Multipurpose lignocellulosic crops: research perspectives and applications

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Agro-forestry biomass for energy production and conversion
Uprising interest on biomass as renewable energy

Cereals price uprising in the World markets

- 3 “C” Factors:
  - Global Climatic Changes and weak harvests
  - China & India (and Co.)
  - Fuel conversion (bioethanol, biodiesel) (30% of USA maize production for bioethanol)
  - European Common Agricultural Policy
Concerns on the sustainability of biofuels (I gen.)

- “Starving” the World;
- Negative Envir. Impact (chemical inputs for pests and weed control; NO\textsubscript{x} emission; energetic and CO\textsubscript{2} balance);
- Improving the consumption of fresh Water and Fertilizers;
- Favoring Deforestation (e.g. palm oil in south-east Asia)
- Supplementing a minimum percentage of the world Energy need (Italy: 100% of agricultural surface for biofuels=15% of fossil fuels for transportatation)
Sustainability of bioenergy crops: highly variable

- Bioethanol from maize (USA), sugar cane (Brazil)
- Biodiesel (soybean, other oil crops)
- Woody biomass (from SRF)
Maize Bioethanol in USA (E85)

- Price at gas station (USA, July 2007)
  Gasoline $3.03 gallon;
  E85 $3.71

- Energetic balance
  Input 1  Output 1.3

- CO₂ Emiss. Balance: -22%

N. G., Oct. 2007
Rapeseed Biodiesel (Germany)

- Price at gas station (Germany, July 2007)
  - Fossil diesel: $6.15 per gallon
  - Biodiesel: $6.73

- Energetic Balance
  - Input 1: Output 2.5

- CO₂ Emiss. Balance: -68%

Wood Chips from dedicated plantations (poplars, Italy)

- Price for the consumer
  45 € per Mg (fresh weight)

- Energetic Balance:
  Input 1  Output 9

Research on SRF plantations at IBAF-CNR and DiSAFRI, Univ of Tuscia

- Genetic variability of species and cultivars (genomics, dendromass yield, WUE, NUE)
- Crop profitability and social acceptance
- Carbon sequestration and Global Changes
- Phytoremediation
Network of Exp. Fields on SRF

- Zinasco (Pv)
- Mantova (Mn)
- Mira (Ve)
- Vinovo (To)
- Terni
- Narni (Tr)
- Tuscania, 1999
- Orvieto (1991)
- Fiumicino (Rm)

Date:
- 2003
- 2004
- 1999
Vinovo-To, Po Valley

Vinovo, (dry matter, 2 biannual cycles)

Energetic balance:
1st cycle: Input 1 Output 1 15
2nd cycle: Input 1 Output 22

Former Crops | Yield (t ha\(^{-1}\) a\(^{-1}\)) | N fertilization (Kg ha\(^{-1}\)a\(^{-1}\)) | Irrigation (mm y\(^{-1}\))
--- | --- | --- | ---
Maize | 10 | 80 | 100-120
Wheat | 4.7 | 15-20 | rainfed

No fertilization
Irrigation: 50 mm year\(^{-1}\)

Hybrid poplars clone

CNR-IBAF, under evaluation
Mira, Venice, Northern Italy

+ Delta yield between the **first** and second coppicing

Energetic Balance:
- 1st cycle: Input 1, Output 52
- 2nd cycle: Input 1, Output 61

<table>
<thead>
<tr>
<th>Previous crops</th>
<th>Yield (t ha(^{-1}) y(^{-1}))</th>
<th>N (Kg ha(^{-1})a(^{-1}))</th>
<th>Irrigation (mm y(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean</td>
<td>3,5</td>
<td>No</td>
<td>40-50</td>
</tr>
<tr>
<td>Maize</td>
<td>11</td>
<td>250</td>
<td>100</td>
</tr>
</tbody>
</table>

- 300 Kg N (in 2 years) during the second cycle
- No irrigation

CNR-IBAF, under evaluation
Robinia and SRF, Orvieto, Central Italy

L.S.D. 0.05 = 0.867

Hungarian clones

CARATTERISTICHE PRODUTTIVE ED ENERGETICHE
Tesi di laurea del Dr. R. Sacchetti
UniVT, 2005
Profitability of S.R.F. plantations in Italy

Affected by many factors:

- Wood chip price at plant gate
- Crop yield
- Production cost
Profitability of SRF in Italy

Wood chip price at plant gate:

- Currently 45 €/t fresh (year 2007)
Profitability of SRF
SRF yield across Italy?

