Giant reed (*Arundo donax* L.): how a “noxious weed” can become a sustainable energy crop for 2nd generation ethanol in warm temperate climates

S. Miele (1), A. Pompeiano(1), E. Bargiacchi (2)

(1) Dep. of Agricultural, Food and Agro-environmental Sciences (DiSAAA), University of Pisa (Italy), smiele@agr.unipi.it
(2) Agronomist, Consortium INSTM, Firenze (Italy)
REPLACEMENT OF FOSSIL FUEL WITH BIOMASS

Fossil resources:
- Natural gas
- Oil

Biomass:
- Short rotation woody crops
- Herbaceous energy crops
- Agricultural residues
- Urban wood waste

Products:
- Energy (fuel)
- Chemicals (specialties & commodities)
- Materials (plastics, etc.)

Petro-refinery:
- Energy (fuels)
- Chemicals (speciality & commodity)
- Materials (plastics, etc.)
- Food & feed

Bio-refinery:
**RENEWABLE ENERGY (RED) AND FUEL QUALITY (FQD) DIRECTIVES: THE TARGETS IN EUROPE**

- 10% renewable energy for the EU transport sector by 2020 (RED)

- Minimum GHG saving requirements of biofuels to count towards the target:
  - 35% GHG saving compared to fossil fuel equivalent from implementation
  - Increasing to 50% from 2017 and 60% for new plants starting from 2018 (RED and FQD)

- Biofuels shall not be issued from high biodiversity or high carbon stock lands

.../....
THE TARGETS

- Biofuels made from waste, residues, non-food cellulose and lignocellulosic (LC) materials count double towards the target (Art. 21.2)

THE CONSEQUENCE

- Non-food LC materials will be the pivot feedstocks for a sustainable renewable energy/biofuels production

HENCE

- A FLEXIBLE, RELIABLE PROCESS IS REQUIRED TO EXPLOIT DIFFERENT, POTENTIAL LC FEEDSTOCKS

WHICH MEANS

- ONE TECHNOLOGY FOR A BUNCH OF SITE-ORIENTED LC FEEDSTOCKS
INDEPENDENTLY UPON HOW AMBITIOUS TARGETS HAVE BEEN POSED

- R&D on perennial lignocellulosic crops should focus on attaining high yields with reduced inputs, especially water, and exploit surplus, marginal, low quality, abandoned lands → LUC & WUE
THE AGRONOMIST’s POINT OF VIEW

- Process technology is only one component of a successful biomass-processing chain project: (quite) the same industrial plant can be easily located in different areas.

- BUT, any biomass-based process: power and thermal applications, or the refining into biofuels and chemicals, requires to focus a site-oriented biomass procurement plan and effectively manage the feedstock supply chain over the years.

- To make this possible, WHAT IS THE BEST CROP MIX TO COPE WITH SOILS & SEASONAL VARIABILITY, IN A GIVEN AREA, AT A REASONABLE LEVEL OF IMPACT?
WHAT KIND OF IMPACT?

- A sustainable, biomass-based energy/fuel production chain, included its logistic system, should be not only productive and economical, but also environmentally and socially viable.

- "Environmentally viable" means "low impact on resources", "preserving ecological niches & biodiversity", "promoting safer alternatives to present uses (misuses)". "Socially viable" means "maintaining rurality" and the related activities (agro-industry).

- For a successful co-existence of food and non-food crops it is crucial to cultivate the latter crops starting from areas left fallow, set-aside, or lands that come from shifting of some traditional crop cultivation. Polluted areas are a starting point for a large public acceptance.
A SUSTAINABLE MIX OF CROPS & CROP RESIDUES

ONE PERENNIAL “BACKBONE” CROP: e.g. Arundo donax

Corn stover
Cereal straw
Dedicated annual crops
Wood & forest residues

Year x
Year x+1
A SUSTAINABLE MIX OF CROPS & CROP RESIDUES (1)

- Cultivation of some annual crops and collection of crop residues help maintain rurality, agro-industry, and environmental biodiversity.
- Wood (from coppice and SRF) and collection of forestry residues may represent a further income for farmers, and an ecological control tool of fires & slope erosion.

**BIOMASS RESIDUES AVAILABILITY IN EUROPE (ML t)**

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Source: Bloomberg New Energy Finance, mod. 2020
A SUSTAINABLE MIX OF CROPS & CROP RESIDUES (2)

- However, some perennial “backbone” crop must be present: a productive, adaptable, undemanding crop, with an extended harvesting period, to fulfill processing plant requirements between different “collecting seasons” (e.g. “straw season”, “stover season”, etc.)

- Farmers will have a more positive attitude towards a supply chain based on a mix of perennial & annual crops + crop residues, allowing them to operate continuously through the year, and face better market uncertainty
PERENNIAL RHIZOMATOUS GRASSES: IDEAL CROPS FOR BIOFUELS PRODUCTION (1)

- Higher yield potential, as compared to annual crops
- Limited ecological/climate demands, better WUE & NUE
- Favorable environmental impact in terms of Carbon balance, improved soil quality and energy balance
- Adaptation to saline soils and saline waters
- No crop rotation: less energy related consumption
- Field storage → harvest & transport to the biorefinery on a “JUST-IN-TIME” strategy basis
- Multiple end uses: LC ethanol, C6-C5 sugar Refinery, CHP cycles, mixed uses → more market opportunities
PERENNIAL RHIZOMATOUS GRASSES: IDEAL CROPS FOR BIOFUELS PRODUCTION (2)

