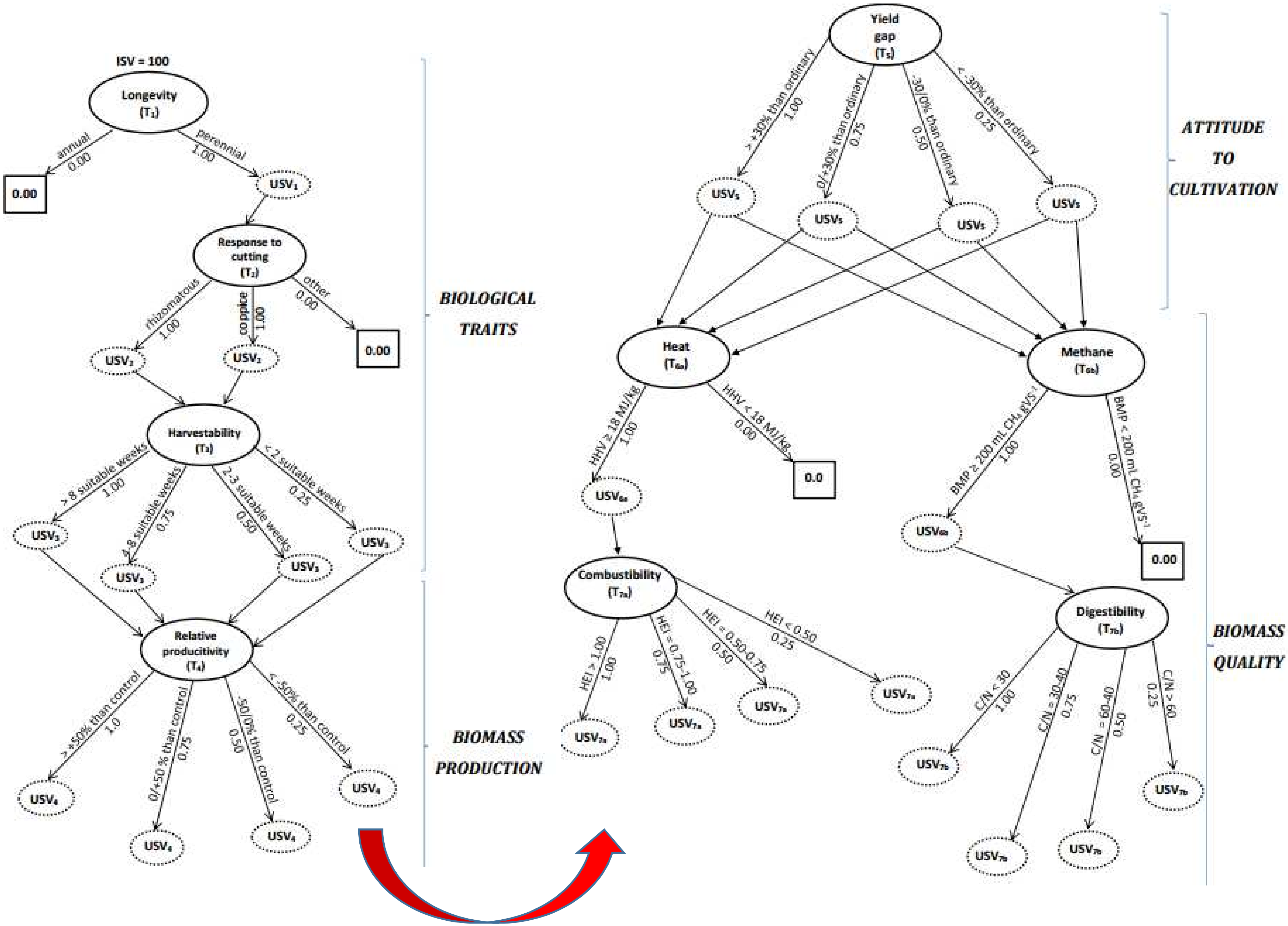

CROP LONGEVITY
RESPONSE TO CUTTING
HARVESTIBILITY
1
BIOLOGICAL TRAITS
HEAT
COMBUSTBILITY
DIGESTIBILITY
METHANE
4
BIOMASS QUALITY
PALUDICULTURE
Selection criteria
2
BIOMASS PRODUCTION
RELATIVE PRODUCTIVITY
3
ATITTUTE TO CULTIVATION
YIELD GAP

Table 1. Threshold values and correspondent degrees of suitability for all the features foreseen by the framework.

