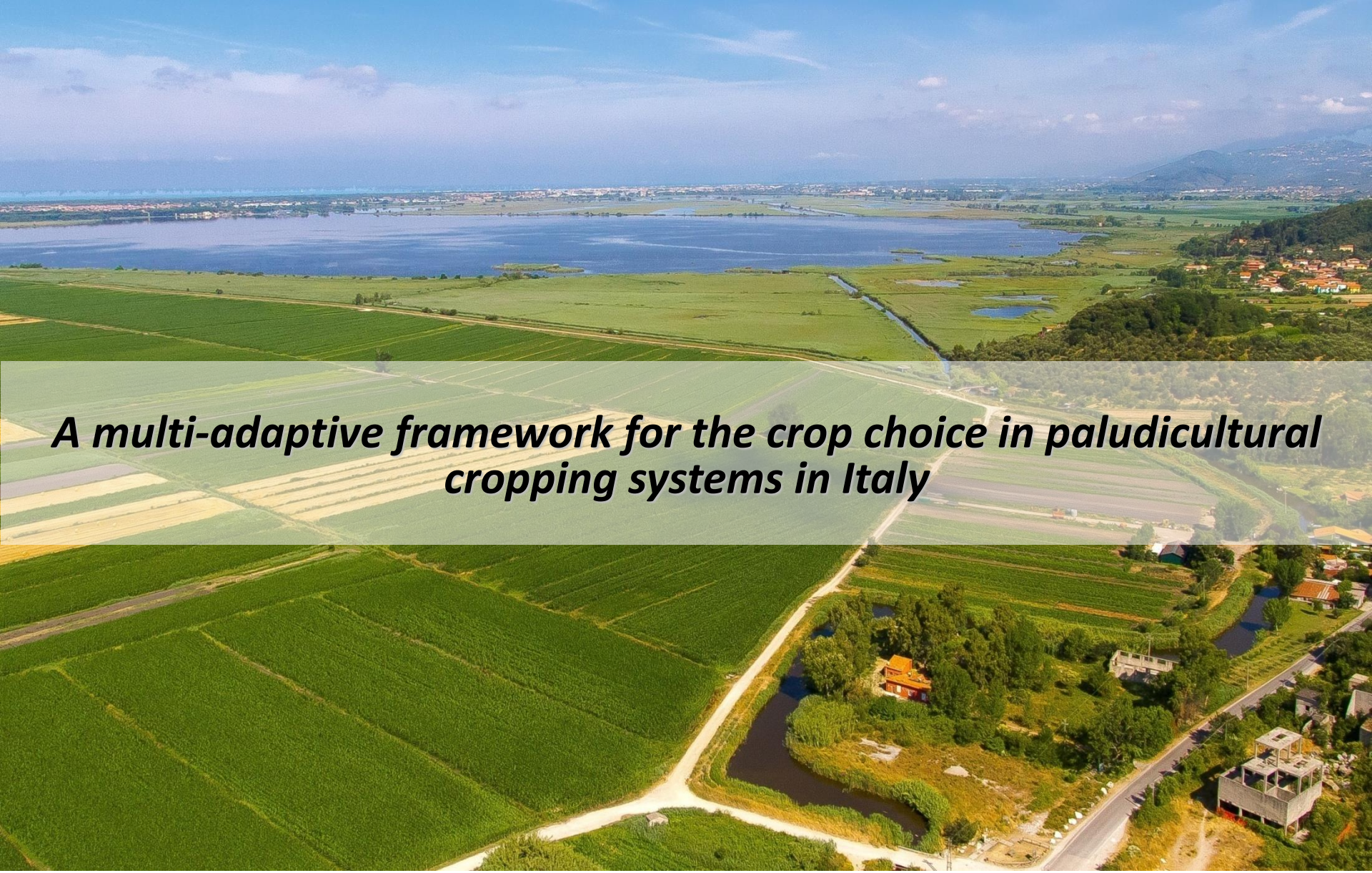

A multi-adaptive framework for the crop choice in paludicultural cropping systems in Italy