- Not enough data from commercial plantations across Italy
- No simulation models available
- Hypothesis:
  +50% or 100% of prevalent crops yield (maize for poplar and wheat for robinia)
Profitability of SRF in Italy with very good site conditions

SRF dry yield = 1.5 vs maize yield

t_f fresh/ha x 2 years: 60 66 72 78 84 96 102 108 114 120 126
Profitability of SRF in Italy: Poplar

On maize fields (average annual yield 9 t/ha)
Wood Chips: 45 €/t
Profitability of SRF in Italy: Robinia

On previous wheat fields (average annual yield 3 t/ha)
Wood Chips: 45 €/t
Profitability of SRF in Italy

Energy Farm

- Selling not biomass for energy but directly energy, thermic and/or electric

- 1 t chips = 2 MWh\text{th}
- 1 MWh\text{th} = 80 € - 40 € cost = 40€ net
SRF and Energy Farm

- Robinia under medium site conditions

![Graph showing Farmer Profitability (€ ha⁻¹ y⁻¹) vs +50% vs ave. wheat, +100% vs ave. wheat, +100% vs ave. Wheat 5t ha⁻¹)](image-url)

- Energy farm
- Only biomass production

Farmer Profitability (€ ha⁻¹ y⁻¹)

- 800
- 700
- 600
- 500
- 400
- 300
- 200
- 100
- 0
- -100
- -200

+50% vs ave. wheat
+100% vs ave. wheat
+100% vs ave. Wheat 5t ha⁻¹

- Energy farm
- Only biomass production
Phytoremediation

- Animal sludges (rich in N, P, K)
- Heavy metals
Preliminary test on sludge application on poplars SRF (Torreimpietra, Rome)
N removed with the harvest in poplar SRF

\[ y = 9.6177x \quad R^2 = 0.8814 \]

\[ y = 6.434x \quad R^2 = 0.7949 \]
Simulation of cattle sludge application on poplar SRF plantations

<table>
<thead>
<tr>
<th>Poplar SRF Yield (t ss ha(^{-1})y(^{-1}))</th>
<th>N removed (Kg N ha(^{-1})y(^{-1}))</th>
<th>N balance N natural (Kg N ha(^{-1})y(^{-1}))</th>
<th>N to be replaced (Kg N ha(^{-1})y(^{-1}))</th>
<th>Eff. Coeff. (%)</th>
<th>Sludge application (t ha(^{-1})anno(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 (1st cycle)</td>
<td>70</td>
<td>20</td>
<td>50</td>
<td>35</td>
<td>143</td>
</tr>
<tr>
<td>15 (2nd cycle)</td>
<td>150</td>
<td>90</td>
<td>60</td>
<td></td>
<td>171</td>
</tr>
<tr>
<td>10 (1st cycle)</td>
<td>70</td>
<td>20</td>
<td>50</td>
<td>67</td>
<td>75</td>
</tr>
<tr>
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<td>150</td>
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<td>60</td>
<td></td>
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</tr>
</tbody>
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5 kg of N per 1 Mg of fresh wood

0.5 Mg of cattle sludge (1% of N) per 1 Mg of fresh wood

1 kg of N to be disposed has a cost of ca. 10€
Heavy metals, restoration of polluted soils (Cadmium)

From Massacci et al., CNR-IBAF
Montelibretti
Some conclusions

- Interesting potentials for forest crops to produce lignocellulosic biomass for multipurpose transformations (I & II gen. energy, biorefinery)

- need for more research in:
  • environmental sustainability
  • environmental improvement by tree crops
  • genomics & biotechnology for quantitative & qualitative increment of biomass production
GRAZIE!

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A European Free Air Carbon Enrichment experiment on Poplar plantations
Effect of high \([\text{CO}_2]\) on poplar growth

+30% at 550 ppm of \(\text{CO}_2\)

DiSAFRi, Uni Tuscia, Viterbo
Poplar SRF – soil C sequestration

[CO₂] 370 ppm

[CO₂] 550 ppm

Project EUROFACE
University Tuscia Viterbo

DiSAFRi, Uni Tuscia, Viterbo
Lignocellulosic material can contain large amounts of non structural carbohydrates (NSC)

- **Large differences between species**
- **Large differences in different tissues**
- **Large differences in potentialities for uses**

Breeding and evaluation of interaction with growth rate

Possibility to control the synthesis by genetic transformation