Optimization of wood production in bioenergy plantations

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Context and objectives

Intensive tree plantations for bioenergy (short rotation coppice, SRC) are often synonymous with soil depletion. To maintain productivity in the long term while reducing inputs (water, fertilizer), an optimized matching between:

1. plant material characteristics (genera, species, genotypes, mixed or not) particularly in terms of efficiencies of resource use (especially water and nitrogen),

2. cultural practices (spraying, densities, pruning, etc.),

And, 3. soil and climate conditions is to find.

The approach taken to meet this objective is to study the effects of the three categories of above factors on productivity and its determinants through the study of carbon, nitrogen and water cycles in a network of plantations spread throughout northern France.

Material and methods

A network of collaborations and plantations has been established in France in order to answer practical questions about SRC itineraries through the study of eight factors on productivity and water and nitrogen use efficiencies (WUE* and NUE, respectively), e.g. planting density, fertilization, N fixing species introduction, etc.

This network is part of three research projects:

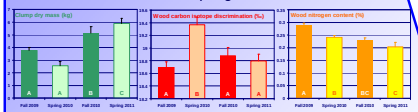
- **CREFF: Cost reduction and efficiency improvement of SRC (ERA-Net Bioenergy project funded by ADEME and FNR, 2009-2012),**
- **SYLVABIOM: New concepts of sustainable energy crops with woody species (ANR Bioenergy project, 2009-2012),**
- **Intens&Fix: Ecological intensification of plantation forest ecosystems (ANR Systerra project, 2011-2014)**

❶ When should we harvest, spring *vs.* fall?

Situation: When harvest is only possible during the leafy period, leaf exportations are likely to alter soil fertility.

Objective: Effect of harvest period during the year on re-growth, WUE and NUE.

Protocol: Biomass, resprouting, WUE and NUE estimations in a willow plantation in Kerguéhennec (56) in fall 2009 and 2010, and spring 2010 and 2011.



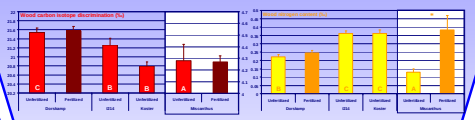
Answer: Despite a constant decrease in N wood content harvest after harvest, there is no clear trend concerning yield and WUE. Re-growth has to be monitored for a longer period.

❷ Is it relevant to fertilize SRC plantations?

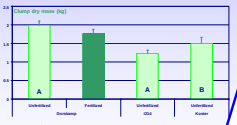
Situation: Bioenergy crops are fertilized, but is it useful to fertilize SRC plantations?

Objectives: Effect of chemical fertilization on biomass production, WUE and NUE, and comparison with fertilized and unfertilized miscanthus plots.

Protocol: Biomass, WUE and NUE estimations in a poplar plantation (4 clones) in Estrées-Mons (80) where some of the blocks were fertilized.



Answer: No. There is no significant yield and N content increases in the poplar fertilized plots.

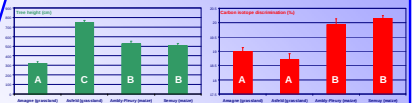


❸ What is the best cultural antecedent?

Situation: To avoid concurrence with food agriculture, SRC plantations will be preferably installed on marginal, less fertile sites.

Objective: Effect of the cultural antecedent (rich vs. poor) on biomass production and WUE and NUE.

Protocol: Biomass, WUE and NUE estimations in four willow plantations in French Ardennes (8) differing by their antecedent, grassland ***vs.*** maize cultivation



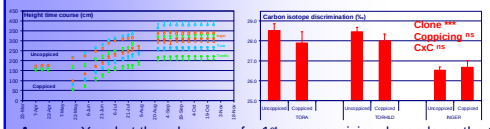
Answer: Yield was not linked to the cultural antecedent. However, willow trees showed a better efficiency to use water on the poorer sites (grassland antecedent).

❹ Do we have to coppice at the end of the first year?

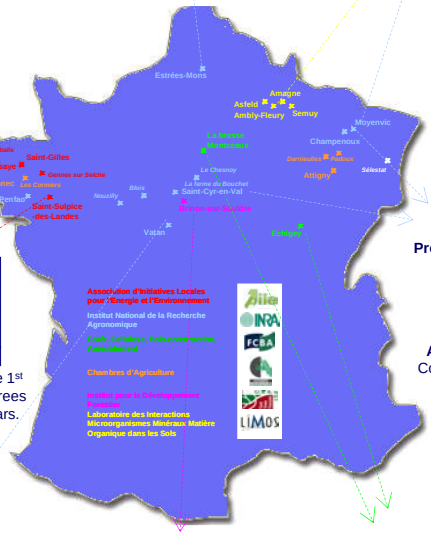
Situation: First year coppicing can stimulate the re-growth during the next year, but it can also affect weak plants when the first year growth has been poor.

