POSITIVE WATER LINKAGES OF BIOENERGY AND PHYTOTECHNOLOGIES: POPLARS AND WILLOWS

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Rationale

Ecosystem services (e.g., provision of food crops and clean water, decomposition of wastes, pollination by insects) are beneficial to society as a whole, yet many are diminishing due to human activities such as the degradation and over-use of resources [1]. Biodiversity is a crucial component to ecosystem services, but is decreasing, largely due to human-induced land use change (LUC). As growing demands for energy necessitate expansion of modern biomass systems, new systems must be orchestrated that foster ecosystem services, in addition to providing biomass for bioenergy.

The UN has established the Sustainable Development Goals (SDGs) in an effort to promote global protection of human life and the environment, including goals directly and indirectly related to energy [2]. Urban expansion and population growth require large sources of power. Biomass, a renewable form of energy, is one way to meet this need. Policy makers are now faced with the task of equitably governing bioenergy; they must devise an approach that simultaneously meets environmental and energy needs. Short Rotation Woody Crops (SRWCs), with their extensive root systems, hydraulic control potential, and rapid growth, constitute a solution that provides ecosystem services and biomass for bioenergy [3].

"Biomass production for energy purposes is a good example of where a holistic perspective can help to identify solutions that serve many objectives."

- Zalesny et al. (2019)

Objective

- Give examples of positive water linkages (e.g., selecting genotypes that effectively produce biomass in both sites that have limited and abundant water) of poplars and willows grown for bioenergy and phytotechnologies, through:
    - Case studies that describe recent examples of such connections in the USA and Europe

Key Points

- Bioenergy systems can be designed to provide economic and environmental benefits
- SRWCs like poplar and willow are ideal candidates for such systems

Poplar Applications

Case Study: Water Use Efficiency

Water use efficiency (WUE) is an important trait in matching specific poplar genotypes to site conditions. Carbon isotope ratios were evaluated in seven poplar genotypes in the case study as a measure of WUE, based on methods of Schulze et al. [4]. Differences in WUE were observed across sites (located in Midwestern USA) and genomic groups.

Case Study: Organics Phytoremediation

Poplars were planted on land contaminated with waste solvents in Illinois, USA using a specialized technique, TreeWells® [5]. Analysis of leaf tissue in just the first year of planting indicated presence of volatile organic compounds (VOCs). Additionally, the study found the groundwater flow system to convey more water than what was originally assumed in the plantation design.

Hybrid Poplar

Photo by Ron Zalesny

Poplar Applications (continued)

Case Study: Biomass Production

Poplar clones of four parentages were established on both marginal agricultural lands and potentially polluted lands across three different physiographic regions in North Carolina, USA. This location has rich silvopastoral opportunities for poplars to improve water quality and quantity. In the study, the effect of genotype on wood biomass and green wood biomass varied across the three locations, and across planting density.

Case Study: Phytoremediation + Biomass Production

Poplar clones of four parentages were planted as cover crops for wastewater management in three land application facilities in North Carolina, USA. Drainage and soil bedding treatments were tested. The effect of genotype on biomass varied among sites and treatments. Land applying wastewater substantially increased the trees' hydraulic loading. Water purification by the poplar systems was also noted, in that nutrient concentrations in groundwater remained below regulatory guidelines.

Conclusions

Human-caused LUC can be beneficial to both humans, in the form of energy production and contaminant reduction, and to the natural environment by providing ecosystem services, while at the same time leading to SDG achievement. Bioenergy systems with intentional localization, design, management, and system integration can produce all of these benefits.

Implications for the Future

- Researchers must further advance genotype selection that maximizes environmental and economic benefits.
    - Then, incentives must be developed that promote blended systems (bioenergy/ phytotechnologies/ecosystem services) to landowners, policy makers, and site managers.

Willow Applications

Case Study: Phytotechnologies + Ecosystem Services

Shrub willow was planted on 0.8 ha of farmland in Illinois, USA to assess its viability for controlling nutrient leaching on marginal agricultural lands. The unfertilized willow plots showed significant decreases in NO_3- leached to soil water and greenhouse gas emissions. Data on the valuation of ecosystem services provided by the plantings are forthcoming.

Case Study: Evapotranspiration Cover + Bioenergy + Ecosystem Services

A shrub willow evapotranspiration cover was established in New York, USA to combat leaching of salts from the by-product of soda ash production. Results showed percolation reduction, production of willow biomass in compliance with graded wood chip standards, and increased structural diversity and biodiversity of the site.

Case Study: Biomass Production Systems

Sweden contains an abundance of commercial willow plantings (over 7,700 ha) [6]. For the case study, sixteen willow plantations in Sweden were studied from 2009 to 2011. When compared to groundwater of adjacent agricultural fields, groundwater in the willow plantations had lower NO_3-N concentrations, but similar PO_4-P values.

Case Study: Wastewater Treatment + Bioenergy

Multiple studies involving willow plantations and their capacity for wastewater treatment, coupled with biomass production, have been conducted in Sweden. Wastewater including landfill leachate, municipal wastewater, and log-yard runoff have all been used to irrigate willow plantations, with minimal effects on aboveground tree growth reported.

Hybrid Willow
Photo by Raju Soolanayakanahally

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