Criteria	Features	Tests and threshold values	DoS
Biological traits	Longevity	Perennial	1.00
		Annual	0.00
	Response to cutting	Coppice	1.00
		Rhizomatous/stolonifer	1.00
		Other	0.00
	Harvestabilty	>8 suitable weeks for crop harvesting*	1.00
		From 4 to 8 suitable weeks for crop harvesting*	0.75
		From 2 to 3 suitable weeks for crop harvesting*	0.50
		<2 suitable weeks for crop harvesting*	0.25
Biomass production	Relative productivity	>+50% than a control crop°	1.00
		From 0 to +50% than a control crop°	0.75
		From -50 to 0% than a control crop°	0.50
		<-50% than a control crop°	0.25
Attitude to cultivation	Yield gap	>+30% than under ordinary growing conditions[#]	1.00
		From 0 to +30% than under ordinary growing conditions[#]	0.75
		From -30 to 0% than under ordinary growing conditions[#]	0.50
		<-30% than under ordinary growing conditions[#]	0.25
Biomass quality[§]	Heat	HHV≥18 (MJ/kg)	1.00
		HHV<18 (MJ/kg)	0.00
	Combustibility	HEI>1.00 (pure number)	1.00
		HEI ranges from 0.75 to 1.00 (pure number)	0.75
		HEI ranges from 0.50 to 0.75 (pure number)	0.50
		HEI<0.50 (pure number)	0.25
	Methane	BMP≥200 (mL CH_4 gVS^{-1})	1.00
		BMP<200 (mL CH_4 gVS^{-1})	0.00
	Digestibility	C/N ratio <30 (pure number)	1.00
		C/N ratio from 30 to 40 (pure number)	0.75
		C/N ratio from 40 to 60 (pure number)	0.50
		C/N ratio >60 (pure number)	0.25

DoS, degree of suitability; HHV, higher heating value (estimated from carbon, hydrogen and oxygen content); HEI, harmful emission index (estimated from potassium, sodium, sulfur and chlorine content); BMP, biochemical methane potential [according to Triolo *et al.* (2011)]; C/N, carbon and nitrogen content ratio. *To be considered as suitable a week must comply with seasonality and plasticity conditions (see text); °a control crop is a crop grown in the same pedoclimate but under drained conditions (see text); [#]ordinary conditions mean no saturated soil, no high acidity or salinity, rainfed cultivation (see text); [§]the two alternative pathways are combustion (heat and combustibility) and biogas conversion (methane and digestibility).



The decision tree scheme

Conclusive remarks

From an agronomic point of view…

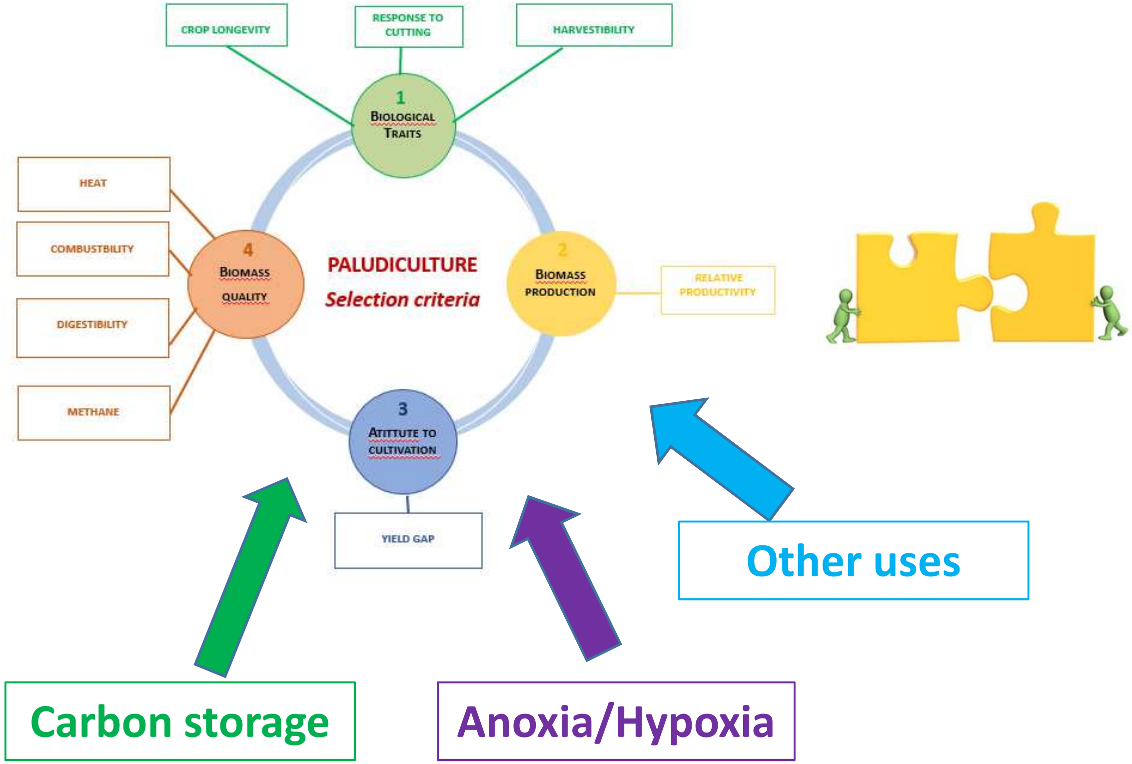
- Our adaptive approach 'PALUDICULTURE' was promising in terms of biomass production and biomass use