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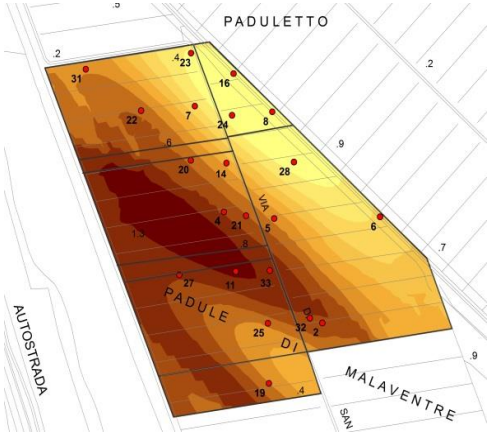
Study area

Massaciuccoli Lake Basin

- **Catchment area: 11430 ha**
- **San Rossore, Migliarino and Massaciuccoli Regional Park**
- **Peaty soils**
- **Ramsar site, Nature 2000**
- **Populated area (47000 inhabitants)**
- **Conventional agriculture (5151 ha)**



Why paludiculture here?

To repair:

- **Subsidence (3-4 cm/year)**
- **Eutrophication of surface- and ground-water (N,P)**

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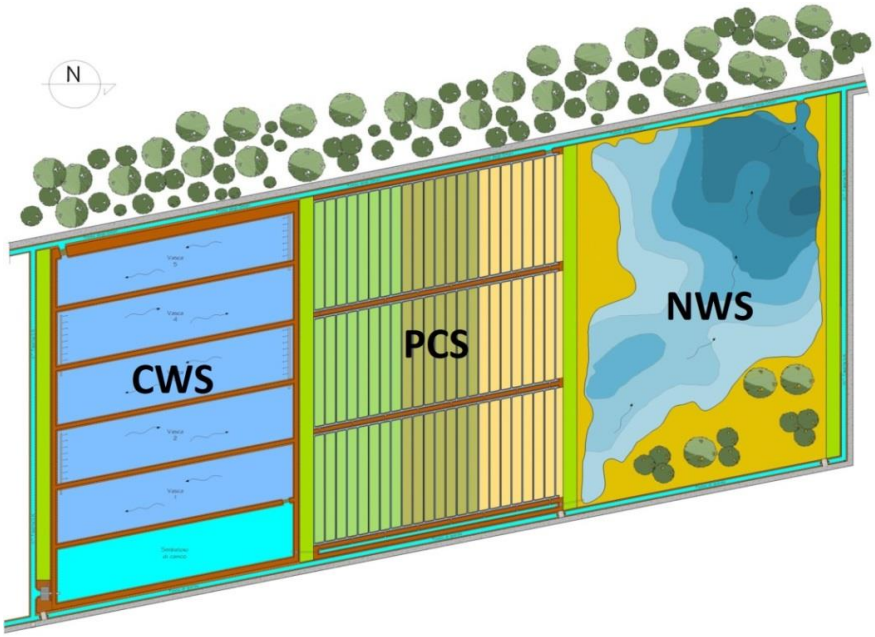
Pilot experimental field



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 in permanent soil saturated conditions

Aims of the research

- Which is the adaptability of the most studied perennial crops under paludicultural conditions?
- What is the possible destination of the harvested biomass?
- Which are the most important criteria for the crop selection in paludiculture?

Paludicultural field set-up

TESTED PLANT SPECIES:

- *Arundo donax* L. (Aru)
- *Miscanthus* x *giganteus* Greef et Deuter (Mis)
- *Phragmites australis* L. (Phr)
- *Populus* x *canadensis* Moench. var 'Oudemberg' (Pop)
- *Salix alba* L. var 'Dimitrios' (Sal)

CONTROL PLANT SPECIES:

- *Zea mays* L.

Paludicultural field set-up

PERENNIAL RHIZOMATOUS GRASSES (PRG)

- ***Arundo donax*** **:** local ecotype, 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 0.75 m)
- ***Salix alba 'Dimitrios'*** **:**
cuttings plantation in June (2.0 x 0.75 m)

