



**International Poplar Commission  
Environmental Applications of Poplar and  
Willow Working Party Workshop meeting**

**17 and 18<sup>th</sup> September 2010**



**Institute of Agro-environment and Forest Biology (IBAF)**

**National Research Council**

**Montelibretti, Rome, Italy**

**Meeting schedule and abstracts**

**Friday 17<sup>th</sup> September**

10.00	Welcome
10.15 to 12.30	Paper presentations
12.30 to 13.00	Discussions
13.00 to 14.00	Lunch
14.00 to 14.30	Walk and visit to the Mass Balance (mesocosms) Chambers used to investigate contaminated water phyto-treatment using Eucalyptus, willow and poplar
14.30-15.15	Visit to the Energy micro-chain facility, Research Unit for Agricultural Engineering of Monterotondo

*Facility includes:*

- SRC biomass plantation established with poplar clones AF2, AF6 & Monviso (single & twin rows), total surface of 4 hectare, 2 year coppicing rotation, 0.2 dt. ha<sup>-1</sup> year<sup>-1</sup>
- Thermo-conversion plant (nominal power of 232kW)

15.15-15.45	Refreshments
15.45-16.45	Poster presentations and discussions
16.45-17.45	Working Party Business meeting
17.45	Close
20.30	Dinner in a typical Roman restaurant

**Saturday 18<sup>th</sup> September**

09.30	Depart to River Sacco Basin, Colleferro ( from Pianabella station car park)
10.45	Arrive at Business Innovation Centre (BIC) Colleferro
11.00-11.30	Welcome by local authorities and presentation of Valle del Sacco activities
11.30-12.00	Visit to the Biomass Power Installation by BIC in collaboration with University of Tor Vergata Rome combining heat and power production
12.00-13.00	Visit to Valle del Sacco Basin Poplar Plantation managed by Atena S.r.l. and to the experimental plots for lindane poplar rhizoremediation
13.00	Lunch
14.30	Return to Rome
16.00	Cultural visit in Rome

This visit will be to either the Sistine Chapel, the Museo Borghese, or the Villa Adriana depending on the weather and final numbers attending the meeting.

## Paper Abstracts

### **Effectiveness of space planted trees for controlling soil slippage on pastoral hill country**

Ian McIvor<sup>1</sup>, Grant Douglas<sup>2</sup>, Andrew Manderson<sup>2</sup>, Malcolm Todd<sup>3</sup>,  
Stan Braaksma<sup>4</sup>, Ross Gray<sup>2</sup>

<sup>1</sup>Plant and Food, Palmerston North; <sup>2</sup>AgResearch, Palmerston North; <sup>3</sup>Horizons Regional Council, Palmerston North; <sup>4</sup>Greater Wellington Regional Council, Masterton

Spaced trees, predominantly species of *Populus* (poplar) and *Salix* (willow), but also species of other genera (e.g. *Eucalyptus*), have been grown to stabilise erodible pastoral hillslopes in New Zealand for more than 40 years. Despite their widespread use, there is negligible quantification of the effectiveness of different densities and sizes of trees for reducing mass movement erosion. This study determined in winter 2007 how much spaced trees reduced soil slippage at 65 sites in Manawatu (40 sites) and Wairarapa (25) following recent storms. There were 53 sites with *Populus* trees and six sites each with *Salix* and *Eucalyptus* trees. Sites had a slope of mostly 25-30°. Diameter at breast height (DBH) of all trees averaged 52 cm and ranged from 18 cm to 99 cm. Over all sites, trees reduced the extent of slippage by an average of 95% compared with slippage on nearby pasture control sites. On sites with trees, slippage (up to 11% of assessed area) occurred at 10 of the 65 sites, and the greatest extent of slippage occurred where trees had a DBH of < 30 cm. It is concluded that spaced trees dramatically reduced the incidence and severity of soil slippage on erodible slopes, and that they were even more effective when their average DBH was 30 cm or greater. Canopy cover of >55% may be a useful target for tree growth required for slope stability.