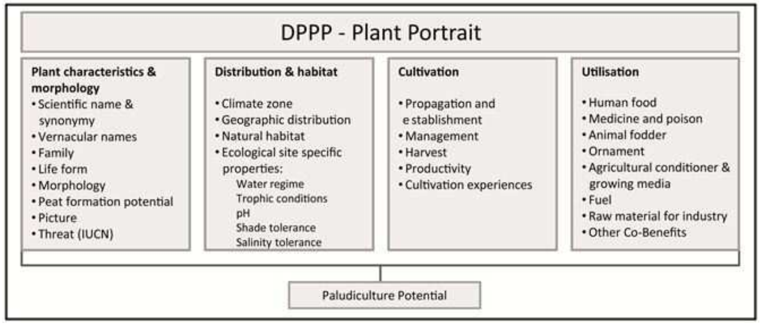
- How can we answer to the two fundamentals of agronomy:
  - **WHAT TO CULTIVATE?**
  - **HOW TO CULTIVATE?**

- In this case maybe we should add:
  - **WHAT TO DO WITH THE HARVESTED BIOMASS?**

THE CRUCIAL ROLE OF THE CROP CHOICE

Perspective of work



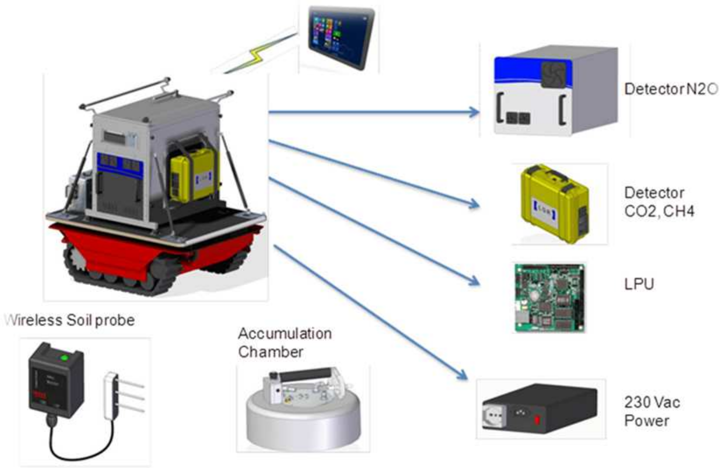


Abel, S. *et al*. 'The database of Potential Paludiculture Plants (DPPP) and results for Western Pomerania' *Plant Div. Evol. Vol.130/3-4 (2013):* 219-228

Perspective of work

- Organization of the harvesting and biomass delivery logistics

- Field monitoring of GHG emissions (CO_2, CH_4, N_2O) using the prototype developed during IPNOA LIFE Project



- Crop physiology modelling under paludicultural conditions

Cited Literature

- Dragoni F., Giannini V., Ragaglini G., Bonari E., Silvestri N. (in press).
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A simple model to assess nitrogen and phosphorus contamination in ungauged surface drainage networks: application to the Massaciuccoli Lake Catchment, Italy. *Journal of environmental quality*, *41*(2), 544-553.

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Thank you!

FOR FURTHER INFORMATION, SUGGESTIONS AND NETWORKING: v.giannini@santannapisa.it