Agroforestry systems for bioenergy production: How to optimize yield and water use efficiency ?

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Sustainable bioenergy production – a new challenge for science

Alternative energy usage in the last decades has become a worldwide central topic, and is moving up the European political agenda to encourage and support an environmentally sustainable economy. In particular, the German Government has set itself the target of increasing the proportion of renewable energies by the year 2020 and promoting the bio-economy sectors [1]. The combination of fast-growing trees and new bioenergy crop have the potential to become a valuable alternative source of profit on marginal lands. Moreover, bioenergy plant production associated with an appropriate land-use managment will improve soil quality, ecosystem funtioning [2] and promote carbon sequestration. To optimize the biomass production, additional physiological and ecological details about new bioenergy plants are required. Water supply is a crucial factor for plant production under dry conditions. Therefore, our project focused on determining the water demand for biomass production.

Water use effiency – a key for optimal biomass production

Water use efficiency (WUE) is defined as fixed organic matter per transpired water amount. An optimal use of the water resources for production is critial on marginal lands, especially in southern Brandenburg, where water resources are limited. As an early successional and nitrogen-fixing tree species, black locust (*Robinia pseudoacacia* L.) (Fig. 1A) grows rapidly even under unfavourable site conditions [2,3]. The knotweed *Fallopia sachalinese* (Fig. 1B) is characterized by a high annual biomass production, it can be harvested 2-3 times during the growing season and can be used for pelletes and biogas production.

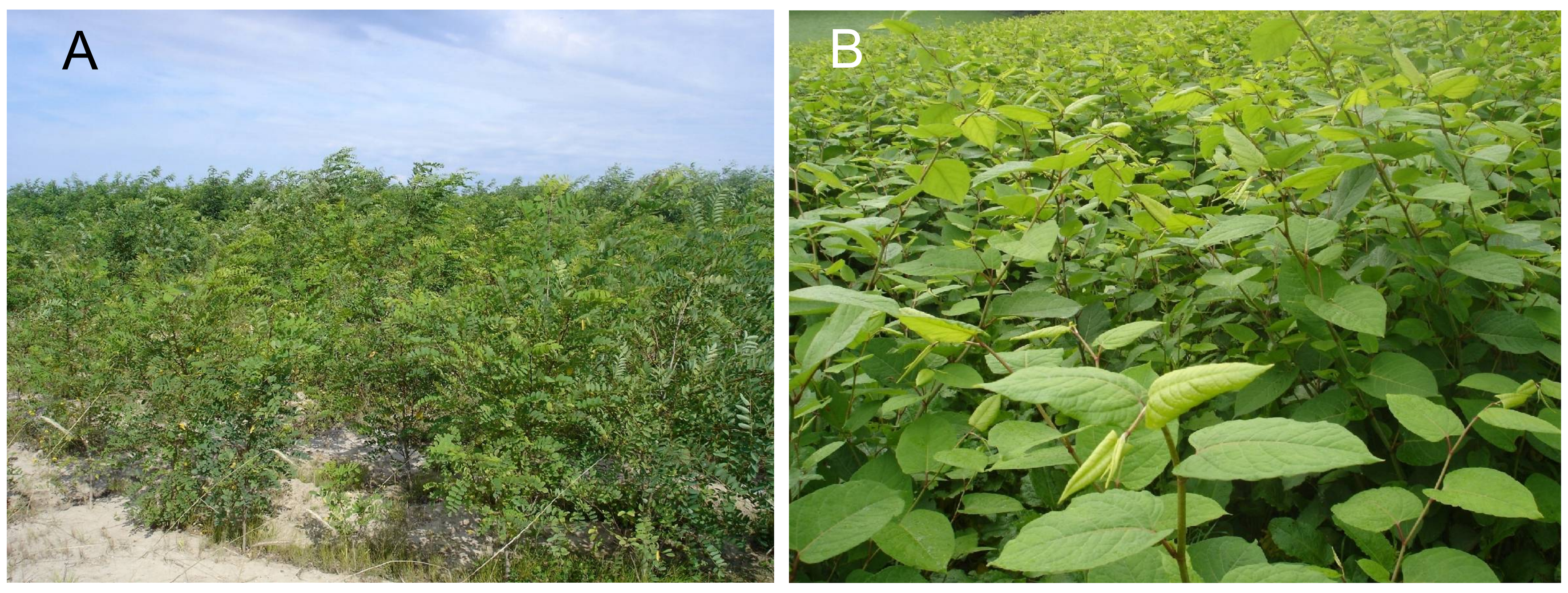

Fig. 1: Bioenergy plants: *Robinia pseudoacacia L.* (A) and *Fallopia sachalinese* (B)