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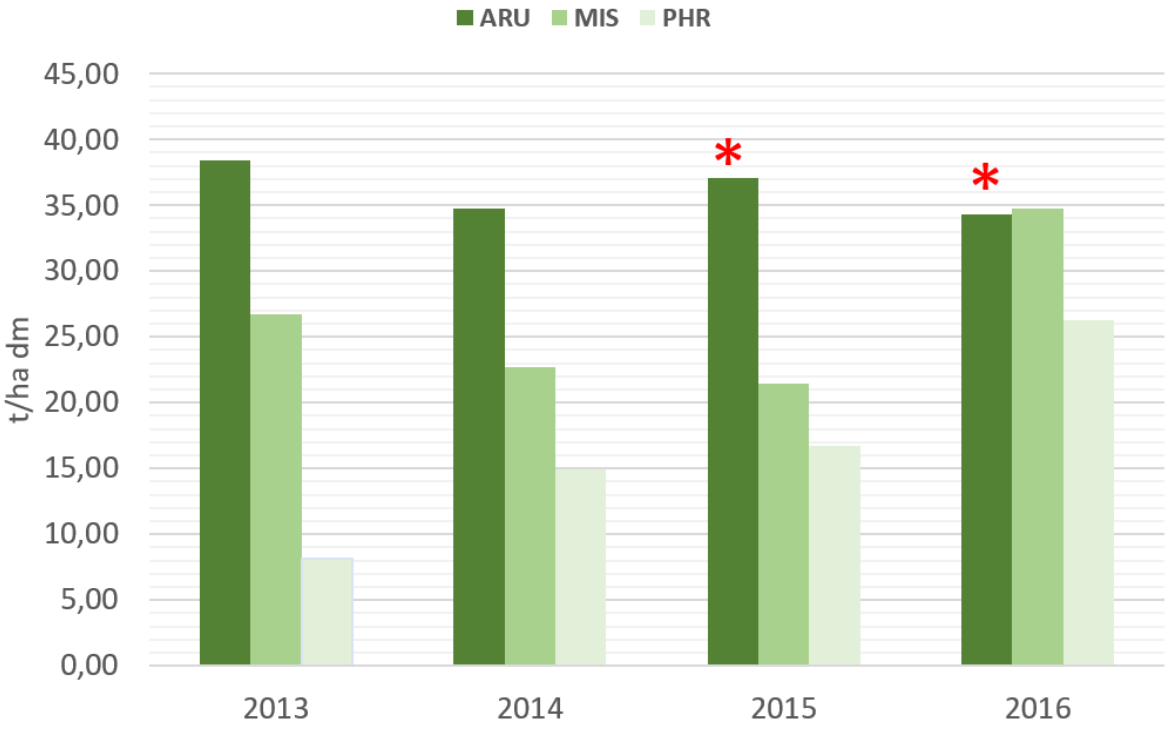
Yields



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

Giannini, V *et al*. (2017). Growth and nutrient uptake of perennial crops in a paludicultural approach in a drained Mediterranean peatland. *Ecological Engineering*, *103*, 478-487.

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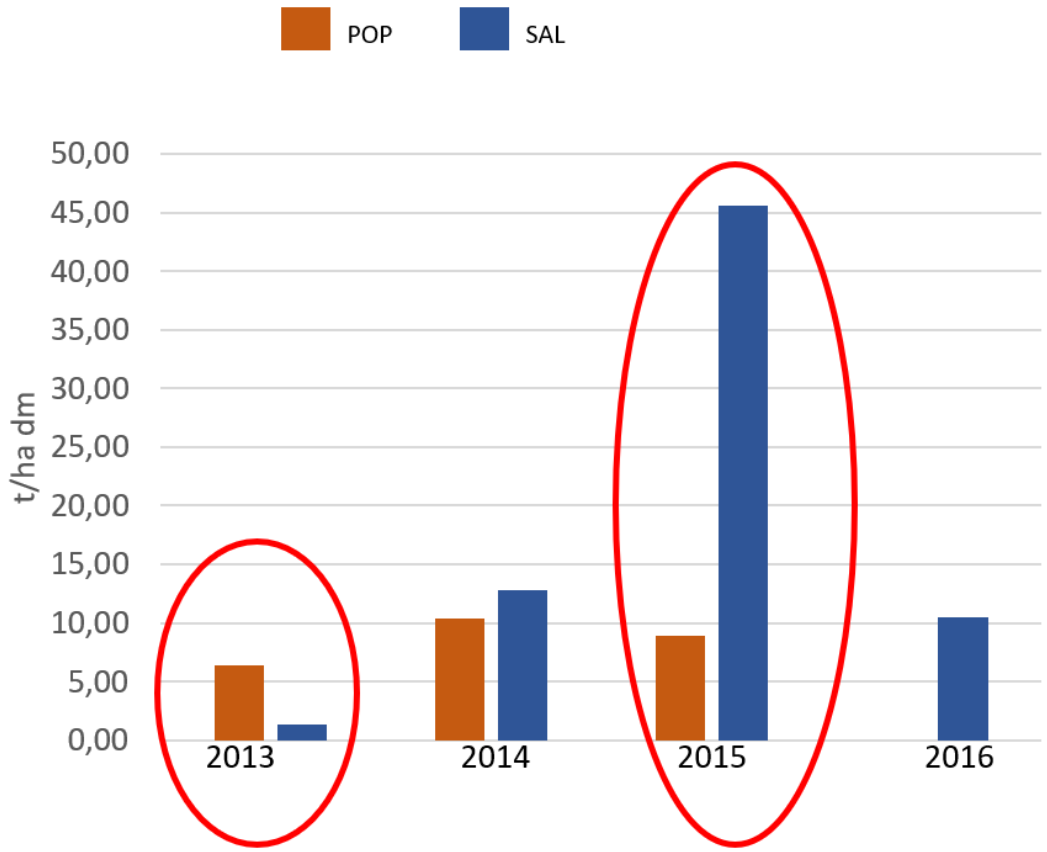
Yields