### ***Populus* spp. strategies to counteract environmental pollutants: phytoremediation perspectives**

D. Di Baccio<sup>a</sup>, A. Minnocci<sup>a</sup>, Tania Bracci<sup>a</sup>, A. Andreucci<sup>b</sup>, G. Celano<sup>b</sup>,  
R. Tognetti<sup>c</sup>, L. Sebastiani<sup>a</sup>

<sup>a</sup>BioLabs, Scuola Superiore Sant'Anna, Pisa, Italy

<sup>b</sup>Dipartimento di Biologia, Università di Pisa, Via L. Ghini 5, I-56126 Pisa, Italy

<sup>c</sup>Dep. Scienze dei Sistemi Colturali Forestali e dell'Ambiente, Univ. Basilicata, Potenza, Italy

<sup>d</sup>EcoGeoFor Lab - Università degli Studi del Molise, Contrada Fonte Lappone, I-86090 Pesche, Italy

Pollution with metals and xenobiotics and climate changes are among the most widespread problems in the environment. Phytoremediation technologies use the plant efficiency in acquiring and concentrating nutrients as well as numerous metabolic activities, providing a low-cost environmental clean-up, that is attracting considerable attention in the past decades. Because of their extensive root system, high biomass production and low-input cultivation, trees are attractive phytoremediators, and poplars, in particular, have been demonstrated tolerant to many abiotic and biotic stresses.

The recent genome sequencing, together with the development of genomics' tools and the ease of genetic transformation of poplar have opened up new avenues for the use of trees in phytoremediation. In our studies we have reported about physiological, biochemical, morphological and molecular responses of hybrid poplar clones to several heavy metals (Zn, Cd, Cu, etc.) present in nutrient solutions or in complex matrices (industrial and agricultural waste) and organic pollutants such as those present in olive mill waste waters. Using the poplar hybrid clone I-214 as a model system, we obtained interesting results for the understanding of tolerance mechanisms to excess and nutrient impairments, also identifying specific genes involved in I-214 (and *Populus*) responses to Zn and other metals. Concerning olive mill waste waters we set up a pilot system of Short Rotation Forestry poplar plantation using I-214 and Monviso clones. The effects of OMWW application will be discussed in terms of modifications in soil and substrate physiochemical properties and plant growth analyses.

### **Poplar-based Phytoremediation Processes**

Louis Licht, P.E.,

Ecolotree Inc., North Liberty Iowa, 52317; lou-licht@ecolotree.com; 319-331-2076 ph.

Keywords: Phyto history, poplar, willow, industrial applications, future phyto applications

This presentation is divided into two segments:

1. A historical perspective in developing phytoremediation as a major pollution cleanup and treatment technique
2. A potential phyto future that contributes to a real potential challenge for good.

Poplar- and willow-based phytoremediation technology that focused on regulated environmental pollution control started in 1988 and has evolved to global application with full-scale field applications, over 300 Ph.D. and M.S. theses awarded.

Many of the modern phytoremediation projects started with poplar (*Populus spp.*). Fundamentally, poplar physiology allowed root placement to a specific subsurface depth. With a defined a root zone 'reactor' volume, the plant dynamics, soil physics and microbial activity has pollutant treatment properties.

As trees and the associated rhizosphere mature, this predictable reactor volume had treatment capacity that improved with time – essential to regulated sites. Treatment is accomplished by in-soil properties and plant-derived exudates requiring less capital construction cost, less refined chemical cost and less electrical energy for pumps and aeration.

The poplar genetic pool was selected for fast fiber growth over a large fraction of the earth's surface - thus a commercially harvested crop that is safe and renewable added to the phyto attraction. Because it is a plant system, the skilled labor and maintenance equipment are normally available – creating honest 'green collar' jobs for the community.

On mature poplar, it is possible to remove 25 metric tons of carbon dioxide per hectare per year, which improves the 'carbon footprint' for waste water and pollutant treatment. There has been a shift in phytoremediation acceptance due to several factors relating to a broader concern for global warming, river and estuary water quality, damaged wildlife habitat, and poor commercial economics.

These poplar traits improve the efficacy and economics of long-term pollution management programs for industry and communities.

### **Learning from our mistakes: achievements and misfortunes in phytotechnology**

Michel Labrecque

Plant Biology Research Institute, (Institut de recherche en biologie végétale), Montreal Botanical Garden

Over the last ten years, our research group has been conducting a variety of phytotechnology projects to address environmental problems in southern Quebec, Canada. Willows and poplars, which constitute highly productive and resistant tools for phytotechnology, were used in the majority of these projects. A number of case studies will be presented, showing both excellent and less successful results. Phytotechnologies' reliance on plants necessarily implies a risk associated with the management of living material. Furthermore, monitoring and maintenance in the mid-long term are necessary to ensure best results. Unfortunately, too many studies are conducted over too short a time period, leading to hasty conclusions.

