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Poplar and willow biomass from marginal land?

Production ecological and environmental implications

Martin Weih

- Land use change/marginal land
- Ecophysiology/breeding
- Environmental issues

24th Session of the International Poplar Commission, Dehradun, India, 29 Oct to 2 Nov 2012

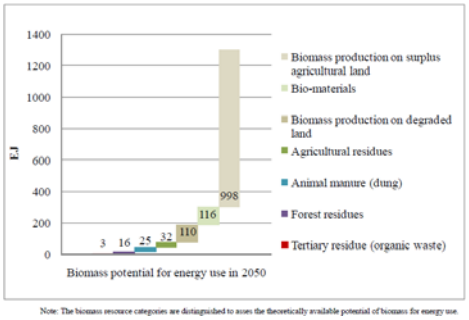
Land is a limited resource

Food vs. bio-energy?

Possible solution:

Food on agricultural land, biomass for bio-energy and bio-based products on "marginal land".

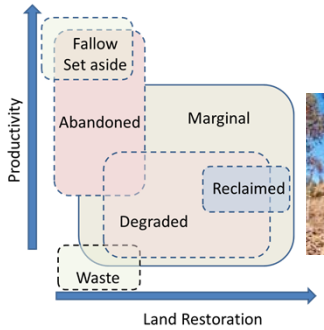
Predictions: High biomass production potential on "surplus land"



Note: The biomass resource categories are distinguished to asses the theoretically available potential of biomass for energy use.

Source: Hoogwijk *et al.* (2003) Biomass Bioenergy

Classes of "surplus land" *vs.* productivity



Source: Dauber *et al.* (2012) BioRisk

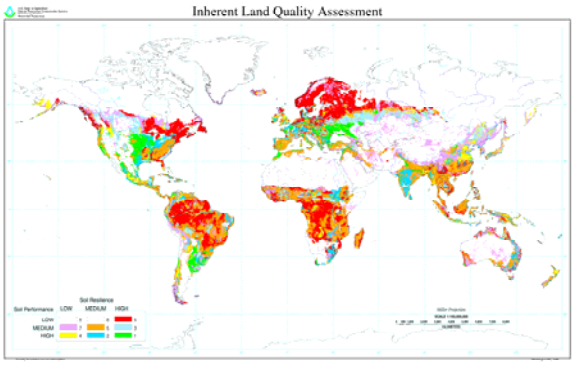
Marginal land

Poor ***soil quality*** = poor soil performance and/or resilience

Poor ***soil performance***: low in nutrients and/or organic matter, highly exposed to erosion and/or compaction (degradation), unstable water regime, etc.

Poor ***soil resilience***: poor ability to recover after disturbance (natural or human-induced stresses).

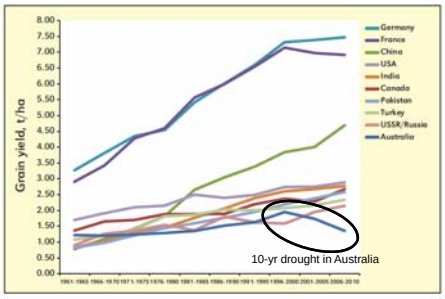
Marginal land



Desirable biomass crop characteristics

- High-yielding
- Resource efficient & stress tolerant (marginal land!)
- readily adopted (not requiring novel cultural practices)
- desirable feedstock qualities
- well adapted to local conditions (short transport distances)
- breeding history

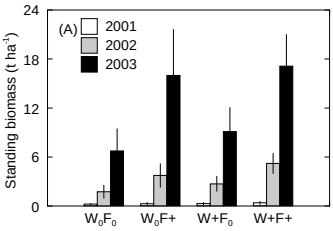
Example wheat: It is much harder to breed for marginal environments!



Source: Phillips & Norton (2012) Better Crops

Marginal yield from marginal land!?

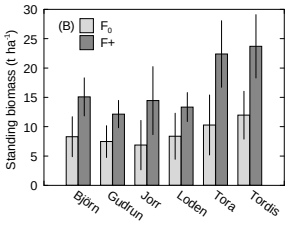
Example: *Salix* SRC grown in Sweden under low vs. high water (W) and mineral nutrient fertilization (F)



From Weih & Nordh (2005) Tree Physiol.

Poplar & willow breeding gain often by means of great fertilization response!

Example: Six commercial *Salix* hybrids grown in Sweden under low vs. high mineral nutrient fertilization (F)



From Weih & Nordh (2005) Tree Physiol.

Tree & crop breeding for marginal land

High yield under optimum conditions is less important breeding target for marginal environments.

What plant traits (and genes behind) are important for improving cropping security on marginal lands (low-quality soils, climate extremes, pests, etc.)?

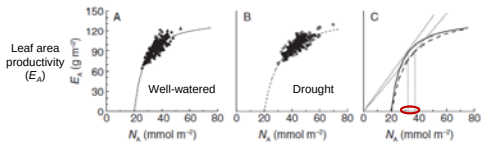
Are improvements constrained by "trade-offs" between crop productivity and stress tolerance traits?

Which natural (ecological) processes can be utilized to improve both productivity and cropping security?

Finding traits & genes to improve cropping security on marginal land

Identifying *plant adaptation strategies*: Increased leaf N content under drought is a functional optimization of N economy (acclimation) and possibly relevant for breeding.

Optimal leaf N (N_A) is higher under drought in *Salix*



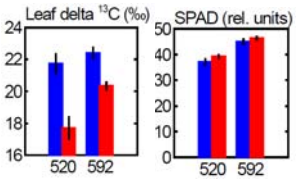
From Weih et al. (2011) Ann. Bot.