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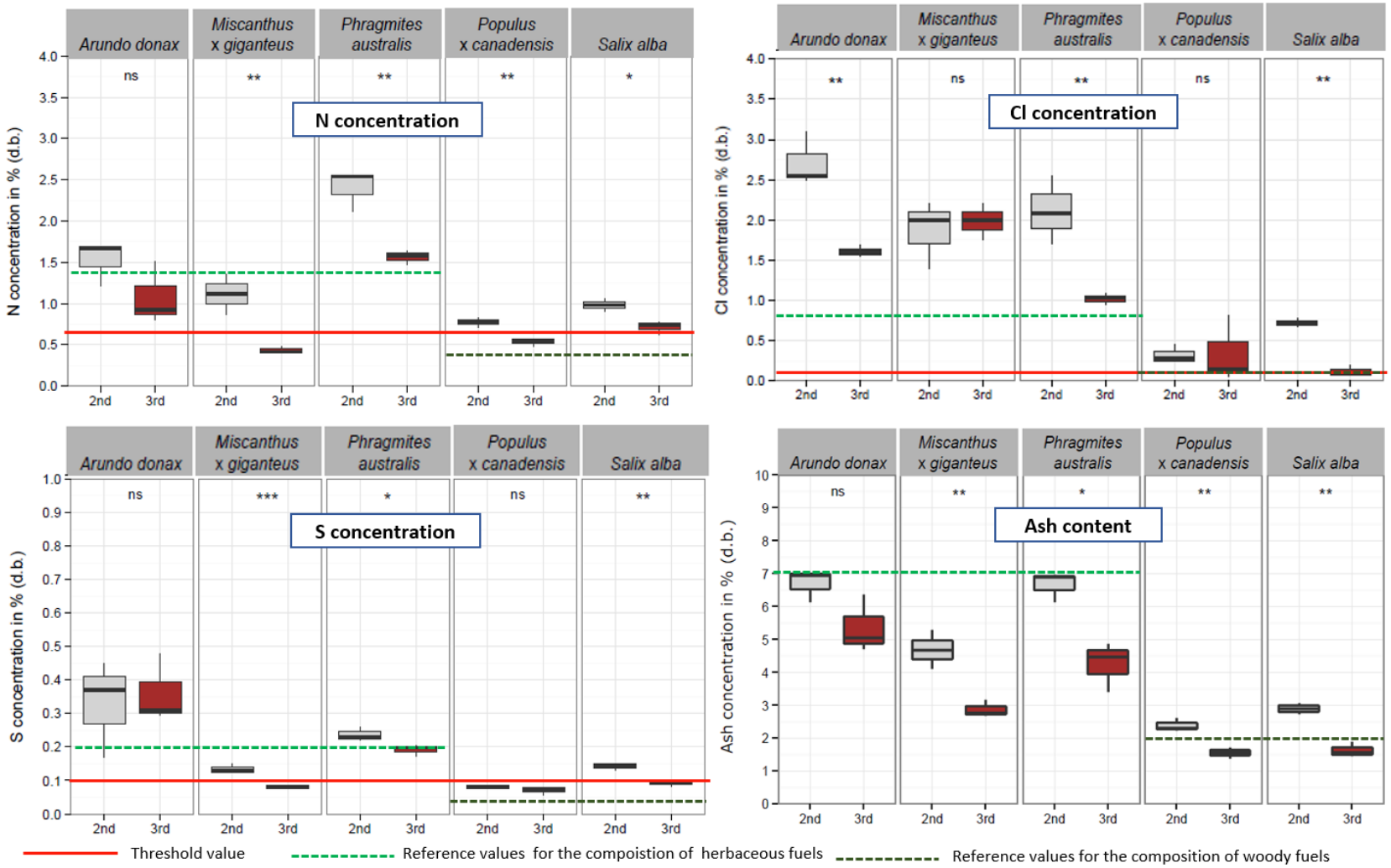
Biomass Harvesting