## **Reasons for increased leaf rust abundance in wastewater treated willow plantations**

Merje Toome and Katrin Heinsoo

IZB, Riia 181, Tartu 51014, Estonia

Willow leaf rust (*Melampsora epitea*) abundance has been shown to increase in case of wastewater irrigation. Since the mechanisms behind that impact are not clear, additional studies have been carried out to determine whether the variation could be due to differences in canopy density or changes in plant leaf morphology. Results revealed that in areas with higher canopy density the rust abundance was higher compared to sparser areas. However, this tendency was clone specific and significant only in case of *Salix viminalis* clones which infection starts from the lower part of the canopy.

Specific leaf area, a widely used leaf morphological trait, was significantly correlated to rust abundance. The leaves with higher leaf area per weight had more rust pustules (irrigated) and those with lower area per weight were less infected (non-irrigated). This implies that wastewater irrigation could have an impact on leaf morphology and cause higher susceptibility to willow leaf rust. By correlating these results with our previous studies we can conclude that wastewater irrigation could significantly increase the leaf rust abundance on willow partly because of higher shoot density and partly due to changes in leaf morphology. Clarifying whether these changes are due to additional water or nutrient application would be the topic of next studies.

## **Evaluate the potential of evapotranspiration covers as a biomass feedstock in urban south-eastern Ontario.**

Jaconette Mirck<sup>1</sup> and Warren E. Mabee<sup>2</sup>

<sup>1</sup> Queen's University, Department of Geography, Mackintosh-Corry Hall, Kingston, Ontario, K7L 3N6, Canada

<sup>2</sup> Queen's University, Department of Geography and School for Policy Studies, Sutherland Hall, Kingston, Ontario, K7L 3N6, Canada

Shrub willows (*Salix* spp.) and hybrid poplars (*Populus* spp.), that can be used as a renewable energy crop, have great potential to be used in alternative landfill caps. Currently many landfills that are present in the urban areas of southeastern Ontario do not have properly engineered leachate collection systems or covers to prevent deep percolation that can lead to groundwater contamination. The cost to close existing waste sites with conventional covers is often prohibitive. The durability of conventional covers composed of compacted fine-grained barrier layers is often insufficient to ensure long-term reliability. Evapotranspiration covers (ET), that may consist out of fast growing shrub willows and hybrid poplars, do not rely on a barrier layer, but instead manage water storage capacity and ET to reduce percolation rates. Evapotranspiration covers are a cheaper and more durable alternative and can potentially provide an array of other environmental and community benefits. One environmental benefit of ET covers is the potential to use the resultant biomass for bioenergy purposes. A major challenge for bioenergy is the realization of sufficient biomass feedstocks, which can be made available at low costs. ET covers can be part of the solution and function as a source of low cost biomass feedstock. The objective of this study is to designate landfills in southeastern Ontario that can potentially be used for ET cover projects and develop a GIS (Geographic Information System) to 'map' these potential landfills.

## **Choosing the Proper Plant Material for Environmental Applications – A Challenge**

J.G. Isebrands, Environmental Forestry Consultants, LLC

P.O. Box 54, New London, Wisconsin, 54961 USA

Choosing the proper plant material for environmental applications is a challenge. Consideration must be given to the plant origin, soil, microclimate, pests, diseases, and application goals. Choosing material adapted to the local growing season is essential. Nurserymen are reluctant to grow a diverse set of new varieties without a reliable market. Landowners and entrepreneurs tend to use available, cheaper material for environmental applications rather than appropriate difficult-to-find varieties; they are often in short supply. Planting inappropriate plant material usually leads to poor growth performance. Thus, a chick and egg dilemma develops. Forest geneticists must be more proactive in working with nurserymen to scale up promising varieties. Plant material must be named, labeled, and kept separate. A phased approach for matching the proper plant material to the site for environmental applications is presented.

## **Phyto-recurrent Selection: A Method for Selecting *Populus* and *Salix* Genotypes for Environmental Applications**

Ronald S. Zalesny Jr, Jill A. Zalesny

U.S. Forest Service, Northern Research Station, Institute for Applied Ecosystem Studies, 5985 Highway K, Rhinelander, WI 54501, USA.

Keywords: poplar, phytotechnologies, selection indices, short rotation woody crops, waste management, willow

Short rotation woody crops (SRWCs) research began in 1968 at the U.S. Forest Service, Northern Research Station, Institute for Applied Ecosystem Studies (IAES) in Rhinelander, Wisconsin, USA. Genetics, physiology, and silviculture were at the forefront of research priorities, and the IAES became a national and global leader in SRWCs research and development. Given the vast amount of information learned during these decades coupled with the growing need for merging traditional intensive forestry with waste management, phytotechnologies research at the IAES began in the mid-1990s. The primary emphasis at the time was to evaluate the use of *Populus* and *Salix* as biological filters atop or adjacent to closed landfills. The practical implications for resources managers included being able to recycle and reuse municipal solid waste landfill leachate on-site to reduce the economic and ecological costs associated with treating the waste waters, along with maintaining regional environmental integrity of groundwater aquifers and nearby water bodies.