- Pollen free → low cross-fertilization risk → stable genotypes
- Most insect repellant
- Phytoremediation
- Lower soil erosion risk, due to better rainfall interception, surface cover for longer time, and massive root system
- Well suited to marginal sites → less competition for land use with food crops
- Easy control of escaped plants with glyphosate
GIANT REED (*Arundo donax* L., *Adx*)

The leading candidate among potential ligno-cellulosic feedstocks in warm temperate & Mediterranean climates:

- Already a part of several natural landscapes (native to India)
- High yield of ethanol per hectare, with low ecological demands
- High photosynthetic capacity, absence of light saturation
- Tolerant to a wide range of soils; adaptable to saline soils & waters;
- Low nutrient and agrochemical requirements
- Positive associations with microrganisms, especially endophytic and mycorrhizal fungi
- Reduced/No tillage during crop cycle increases soil OM and microbial biomass, as compared to annual crops
Adx CULTIVATION PROTOCOL

1. Plowing
2. Refinement
3. Plantation
4. Pre-emergence
5. Processing
6. Harvesting
7. Shooting

Courtesy: M&G Group
CLAIMS ON “INVASIVITY” OF Adx

- Named as one of the top 100 Worst Invaders of the World
- Asexual reproductive species although produces flowers: spreading is related only to rhizome transport
- Invasivity is site-dependent: grown away from riparian areas (=areas adjacent to streams & rivers, prone to flooding), it is not an invasive plant
- Buffer strips of some turf species may be used along riparian areas to further control any chance of spreading
- Should it escape from upstream cultivations, it can be easily controlled with glyphosate
- Briefly, its present invasivity potential is not greater than that of volunteer sunflower or beet, and less than that of Johnsongrass-Sorghum halepense (where glyphosate-resistant types were identified)
CONTROL OF SPREADING (DURING & AFTER)

A yearly maintenance of a border (=buffer) strip around fields avoids any uncontrolled spreading.

After a 10-year cycle, root system can be removed by a sequential treatment of glyphosate after last cut + rhizome mechanical removal.

20 cm

Courtesy: M&G Group
CONTROL OF SPREADING (in the long run)

• No problem of unwittingly spreading under cropping conditions, as indicated by the Torviscosa (Italy) experience in 1930-1960s in Northern Italy
• Here Adx -for the first time- was extensively cultivated on a large scale basis (>6 000 ha) as an energy crop and a cellulose source for over 20 yrs, with no problem of long-term containment in the cultivation area
• Presently the area is cropped with corn-soybeans-wheat, and Adx presence is limited to small natural patches
M&G GROUP’s RESEARCH ON LC CROPS & Adx

- LC crops for biofuels adapted to different locations:
  - Southern Europe,
  - Mediterranean areas,
  - other World areas

- Adx ecotype plot & field tests

1st CUT, JULY 20

1 MONTH REGROWTH

Courtesy: M&G Group
BETA Renewables’s CRESCENTINO PLANT

http://www.biofuelsdigest.com/bdigest/2012/09/18/tranquility-base-here-the-crescentino-project-has-landed/
MAJOR RESEARCH AREAS ON Adx
AT THE DiSAAA-UNIVERSITY OF PISA

- Crop resistance to:
  - environmental stress: heat, freeze
  - soil stress: salinity, anoxia
- Effect of plant mycorrhizal infection on early growth, water stress resistance, photosynthetic activity
- Micropropagation and somatic embryogenesis vs. rhyzome and cane propagation
- Effect of irrigation and Nitrogen fertilization on the crop growth in its establishment year
- Innovative harvest equipment for improved field storage

in collaboration with CHEMTEX AGRO
MAJOR RESEARCH AREAS ON Adx AT THE DiSAAA-UNIVERSITY OF PISA

- Leading crop for Nitrate Vulnerable Zones (NVZ): management & reclamation
- Soil bioremediation (heavy metals)
- Energy crop (exhausted lignin) for CHP cycles, both for dedicated plants & on-farm burners (e.g. curing barns of Virginia Bright tobacco)

ENVIRONMENTAL ISSUES:
CROP & PROCESS

- Evaluation & recycling as a plant nutrient source of: exhausted lignin-ashes from Adx & other biomass feedstocks, and of “wastes” of a LC biorefinery

in collaboration with CHEMTEX ITALIA
Adx: VIEWPOINTS, BRIEFLY

- FARMER: It’s a financially attractive option, preferable to other energy crops, for its high and stable (10 yrs) yields, low production costs, and capacity to exploit marginal lands.

- INDUSTRY: It’s a high quality feedstock, with an ample and flexible harvesting “window”, favorable storage & bulk density. High quality, recyclable, post-process “wastes”.

- AGRONOMY: It helps reduce Nitrogen runoff into waterways and increase Carbon sequestration. It adds value to marginal (saline, polluted, non-irrigated) lands, unsuitable for row crop production.

- ENVIRONMENT: It’s a natural presence in several areas. Due to high yields (bulk density: 105 kg/m$^3$), less land and logistics (traffic, emissions) are required to feed a biorefinery. It helps in bioremediation programs.
CONCLUSIONS

- *Adx* offers substantial advantages over other potential biomass crops for yield, quality, low ecological demands, and post-process “wastes” recycling.

- It represents an ideal backbone crop for any biomass supplying chain based on a mix of perennial & annual crops + crop residues.

- Any sustainable, biomass-based energy/fuel production chain, to be productive, economical, environmentally oriented, and socially viable should be agronomically designed on/to the site, maintain biodiversity, and respect farmers’ convenience (and freedom) to become an active part of it.
Thank You

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