Biomass Quality - Combustion



Giannini, V *et al.* (2016). Combustibility of biomass from perennial crops cultivated on a rewetted Mediterranean peatland. Ecological Engineering, 97, 157-169.

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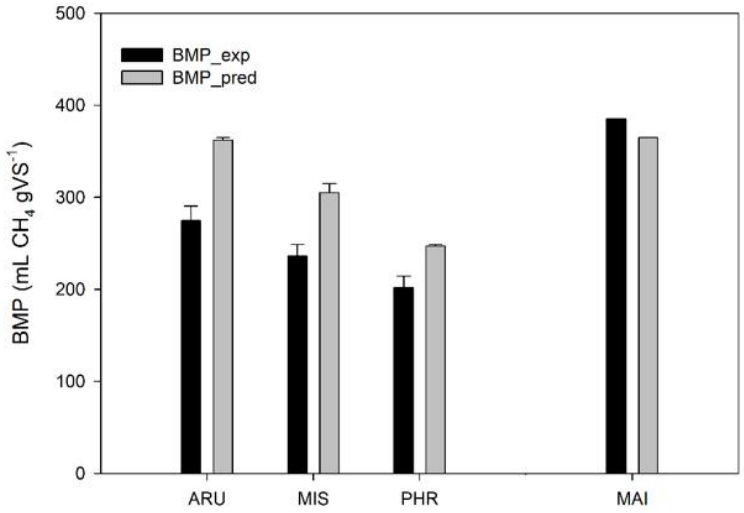
Biomass Quality – Anaerobic digestion

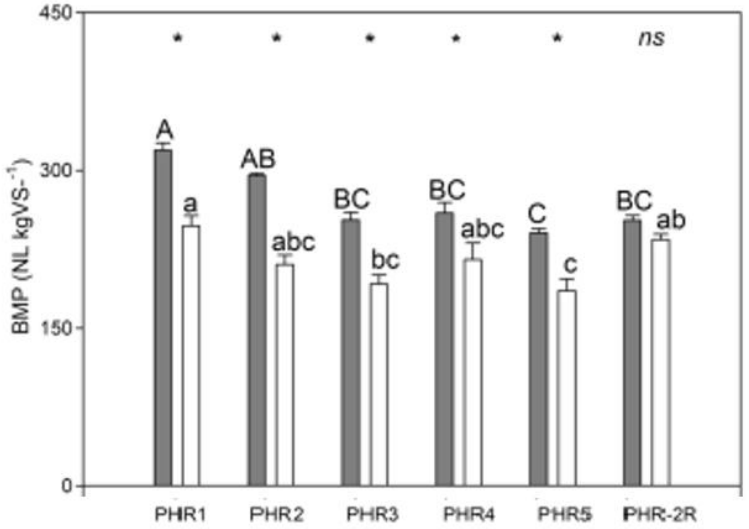
Experiment 1

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





Dragoni, F. (2017). Effect of harvest time and frequency on biomass quality and biomethane potential of common reed (*Phragmites australis*) under paludiculture conditions. Bioenergy Research, 10, 1066-1078.