Early phytotechnologies research at the IAES involved testing the performance and phytoremediation capabilities of SRWCs in greenhouses and growth chambers, then progressed to field tests in tanks with engineered soil layers and ultimately field-scale plantations. Current research involves a combination of greenhouse and field tests. Adopting crop and tree improvement strategies used in forestry, horticulture, and agronomy, *phyto-recurrent selection* was developed to choose superior-performing genotypes for specific environmental applications. The method involves using multiple testing cycles to evaluate, identify, and select favorable clones based on the response of genotypes to variable wastewater chemistries and site conditions. Early cycles are relatively short and data collected are easy to acquire (typically done in the greenhouse or growth chamber), while later cycles require more time and resources to increase knowledge of genotypes advancing (typically done in the field). Less clones are tested as the complexity of the data increases, and multiple-trait selection strategies are used to evaluate the combination of complex phenotypic expressions regulated by quantitative traits. The ultimate goal is to deploy a combination of genotypes with improved phytoremediation potential over the original set of clones, as well as adequate genetic variation to guard against insect/disease outbreaks, changes in soil

conditions (especially those induced by the wastewaters), and unfavourable genotype × environment interactions.

We will summarize these efforts by integrating results from eleven studies conducted during the last decade and a half in order to highlight the importance of phyto-recurrent selection for research studies and practical applications.

### **An Own Consumption Wood Energy Micro-Chain**

Stefano Verani<sup>1</sup> Giulio Sperandio<sup>2</sup>, Rodolfo Picchio<sup>3</sup>

<sup>1</sup> Agricultural Research Council. Research Unit for Wood Production Outside Forest. CRA-PLF Via Valle della Quistione, 27 00166 Rome, Italy

<sup>2</sup> Agricultural Research Council. Research Unit for Agricultural Engineering. CRA-ING. Via della Pascolare, 16 00016 Monterotondo (Rome). Italy

<sup>3</sup> Tuscia University. Environment and Forest Department (DAF). Via S. Camillo de Lellis, 01100 Viterbo, Italy

The micro-chain has been realized inside the firm of the research unit for agricultural engineering of Monterotondo (Rome). The action, financed by Italian Agriculture and Forestry Ministry has started in 2005. The purpose is to produce biomass to use for the Institute heating (total volume of 5.880 m<sup>3</sup>) in substitution of the actual diesel system. The sanitary water is produced also. The installed thermal boiler, has a nominal power of 232 kW. The poplar short rotation coppice (SRC), established with the clones AF2, AF6 and Monviso (single and twin rows), feed the micro-chain. The total surface is 4 hectare. The rotation of plantation is two years, beginning from the third year. The average plantation production (t dm ha<sup>-1</sup> year<sup>-1</sup>) has been of 10.2, with a maximum value of 13.53 for the twin rows AF2 and minimum value of 8.00 for the single row Monviso. The annual economic advantage in comparison to the diesel has been of around 18,700 €. The energetic budget of plantation, compiled using the Gross Energy Requirements method, it has furnished output/input index (in comparison to different clones and planting typology) varying from a minimum of 9.6 to a maximum of 16.5. The lowest output/input index for the whole micro-chain it has been of 4.

### **Who's interested in growing energy crops in the UK?**

Kevin Lindegaard

Crops for Energy, 35 Beaconsfield Road, Knowle, Bristol BS4 2JE, UK

The energy crops industry in the UK has been very slow at getting a foothold and there are still only around 10,000 hectares of woody energy crops planted. So why is there so little action on the ground? Unfortunately, many of the “incentives” offered by the Government do not directly benefit growers and too few have been persuaded to take the risk on growing these crops. This paper will briefly explore what farmers need to make them more interested in planting willow and poplar for both power and heat markets.

Despite the low take up by farmers a great deal of interest is being shown by industrial land owners (including waste management companies, water and sewage treatment companies, airports, aggregates companies and breweries). In many cases energy crops offer a suitable land use for brown earth sites and economic alternatives to industrial treatment of effluents. Furthermore, when the fuel produced from these crops is used in biomass boilers they have the fringe benefits of reducing carbon emissions and helping ensure long term security of supply. If more industrial land owners are attracted to growing these crops then there will be a need for more investment in infrastructure and more local contractors offering services. This will bring competition and make the venture less risky for other growers, leading to an increase in planting.