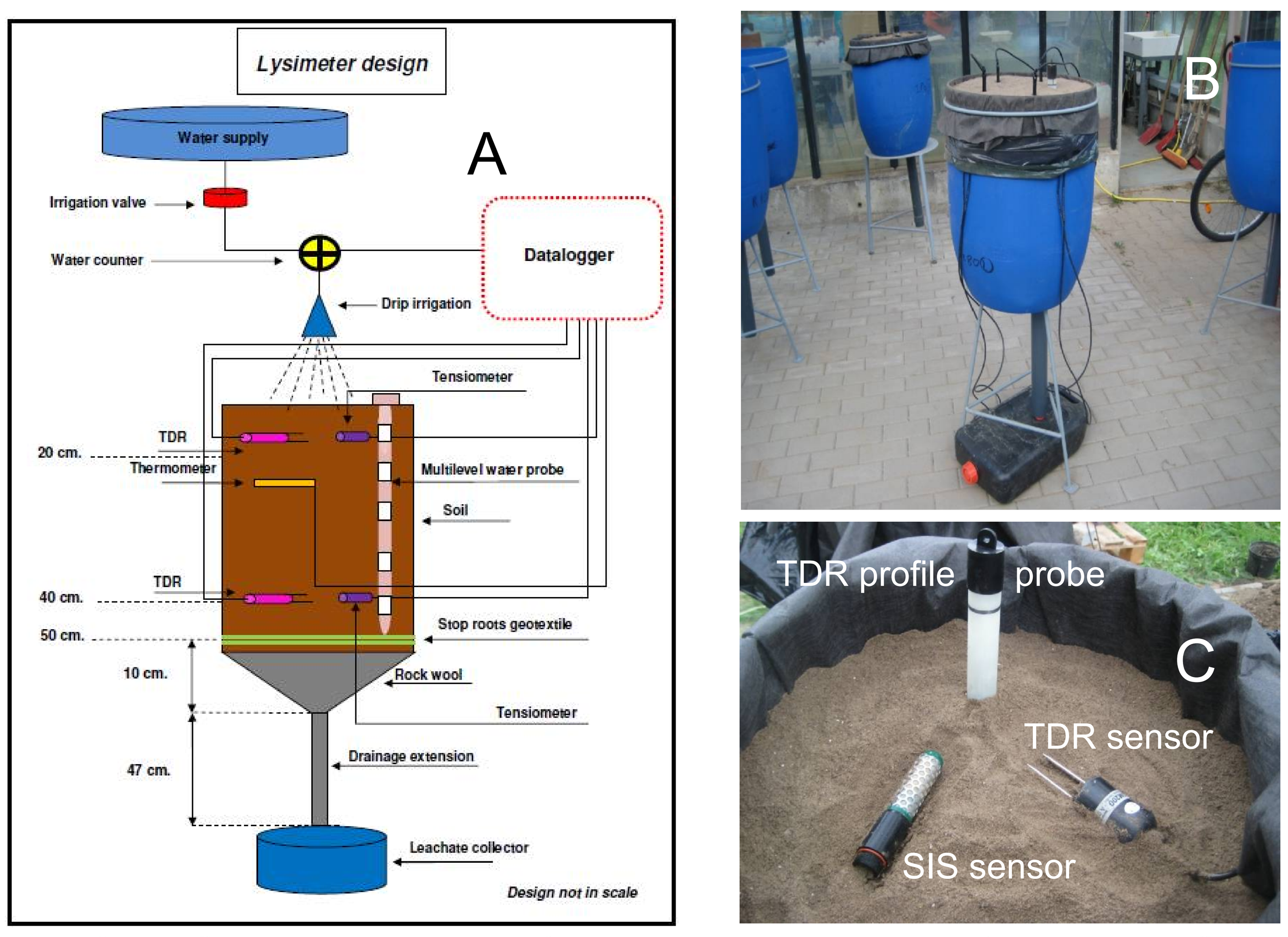

Fig. 2: (A) Schemetic diagram of the new wick lysimeter , (B) lysimeter (C) installted TDR systems and SIS Smart-Irrigation-Sensor for the monitoring of soil water content and soil matrix potential.

a) Plant level : Transpiration-yield relationships

Lysimeters are ideal tools for the determination of transpiration-yield relations at whole plant level. We developed a new modified wick lysimeter system (Fig 2) [4], which allows us to study plant growth under controlled water regimes (well-watered, moderate, drought). Water will be supplied by an automatic drip irrigation system and water amounts will be controlled by the actual evapotranspiration. Therefore, solar radiation, air temperature, humidity and wind speed will be monitored continuously for the regulation of the irrigation. Transpiration will be calculated on the basis of water input, storage and drainage in daily intervals and related to the ambient climatic conditions and ecophysiological plant performance. Volumetric water content and matric potential of the soil column will be measured at two soil depths .

The lysimeters will be placed under a light-transmissive roof to prevent uncontrolled precipitation. The open constructions allows air temperature, humidity and wind regimes similar to ambient conditions.

b) Leaf level: Regulation of photosynthesis and transpiration

Photosynthesis is the essential process for biomass productivity. CO_2 uptake and water loss is controlled by the stomata on the leaf level. Environmental stress is effecting this physiological process. Therefore, the ecophysiological response of the plants to drought stress will be investigated by using a portable gas exchange system with a mini-cuvette chamber (Fig. 3). The system allows the simulation of various light, temperature and air humidity regimes. First results indicates a high water use of *Robinia pseudoacacia L.* under well-watered condtions and a drastic response of photosynthesis and transpiration to drought stress [5].

Fig. 3: Climatic controlled mini-cuvette chamber for measuring CO_2 and H_2O exchange of leaves.

c) Yield-transpiration modelling – an integrative ecological modelling approach

For the understanding of the governing processes of an efficient water use in agricultural systems it is important to develop a crop growth models for predictions of biomass production under various water regimes. The soil-plant-atmosphere processes as well as the ecophysiological plant performance obtained from the experimental water balance and the gas-exchange measurements will be integrated into a physical-based coupled ecological model (CoupModel, [6]). After the model calibration and validation, yield crop modelling under different environmental scenarios will be performed.

Conclusion

The cultivation of fast-growing plant for energetic usage is a significant alternative in marginal lands in Europe. As the availability of water influences the primary production and therefore the biomass production significantly, a central role is played by the optimisation of these processes through the species selection. Furthermore, to describe and quantify the complex interactions of process involved in the soil-plant–atmosphere system, and thus optimize the biomass production, physical and mathematical tools are integrated into a simulation model. However, to improve their applicability and efficiency in existent situations, more experiments are needed for successfully application under different environmental conditions.

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