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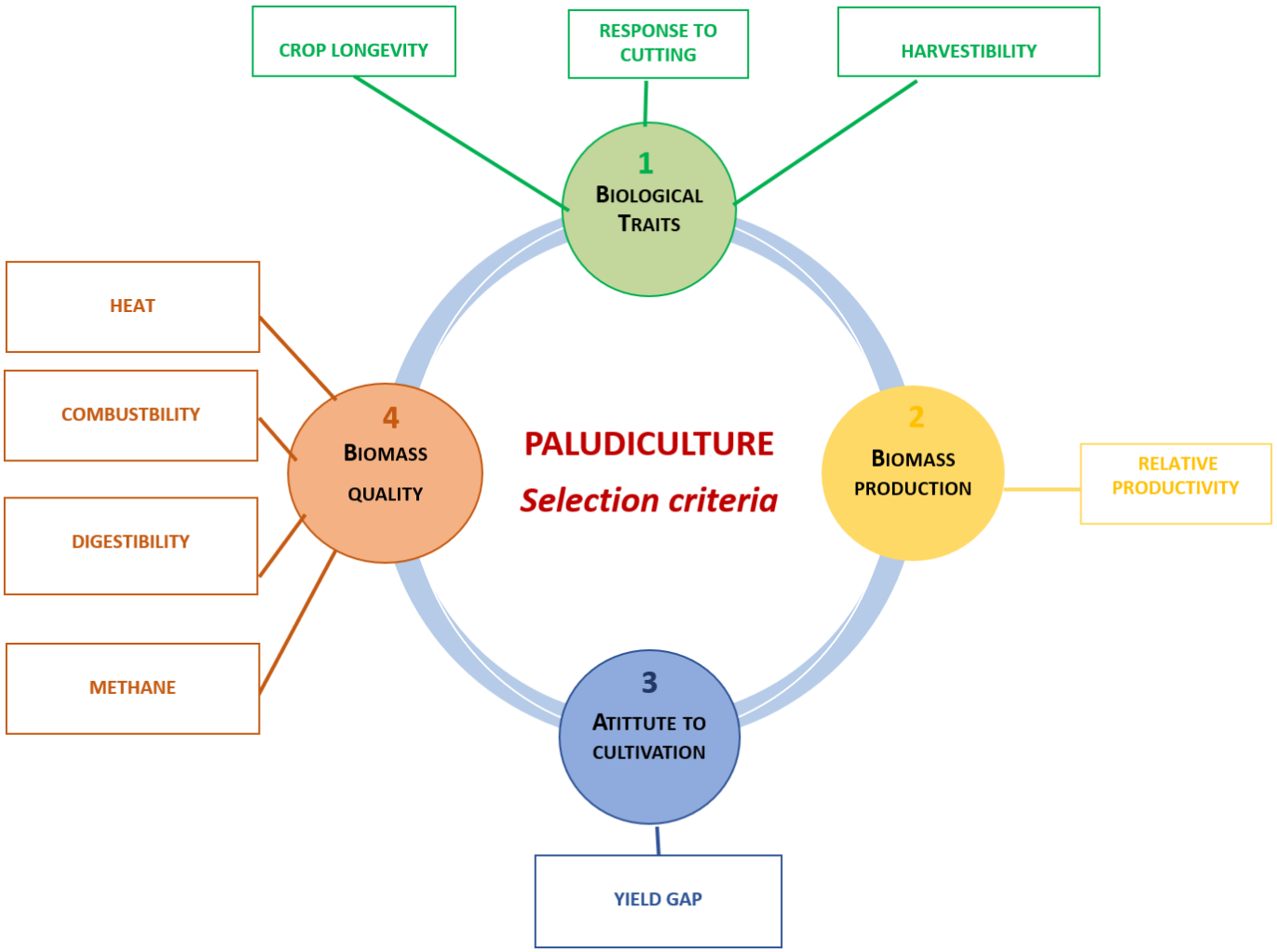
How we can identify the most suited crops for paludiculture?



Silvestri, N. *et al.* (2017). A multi-adaptive framework for the crop choice in paludicultural cropping systems. Italian Journal of Agronomy, 12(1).

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A framework for supporting crop chioice

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).