However, for this to happen, more projects need to get beyond the feasibility study stage and into practical deployment. Nevertheless, many environmental applications are constrained by

planning and consents. This is because they are often seen as bespoke solutions and planners need to be certain that the use of the crop will not have detrimental side effects. In addition, because of the high establishment costs project developers need to be certain that their crop will be able to thrive on challenging land and be able to deal with complex cocktails of chemicals in waste water, leachate and effluents from industrial processes.

The paper will briefly identify areas in which scientists could provide support to the industry in order for more of these projects to be implemented and as a result stimulate the energy crops sector to meet renewable energy targets and carbon reduction targets in the UK and elsewhere.

### **Production of short rotation woody biomass with and without irrigation with treated municipal sewage wastewater.**

Richard Krygier

Canadian Wood Fibre Centre, Canadian Forest Service, Natural Resources Canada, 5320 122 Street, Edmonton, Alberta, T6H 3S5, Canada

At Whitecourt, Alberta, a short rotation woody crop (SRWC) plantation is being grown with and without irrigation using treated municipal sewage wastewater. This project is part of a nation-wide Canadian Biomass Innovation Network study, led by Natural Resources Canada, which is investigating growing of SRWC's as a bioenergy feedstock. The Whitecourt site was chosen because of its accessibility for demonstration purposes, its proximity to a wastewater treatment facility, and the fact that a potential end user of the wood fibre produced (a waste-wood fired power plant) is located in the community. Five willow clones and two poplar clones are being monitored for their performance with and without irrigation. Growth, survival, biomass yield, insect and disease issues, heavy metal uptake by the willow, accumulation of heavy metals in the soil and ground water are being monitored. The use of wastewater for irrigation offers the opportunity to increase yields of willow biomass by augmenting low rainfall in western Canada, to reduce environmental impacts of waste water disposal and to decrease the need for manufactured fertilizers. This has the potential to reduce operating costs and improve the net carbon budget of plantations. At the end of the first rotation, yield increases up to 30% have been measured for some clones. No adverse effects on soil chemistry have been detected. Ground water sampling is underway. Four new irrigation installations and two biosolids installations are being developed to further test the concept of utilizing SRWC plantations for waste treatment in Western Canada.

### **Using willow riparian buffers for biomass production and riparian protection**

William Schroeder

Agricultural and Agri-food Canada, Box 940, Indian Head, Saskatchewan, S0G 2K0, Canada

There is increasing interest in the development of willow biomass as a renewable source of energy and woody lignocellulosic feedstock for bioproducts. Riparian buffers have been identified as an effective barrier to soil and nutrient movement from agricultural fields into watercourse. Willows are ideal riparian species in that they are well adapted to growing conditions in riparian zones and they vigorously re-grow following coppicing which allows them to be harvested for biomass in 3-4 year cycles. Characteristically riparian edges are highly productive due to water availability, therefore it is anticipated that willow biomass yield per unit area in riparian zones would be attractive. Research is being conducted to determine if using riparian buffer strips for willow biomass production provides energy alternatives and economic opportunities for land owners, but also leads to environmental benefits such as reduced erosion and nutrient leaching and preservation of water quality.

## Poster Abstracts

**Authors please note poster board dimensions are 160 high by 110cm wide**

### **Phytoremediation research using poplars and willows in Serbia**

Andrej Pilipovic and Sasa Orlovic

Institute of Lowland Forestry and Environment, Antona Cehova 13 , 21000 Novi Sad, Serbia

This paper presents review of research related to the use poplars and willows for phytoremediation conducted at the Institute of Lowland Forestry and Environment from 2003 till now. Research started first with nitrates and heavy metals Cd, Ni and Pb. First screenings were done with larger number of different poplar and willow genotypes in order to select best candidates for further work. Experiments were conducted in greenhouse with hydroponically grown plants on different concentrations of contaminants. Screening resulted in selection of four poplar and five willow genotypes with high potential for phytoremediation. Afterwards research started in 2006 included phytoremediation of crude oil contaminated soils with use of poplars and willows. The aim of this research is to investigate potential of selected clones for growing on this soils and stimulating of petroleum degrading microorganisms. Nowadays phase of research moved to field experiments with artificially contaminated soils which are still in progress.