Objective: Effect of a first year coppicing on biomass production, re-growth and WUE and NUE.

Protocol: Biomass, resprouting, WUE and NUE estimations in a willow plantation (3 clones) in Saint-Sulpice-des-Landes (44) where a part only has been coppiced at the end of the first year.



Answer: Yes, but the relevance of a 1st year coppicing depends on the 1st year growth. Here, coppiced trees were almost as big as uncoppiced trees after 2 years.



❺ Is it interesting to variegate plantations with N fixing species?

Situation: Mixture of poplar, willow or eucalyptus with N fixing species (black locust, acacia, alder) can be a way to improve or to maintain soil fertility in intensive plantations.

Objective: Effect of mixture of poplar with black locust on biomass production, WUE and NUE.

Protocol: Biomass production, WUE and NUE estimations in a poplar / black locust plantation in Saint-Cyr-en-Val (45) with pure and mixed blocks (alternating rows) of the two species.

Answer: The mixture of eucalyptus with acacia in Brazil or in Congo has not shown a clear effect on biomass production. In Europe, the experiments are in progress.

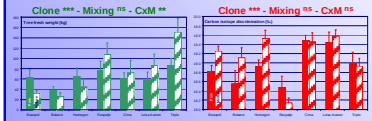
INTENS&FIX

❻ Do we have to use monoclonal blocks or mixtures of clones?

Situation: Mixture of clones and varieties is a way to limit pathogen development, but what is the effect on biomass production due to more intense competition?

Objective: Effect of a clonal mixing on biomass production, WUE and NUE.

Protocol: Biomass, resprouting, WUE and NUE estimations in a poplar plantation in Vatan (36) with pure and mixed blocks of different clones.



Answer: Clonal mixture has no significant effect on biomass production, but it is recommended to prevent pathogen development.

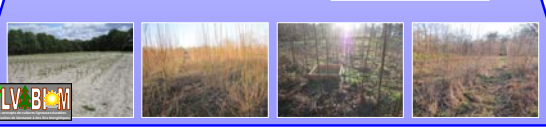
❼ Is sludge spreading a relevant practice?

Situation: Sludge spreading in SRC could be a way to valorize these wastes, but do the trees need this additional fertilization?

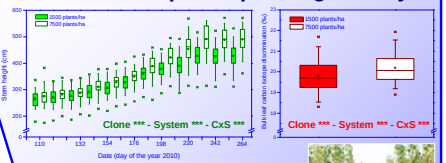
Objective: Effect of different quantities of sludge on biomass production, WUE and NUE.

Protocol: Biomass production, resprouting, WUE and NUE estimations in a willow plantation in Brinon-sur-Sauldre (18) with sludge inputs or not.

Answer: The experiment is still in progress. Results are likely to be dependent on soil fertility: SRC on rich soils does not need additional nutrient inputs and elements will probably not be assimilated by plants and remain on the soil.



❽ Is there an optimal planting density?



Situation: How does competition among plants in dense plantations affect biomass production?

Objective: Effect of planting density (SRC, 1500 ***vs.*** very SRC, 7500 trees / ha) on productivity, WUE and NUE.

Protocol: Biomass, WUE and NUE estimations in a 2-year old poplar plantation in Echigey (21) with different planting densities.

Answer: After two years, trees were higher in the denser plantation. However, they were more water-use efficient in the less dense plantation.

Plantation network partners:

Conclusion

Most experiments are still running and conclusions are only preliminary. However, it appears that it is difficult to generalize because results are highly dependent on initial soil fertility. Soil richness is indeed a key factor and SRC technical itineraries as well as plant material have to be adapted to soil quality in order to maximize the growth potential while avoiding rapid soil depletion and loss of fertility.

*** In the different experiments, intrinsic water-use efficiency (WUE_i, assimilated carbon per unit of transpired water) is estimated through its well-known surrogate (Farquhar and Richards 1984): carbon isotope discrimination ($\delta^{13}C$, ‰), estimated from wood (panels 1, 2, 3 and 6) or leaves (panels 4 and 8).**

Farquhar GD, Richards RA. 1984. Aust. J. Plant Physiol. 11:539-52.