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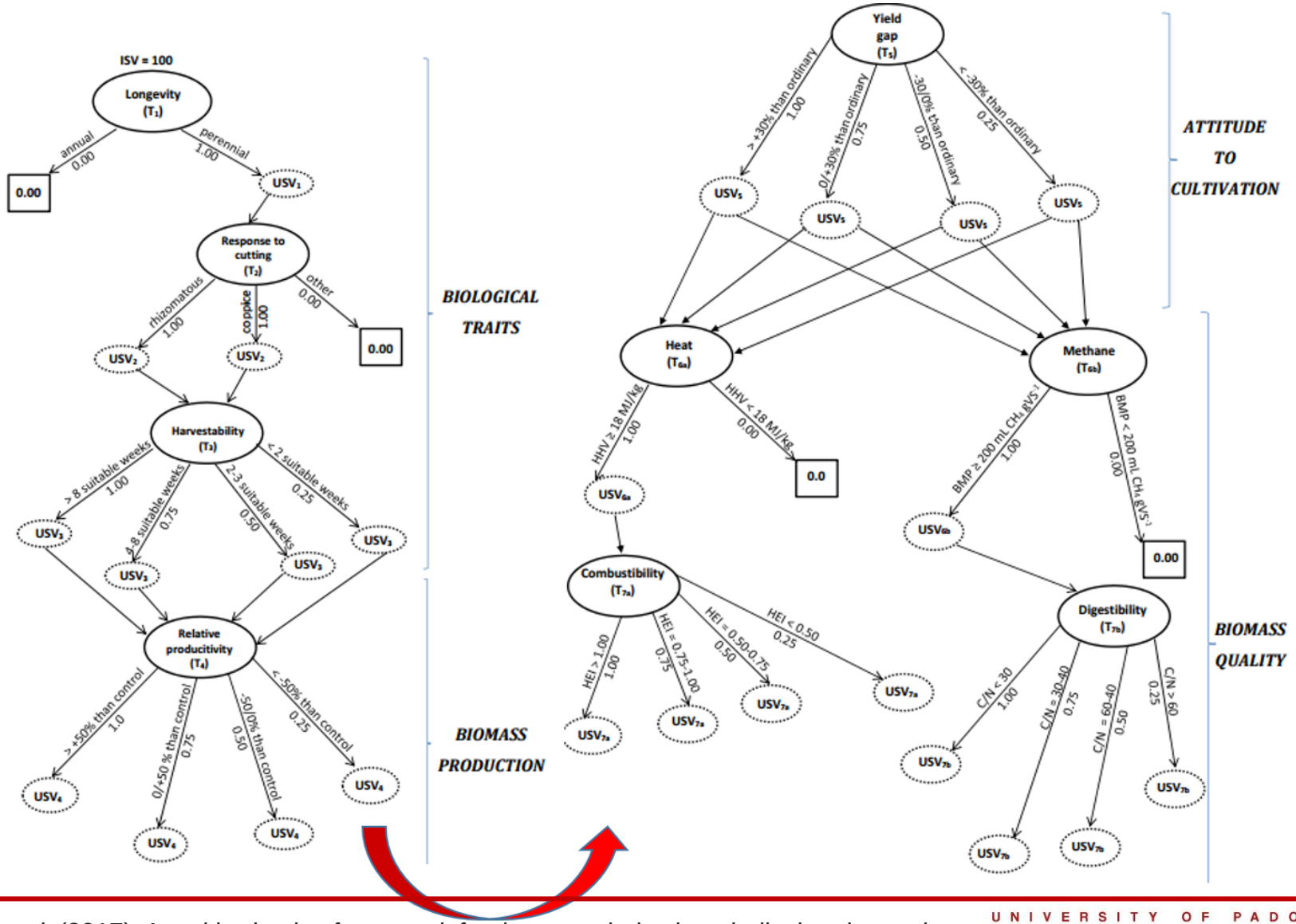
The decision tree



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The output for our pilot experiment

Crops	ISV	Tests									FSV
		T_1 USV_1	T_2 USV_2	T_3 USV_3	T_4 USV_4	T_5 USV_5	T_{6a} USV_{6a}	T_{7a} USV_{7a}	T_{6b} USV_{6b}	T_{7b} USV_{7b}	
Arundo	100	100	100	100	100	50	50	25	-	-	25
Miscanthus	100	100	100	75	56	28	28	7	-	-	7
Phragmites	100	100	100	100	50	50	50	25	-	-	25
Arundo	100	100	100	100	100	50	-	-	50	38	38
Miscanthus	100	100	100	75	56	28	-	-	28	14	14
Phragmites	100	100	100	100	50	50	-	-	50	50	50
Salix	100	100	100	75	19	19	19	19			19
Popolus	100	100	100	75	38	9	9	9	-	-	9

ISV, Initial suitability value; T_1, longevity; T_2, response to cutting; T_3, harvestability; T_4, relative productivity; T_5, yield gap, combustion chain; T_{6a}, higher heating value; T_{7a}, harmful emission index; T_{6b}, biochemical methane potential; T_{7b}, carbon and nitrogen content ratio; $USV_{1\text{-}7b}$, upgrade suitability values; FSV, final suitability value. For perennial rhizomatous grasses, both bioenergy chains were evaluated.

Conclusive remarks
from an agronomic perspective

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

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Thank for your attention!