### **The impact of harvest interval on short rotation coppiced willow plantations and phytoextraction of metals from biosolids.**

**W Scott Laidlaw<sup>1</sup>, S. Arndt<sup>2</sup>, D. Gregory<sup>3</sup> and A.J.M. Baker<sup>1</sup>.**

<sup>1</sup> School of Botany University of Melbourne, AUSTRALIA

<sup>2</sup> Forest and Ecosystem Science, University of Melbourne AUSTRALIA

<sup>3</sup> Research and Technology Division, Melbourne Water Corporation AUSTRALIA

Domestic and industrial loading of metals/metalloids into the sewage stream can result in production of contaminated biosolids. Exceeding regulatory contamination limits can preclude these biosolids for reuse as a soil amendment in agriculture, forestry or land rehabilitation. Contaminants in these biosolids can however be reduced by phytoremediation or more specifically for metals by phytoextraction.

*Salix* species (Willows) have been shown to accumulate bio-available metals such as cadmium, zinc and nickel within their biomass when grown on metal-contaminated substrates such as biosolids. The amount of metals that can be removed in the harvestable biomass is the product of plant tissue metal concentration and the biomass produced. These factors are likewise determined by characteristics of the willow species/clone and the physico-chemical nature of the soil or biosolids. Previous trials (Laidlaw *et al.* 2008<sup>1</sup>) have shown that *Salix* growing in metal-rich biosolids produces leaves with higher concentrations of metal than stems. Further, annual harvesting of both leaves and stems together can increase metal removal up to 50% above a stem only harvest. For heavily contaminated soils and sludges reduction of contaminants to acceptable levels by phytoremediation can potentially take several decades. Increasing biomass production and/or metal uptake would increase the efficiency of this process by shortening the timeframe required. The present study aimed to assess the impact on phytoextraction efficiency of manipulating leaf and stem production through variations in harvest interval.

Small (n=16) high density (40K stems ha<sup>-1</sup>) blocks of willows were planted in biosolids and harvested annually for two years. All blocks were irrigated with potable water by drip irrigation. In the third season the blocks were harvested at different intervals both within a

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<sup>1</sup> Laidlaw WS, Gregory D, Huynh TT, Godino M and Baker AJM (2008). "Phytoextraction of cadmium, zinc and nickel from contaminated biosolids by willows grown under field conditions." 23<sup>rd</sup> Session of the International Poplar Commission, Beijing, P.R. China, October 2008.



growing season and between growing seasons. Blocks of willows were harvested 1) early summer, 2) late summer and 3) mid autumn. Group A blocks were harvested 3 times within the growing season, group B twice and group C once at the end of the growing season. Harvested biomass was divided into leaves and stems and weighed as dry matter. Sub-samples were analysed for metal content. A single harvest ( $22 \text{ t ha}^{-1}$ ) produced a greater biomass than the cumulative mass removed from two and three intra-seasonal harvests (12 and  $8 \text{ t ha}^{-1}$  respectively). In addition, multiple harvests did not increase the cumulative leaf harvest significantly and hence had little impact on overall contaminant metal removal from the biosolids.

Two models of a phytoextraction system incorporating a combined leaf and stem harvest in autumn were developed. Biomass production and metal concentration data from previous trials (Laidlaw *et al.* 2008) were incorporated into the models to compare the impact of 1-year and 2-year harvest rotations on cumulative metal extraction over a 7 year period. Models assumed biomass production was constant after year 3 and plant tissue metal concentration (uptake) was constant. One third of annual leaf production was removed at each harvest event with the remainder falling as litter. The models showed that annual harvests removed 13% more metal than a system based on biennial harvests. In addition a stem only harvest would remove 14%-24% less metal. The harvesting of leaf biomass contributes significantly to metal removal by a willow based phytoextraction system.

The results of this field trial and modelling indicate that early autumn harvests of stem and leaf produced the most efficient removal of contaminant metals from biosolids. This conclusion however needs to be validated with longer term data from field trials subject to 1 year rotations for a period greater than three years.

### **Full greenhouse gas balance of a bio-energy plantation (POPFULL)**

**D. Zona<sup>1</sup>, J. Cools<sup>1</sup>, A. Zaldei<sup>2</sup>, and R. Ceulemans<sup>1</sup>**

<sup>1</sup>*Department of Biology, PLECO, University of Antwerp, Belgium*

<sup>2</sup>*National Research Council (CNR), Biometeorology Institute, Firenze, Italy*

The ecosystem scale research project we just started in Flanders (Belgium; POPFULL) will provide a full accounting of the greenhouse gas balance of a 19 ha short rotation coppice (SRC) plantation of fast-growing poplar and willow. The ultimate goal is to examine the potential of SRC cultures to reduce atmospheric CO<sub>2</sub> concentrations in Europe –through fossil fuel substitution – and to mitigate climate change.

