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

* Project funded by Land Reclamation Authority Toscana 1 Nord and Tuscany Region

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Problem description
- MASSACIUCCOLI LAKE BASIN-

ENVIRONMENTAL ASPECTS

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

SOCIO-ECONOMICAL ASPECTS

- Populated area (46000 inhabitants)
- Conventional agriculture (5151 ha)\(^1\)

History
- MASSACIUCOLI LAKE BASIN-

• Forced drainage since 1920s-30s
• Shallow water table
• Large peaty areas
• Agricultural diffuse pollution
• Urban wastewater
• Lack of buffer areas
Problem description
- MASSACIUCCOLI LAKE BASIN-

MAIN PROBLEMS:

- Subsidence (2-3 cm/year)
- Peat degradation
- Eutrophication of surface- and ground-water² (N,P)
- Difficulties in land cultivation

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

<table>
<thead>
<tr>
<th>Year</th>
<th>ARU</th>
<th>MIS</th>
<th>PHR</th>
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<tbody>
<tr>
<td>2013</td>
<td></td>
<td></td>
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<tr>
<td>2014</td>
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<td>2015</td>
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<td>2016</td>
<td></td>
<td>*</td>
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</tbody>
</table>

HARVEST TIME: SEPTEMBER

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

Yields – Short Rotation Coppice

- 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

HARVEST TIME: FEBRUARY
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).

* Published as: Giannini et al. (2017). Growth and nutrient uptake of perennial crops in a paludicultural approach in a drained Mediterranean peatland. *Ecological Engineering* 103: 478-487
Main results
Biomass conversion – Combustion

* Published as: Giannini et al. (2016). Combustibility of biomass from perennial crops cultivated on a rewetted Mediterranean peatland. Ecological Engineering 97: 157-169
Main results

Biomass conversion – Combustion

* Published as: Giannini et al. (2016). Combustibility of biomass from perennial crops cultivated on a rewetted Mediterranean peatland. Ecological Engineering 97: 157-169
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 to September (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

PALUDICULTURE
Selection criteria

1. Biological Traits
   - CROP LONGEVITY
   - RESPONSE TO CUTTING
   - HARVESTIBILITY

2. Biomass Production
   - Relative Productivity

3. Attitude to Cultivation
   - Yield Gap

4. Biomass Quality
   - Heat
   - Combustibility
   - Digestibility
   - Methane
Table 1. Threshold values and correspondent degrees of suitability for all the features foreseen by the framework.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Features</th>
<th>Tests and threshold values</th>
<th>DoS</th>
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<tbody>
<tr>
<td>Biological traits</td>
<td>Longevity</td>
<td>Perennial</td>
<td>1.00</td>
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<td></td>
<td></td>
<td>Annual</td>
<td>0.00</td>
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<tr>
<td></td>
<td>Response to cutting</td>
<td>Coppice</td>
<td>1.00</td>
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<tr>
<td></td>
<td></td>
<td>Rhizomatous/stolonifer</td>
<td>1.00</td>
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<tr>
<td></td>
<td></td>
<td>Other</td>
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<td></td>
<td>Harvestability</td>
<td>&gt;8 suitable weeks for crop harvesting*</td>
<td>1.00</td>
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<tr>
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<td>From 4 to 8 suitable weeks for crop harvesting*</td>
<td>0.75</td>
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<td>From 2 to 3 suitable weeks for crop harvesting*</td>
<td>0.50</td>
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<td>&lt;2 suitable weeks for crop harvesting*</td>
<td>0.25</td>
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<td>Biomass production</td>
<td>Relative productivity</td>
<td>&gt;+50% than a control crop°</td>
<td>1.00</td>
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<td></td>
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<td>From 0 to +50% than a control crop°</td>
<td>0.75</td>
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<tr>
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<td>From -50 to 0% than a control crop°</td>
<td>0.50</td>
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<tr>
<td></td>
<td></td>
<td>&lt; -50% than a control crop°</td>
<td>0.25</td>
</tr>
<tr>
<td>Attitude to cultivation</td>
<td>Yield gap</td>
<td>&gt;+30% than under ordinary growing conditions¶</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>From 0 to +30% than under ordinary growing conditions¶</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>From -30 to 0% than under ordinary growing conditions¶</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; -30% than under ordinary growing conditions¶</td>
<td>0.25</td>
</tr>
<tr>
<td>Biomass quality®</td>
<td>Heat</td>
<td>HHV≥18 (MJ/kg)</td>
<td>1.00</td>
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<tr>
<td></td>
<td></td>
<td>HHV&lt;18 (MJ/kg)</td>
<td>0.00</td>
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<tr>
<td></td>
<td>Combustibility</td>
<td>HEI≥1.00 (pure number)</td>
<td>1.00</td>
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<tr>
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<td>HEI ranges from 0.75 to 1.00 (pure number)</td>
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<td>Methane</td>
<td>BMP≥200 (mL CH₄ gVS⁻¹)</td>
<td>1.00</td>
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<tr>
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<td>BMP&lt;200 (mL CH₄ gVS⁻¹)</td>
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<td>Digestibility</td>
<td>C/N ratio &lt;30 (pure number)</td>
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<td>C/N ratio from 30 to 40 (pure number)</td>
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<td>C/N ratio from 40 to 60 (pure number)</td>
<td>0.50</td>
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<tr>
<td></td>
<td></td>
<td>C/N ratio &gt;60 (pure number)</td>
<td>0.25</td>
</tr>
</tbody>
</table>

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 Trinco et al. (2011)); C/N, carbon and nitrogen content ratio. *To be considered as suitable a week must comply with reasonability and plasticity conditions (see text); †a control crop is a crop grown in the same pedoclimatic but under drained conditions (see text); ‡ordinary conditions mean no saturated soil, no high acidity or salinity, raised cultivation (see text); §the two alternative pathways are combustion (heat and combustibility) and biogas conversion (methane and digestibility).
The decision tree scheme

ATTITUDE TO CULTIVATION

BIOLOGICAL TRAITS

Yield gap (TY)

Heat (TH)

Methane (TM)

Combsitibility (TM)

Digestibility (TD)

Relative productivity (TR)

Harvestability (TH)

Response to cutting (T)

Longevity (Tl)

0.00

Biomass PRODUCTION

BIOMASS QUALITY

Yield gap (TY)

Heat (TH)

Methane (TM)

Combsitibility (TM)

Digestibility (TD)

Relative productivity (TR)

Harvestability (TH)

Response to cutting (T)

Longevity (Tl)

0.00

Biomass PRODUCTION

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Response to cutting (T)

Longevity (Tl)

0.00
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

• Organization of the harvesting and biomass delivery logistics

• Field monitoring of GHG emissions (CO₂, CH₄, N₂O) using the prototype developed during IPNOA LIFE Project

• Crop physiology modelling under paludicultural conditions
Cited Literature


Thank you!

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