Finding traits & genes to improve cropping security on marginal land

Identifying *genes behind drought acclimation through gene expression*: Comparing phenotype responses to drought (eco-physiology) with gene expression pattern in *Salix*.

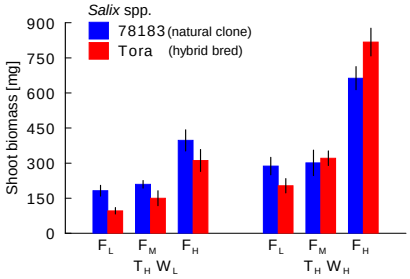
Leaf gas exchange (delta ^{13}C) was less affected by drought (red bars) in the *Salix* genotype 592, which has higher leaf N (SPAD).

The pattern matches gene expression data: Fewer drought response genes in 592 leaves.



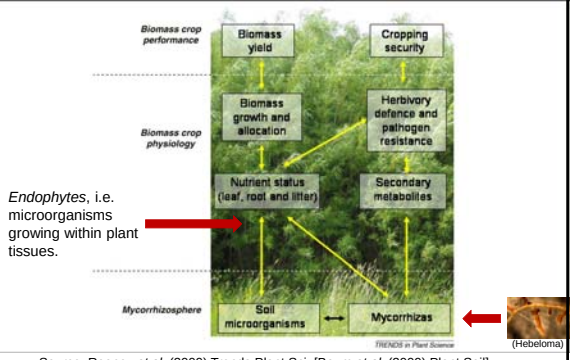
From Berlin Kolm *et al.*, in prep.

Trade-off between productivity and stress tolerance?



From Weih (2001) Tree Physiol.

Natural (ecological) processes to improve productivity & cropping security



Endophytes, i.e. microorganisms growing within plant tissues.

(Hebeloma)

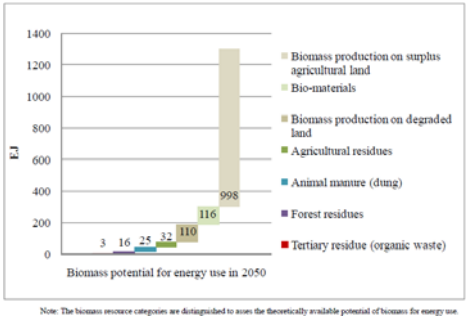
Source: Rooney *et al.* (2009) Trends Plant Sci [Baum *et al.* (2009) Plant Soil]

How to achieve environmentally sound production of biomass on marginal land?

Culture of biomass crops for bio-energy and bio-based raw material needs to be environmentally sound, because motivation for growing those crops is based on environmental arguments (e.g. climate change mitigation).

- Focus of pre-breeding research on cropping security to minimize "boosting" actions that harm the environment;
- Utilization of natural/ecological processes to increase sustainability in production;
- Land use change: Conversion of marginal land to production land must not jeopardize environmental motivation of growing biomass crops.

Cultivation of "surplus land" will result in significant land use changes



Source: Hoogwijk *et al.* (2003) Biomass Bioenergy

Cultivation of "surplus land" will result in significant land use changes

Consequences for the environment?

Marginal land is frequently located in small-scale heterogeneous landscape, which is important for biodiversity preservation.

=> Intensification of land use can negatively affect biodiversity, despite findings that e.g. poplar and willow SRC can benefit landscape biodiversity.

Cultivation of ”surplus land” will result in significant land use changes

Consequences for the environment?

Landscape polarisation in terms of optimising one function (i.e. agricult. production) may lead to:

- Functional landscape simplification?
- Limited capacity to support multiple ecosystem services?
- Increased vulnerablity to diseases, climatic extremes or spread of invasive species?

Cultivation of ”surplus land” will result in significant land use changes

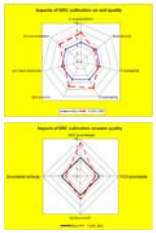
Consequences for the environment?

Large-scale implementation of *bio-energy crops* on marginal land…

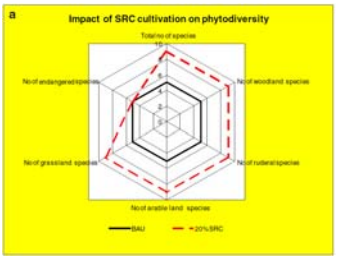
- …will affect the environment!
- …makes sense only if the cultivation proves to reduce negative effects on the environment, especially when compared to other alternatives for reduction of fossil energy sources.

Evaluation of environmental impact when marginal land is cultivated

Example: Environmental impact assessment poplar & willow cultivation in European agricultural landscape



"BAU" Business as usual



Source: Langeveld *et al.* (2012) BioEnergy Res

Conclusions 1

- One opportunity in the ‘food-vs.-biomass’ dilemma is to grow food on agricultural land, and biomass on “marginal land”. Large marginal land areas are predicted world-wide to be suitable for biomass production.
- Crop breeding research often focuses on high yields under favourable conditions for growth, but should increasingly focus on cropping security (low-quality soils, climate extremes, pests, etc.) in “marginal” conditions.
- Efficient pre-breeding methods include molecular tools (e.g. gene expression studies), but should increasingly consider utilization of natural (ecological) processes for improving both productivity and cropping security.

Conclusions 2

- Major motivation for growing biomass crops is environmental (e.g. climate change mitigation), BUT large-scale culture of biomass crops on “marginal land” will affect the environment (soil, water, biodiversity).
- We need to determine which biomass production systems are most adequate for marginal land, by taking into account issues such as yields that realistically could be achieved on those lands; inputs and costs, as well as potential environmental and socio-economic impacts.