As atmospheric CO<sub>2</sub> concentrations will inevitably increase further from 370 ppm at present to values between 490 ppm (best case scenario) and 1260 ppm (worst case scenario) at the end of this century (IPCC, 2007), we test the potential of SRC plantations to sequester CO<sub>2</sub> from the atmosphere and also investigate the emission/uptake of the other most important greenhouse gases (H<sub>2</sub>O, CH<sub>4</sub>, N<sub>2</sub>O) from the plantation and their environmental controls. We will measure the different greenhouse gases exchange of this high-density SRC culture will be monitored for four years using eddy covariance techniques. This would represent the first project in which all these greenhouse gases are investigated at the same time in a SRC coppice plantation. Moreover, as poplar is a sensitive species to O<sub>3</sub>, a strong pollutant in many European areas, we also investigate the effect of ozone damage to CO<sub>2</sub> uptake and on the net exchange of H<sub>2</sub>O, CH<sub>4</sub>, and N<sub>2</sub>O from the SRC plantation.

Within the framework of the POPFULL project we are also quantifying the complete energy balance and the full economic balance in line with a full life cycle assessment. This research receives funding from the European Research Council under the European Community's Seventh Framework Program (FP7/2007-2013), ERC grant agreement nr. 233366 (POPFULL).

## **Phytosanitary concerns in the biomass poplar plantation of the COFEA Project (Monterotondo – Rome)**

Achille Giorcelli<sup>1</sup>, Gianni Allegro<sup>1</sup>, Stefano Verani<sup>2</sup>

<sup>1</sup>CRA – Research Unit for Intensive Wood Production, Casale Monferrato (AL)

<sup>2</sup>CRA – Research Unit for Intensive Wood Production, Roma

A six-year monitoring survey (2005-2010) was carried out in a biomass poplar plantation established with three *Populus xcanadensis* clones in the spring 2005 in Monterotondo (Rome) (Cofea Project) with the goal of assessing the phytosanitary damage caused by pests and diseases.

Survival rate was fairly good, being negatively affected only in restricted areas due to stagnant water. Huge attacks of *Monoisteira unicastata* on leaves, felt down early in the season, were recorded during 2006-2008, which worsened the effects of summer droughts. No fungal attacks were detected, probably because of the hot and dry climate in the area, but the physiological disease of "black spots" appeared in the third year of cultivation, due to strong plant competition as well as summer drought.

The most serious problem arose for the 'poplar and willow borer' (*Cryptorhynchus lapathi*), which rapidly spread inside the plantation coming from external infestation sources. Attack intensity progressively increased during years, causing severe stem breakage starting from 2009. Three insecticide sprayings were annually carried out in a few plots during 2006-2008; they consistently limited pest populations and significantly reduced damage (1-2% of broken stems in the treated plots versus 10-30% in the control plots). By the way, chemical sprayings in SRF plantations must be given careful consideration from an economical as well as environmental point of view.

## **Environmental effects and energy balance of short rotation crops for bio-energy production: a review**

**Ouafik El Kasmioui, Sylvestre Njakou Djomo and Reinhart Ceulemans**

*University of Antwerp, Department of Biology, Research Group of Plant and Vegetation  
Ecology, Universiteitsplein 1, B-2610 Wilrijk, Belgium*

Short rotation woody crops (SRWCs) are a potential future source of renewable energy. They can be converted into electricity and/or heat using conventional or modern biomass technologies. In recent years many studies have examined the energy balance and environmental impacts of short rotation bio-energy production systems using various approaches. The outcomes of these studies have, however, generated controversy among scientists, policy makers, and the society. This paper reviews 26 studies on the environmental effects and energy balance of poplar and willow SRWC for bio-energy production published between 1990 and 2009. The data published in the reviewed literature gave energy ratios (ER) between 13 and 55 for the cradle-to-farm gate and between 3 and 11 for cradle-to-plant assessments, while the intensity of greenhouse gas (GHG) emissions ranged from 0.55 to 10.6 g CO<sub>2eq</sub> MJ<sup>-1</sup> and 39 to 132 g CO<sub>2eq</sub> kWh<sup>-1</sup>. These values vary substantially among the reviewed studies depending on the system boundaries and the methodological assumptions. Among the reasons for the conflicting numerical results in the literature are different system boundaries and lack of transparency, which hampers meaningful comparisons among studies. Although specific numerical results differ, our review revealed a general consensus on two points: the ER is greater than unity and GHG emissions are lower than those of fossil fuels. These conclusions were independent of biomass yield, or the definition of the system boundaries. ER and GHG emissions are the most studied impacts, while acidification and eutrophication impacts are common to only seven of the reviewed studies. Land and water use, biodiversity, and human and eco-toxicity are seldom included. The review suggests the need for a unified and rigorous system boundary, the adoption of particular assumptions that

are more representative for bio-energy systems and for the development of a widely accepted framework toward a reliable analysis of energy in bio-energy production systems.

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### **Treating waste water in poplar and willow root zones**

Louis Licht, P.E.,  
Ecolotree Inc., North Liberty Iowa, 52317

Rhyzo waste water treatment concept is straight forward and understandable –“Each drop of waste water passes within an inch of a root before pipe discharge or percolation”. „EWastewater” is a trademarked process that can be a practical and economical alternative to „conventional” water pollution control.

Ecolotree has worked specifically with poplar & willow trees to grow predictable rooted soil reactors to remove regulated contaminants as deep as 5 meters below ground surface. Effluent that now requires further treatment is filtered, pumped and irrigated into the root zone. By design, the effluent water flows through the root system where specific pollutants are adsorbed, entrained, mineralized or taken into the plant. Water then percolates to the ground water or reaches a drain line to a stream. Sufficient dwell time and soil chemistry are essential to remove nitrogen, phosphorous, pathogens, pharmaceuticals, metals, oils/greases, BOD, total dissolved solids (TDS), and total settleable solids (TSS).

These are the same processes that are used in conventional water treatment systems. One major exception is the plant-based treatment reactions that beneficially use the nutrients and water to grow biomass.

The EWastewater treatment concept is ready to be deployed on a large scale based on data from prototypes and full-scale systems. Reasons to expand the concept of rhyzofiltration wastewater treatment:

1. Money –cheaper to build and operate if land is available with less tax requirement
2. Jobs - local, new „green collar” jobs
3. Carbon foot print – significantly less fossil carbon power requirement while fixing and sequestering biomass
4. Watershed-scale benefits – EWastewater is part of the new sustainable landscape that performs „utility functions” including ground water recharge, nutrient cycling, pollutant capture, habitat diversity, biomass production, and ambiance.
5. Technology –available irrigation, drainage and monitoring systems can control a predictable plant root reactor for year-round operation

### **Root and shoot pruning of hybrid poplar for establishment in heavy clay soils**

Annie DesRochers

Universite du Quebec en Abitibi-Temiscamingue, 341 Principale Nord, Amos, Quebec, J9T 2L8, Canada.

Planting stock type and quality can have an important impact on early growth rates of plantations. The goal of this study was to evaluate early growth and root/shoot development of different planting materials in typical heavy clay soils of north western Quebec. Using 1 year-old bareroot hybrid poplar dormant stock, four planting materials were compared: 1) regular

bareroot stock, 2) rootstock (stem pruned before planting), 3) whips (roots pruned before planting), and 4) cuttings (30 cm stem sections taken from the basal portion of bareroot trees, i.e. roots and shoot pruned). Rooted stock types (bareroot and rootstock) produced on average 1.2 times larger trees than unrooted stock types (cuttings and whips). However, shoot-pruned stock types (rootstocks and cuttings) reached similar heights and basal diameters as unpruned stock types (bareroots and whips), during the first growing season. Shoot pruning reduced leaf carbon isotopic ratios, suggesting that unpruned stock types were stressed for water during the first growing season. The stress was most likely caused by early leaf development while root growth occurred later in the summer. We conclude that shoot pruning bareroot stock is a useful management option to reduce planting stress without compromising early growth rates of hybrid poplars.

### **Early roots development of willow unrooted stems under different water table and aeration levels**

Werther Guidi, Hafssa Kadri and Michel Labrecque

Institut de recherche en biologie végétale (IRBV) - Université de Montréal  
4101 Sherbrooke East, Montreal, QC H1X 2B2 , Canada

The *Salicaceae*, which includes willows and poplars, is currently one of the most popular plant family proposed for phytoremediation. For such purpose, to be established on site, plants need their roots to be rapidly developed. However in most case the environment in which they have to grow is not always the best suited for plants growth (e.g. polluted sites, flooded areas, etc.).

This trial was carried out to test the early response in terms of root formation of one willow clone, very common in our environment, following several water table and aeration levels.

We found that at any water table depth, the majority of root biomass was concentrated in the first layers below the water surface. In addition, aeration significantly increased the root biomass production of the whole plant also enhancing root biomass production of the deeper stem layers.

We concluded that when willows need to be grown under low aerated soils, an additional supply of air may allow for a more effective root (and thus plant) development and establishment.