Aboveground biomass production of 30 shrub willow and 7 hybrid poplar varieties over four coppice harvest cycles

Timothy A. Volk*, Jason Maurer, D. Moghariya, and Lawrence Abrahamson

Dept. of Forest and Natural Resources Management, State University of New York College of Environmental Science and Forestry (SUNY ESF)

Under the current production model in North America, willow biomass crops are harvested every 3-4 years for seven rotations. Yields typically increase at the second harvest, compared to the first and are expected to be maintained over the subsequent rotations. However, there are very few long term willow biomass trials in North America. Long term survival and production data is an essential input to models that project the long term productivity of willow crops across different regions of the country, assess the economics of the willow production system, and quantify some of the environmental benefits and impacts of the system using life cycle analysis.

A trial established in 1997 in Tully, NY contains 30 unimproved willow clones and seven hybrid poplar clones planted at a density of about 18,500 plants ha^{-1}. This is the oldest known trial for three willow clones that are currently being marketed for commercial production. Data from four three-year harvests is now available. In the first rotation production was 5.3 to 28.2 odt ha^{-1} for willow and 13.8 to 33.3 odt ha^{-1} for hybrid poplar At the end of the fourth rotation willow production ranged from 5.3 to 40.3 odt ha^{-1} and 14 of the 30 willow varieties that survived increased their biomass production between the first and fourth rotation. Biomass production increased by 22.6% between the first and fourth rotations across all willow clones. Hybrid poplar production in the fourth rotation was 5.0 to 38.5 odt ha^{-1} and only two of the hybrid poplar clones (DN74 and NM6) had higher production in the fourth rotation compared to the first rotation. Across all hybrid poplar clones biomass production decreased by 28.5% between the first and fourth rotations, suggesting that many of these clones are not suited to these high density, short rotation coppice systems.

Keywords: *Salix*, short rotation woody crops, long term production

*** Corresponding author:**
346 Illick Hall, SUNY ESF, Syracuse, NY 13210;
Phone: +1 (315) 470-6774; Email: tavolk@esf.edu

Subject Area: Production Systems and Operations

Above- and Below-ground Biomass and Soil Organic Carbon Inventories of Willow Biomass Crops Across a 19 year Chronosequence

Renato S. Pacaldo*, Timothy A. Volk, Lawrence P. Abrahamson, and Russell D. Briggs
Department of Forest and Natural Resource Management, SUNY College of Environmental Science and Forestry, 1 Forestry Drive, Syracuse, NY 13210

Assessing changes in above and below ground biomass and soil organic carbon (SOC) levels in willow biomass crops is critical for evaluating carbon and greenhouse gas balances in willow biomass crops. While data are available on long-term above ground biomass production, little is known about changes belowground. This study measured above- and below- ground biomass and SOC in a single willow variety (SV1, *Salix x dasyclados*) across a 19-year chronosequence.

Below ground biomass to a depth of 45 cm was significantly different among the age classes, ranging from 11.1 in 5-year-old crops to 21.0 Mg ha^{-1} in 19-year-old crops. Belowground biomass decreased with soil depth in all age classes from 3.5 to 6.9 Mg ha^{-1} in 0-15cm depths, 1.4 to 2.2 Mg ha^{-1} in 15-30 cm depths, and 0.6 to 0.8 Mg ha^{-1} in 30-45 cm depths. There was no significant difference in fine root biomass across chronosequence. Coarse root biomass was highest in 15-30 cm soil depth and comprised from 5.5 to 18.6 % of the total below ground biomass. Coarse root biomass was not significantly different among the 12, 14, and 19-year old crops, but was lower in 5-year-old crop. Belowground stool biomass ranged from 4.93 to 10.21 Mg ha^{-1} for 5- and 19-year-old crops, respectively.

Total aboveground biomass ranged from 7.19 Mg $ha^{-1}yr^{-1}$ for 5-year-old crop to 20 Mg ha^{-1} yr^{-1} for 19-year-old crop. Stool biomass production increased with age and ranged from 4.84 Mg ha^{-1} for 5-year-old crop to 10.17 Mg ha^{-1} for 19-year-old crop. The average above:below ground biomass ratio was 3:1.

The amount of SOC over a depth of 45 cm ranged from 163.72 to 188.15 Mg ha^{-1}. There was no significant difference in amounts of SOC among the five age classes and SOC also decreased with depths in these systems.

Keywords: *Salix dasyclados*, age, fine roots, coarse roots, belowground stool, foliage, stem, stump, biomass ratio, short- rotation willow crop.

*** Corresponding Author:**
338 Illick Hall, SUNY- Environmental Science and Forestry
1 Forestry Drive, Syracuse, NY 13210 USA
Phone: 315-470-4924/315-395-7562; Email: renatopacaldo@gmail.com

Subject Area: 1. Production Systems and Operations

Short Rotation Woody Crop Published and Reported Yields in the US for Poplars, Willows and Pines

Lynn Wright*
WrightLink Consulting

The US interest in biomass energy as an alternative to fossil fuel use, especially oil imports, continues to ramp up in 2010 with new comprehensive energy legislation being considered and many new biomass facilities being proposed. Accordingly the demand for published data on short rotation woody crop (SRWC) yields is also ramping up. While the SRWC literature is voluminous, published growth curves from full-rotation studies of woody crops are sparse. With rigorous searching of the published literature on woody crop yields, it was possible to identify 67 unique experimental field trials with a total of 364 unique genotype x treatment x location combinations. Our primary interest was in research stands that had been measured for enough years to verify the point of maximum mean annual increment (MAI_{max}), since that data point is most appropriate for predicting the average yield potential of woody crops at their optimal harvest age. Of the 364 unique treatment combinations, only a relatively small portion (90) could be verified as having likely achieved MAI_{max} during the 3 to 15 years that studies were measured (for a total of 440.5 measurement years). Not all treatments reaching MAI_{max} were useful for yield potential estimation but some treatments where MAI_{max} could not be validated, appeared to be reasonable estimates of harvest yield potential. By using personal judgment on reasonable yield levels, a total of 127 data points were extracted from the published literature as suitable for yield potential estimation. Because very few growth curves from new clonal materials resulting from controlled breeding conducted in the past 15-20 years are yet represented in the published literature, and since yields from successful commercial SRWC plantations are also not being reported (as total biomass yields) it is not possible to capture the true current yield potential status of short rotation woody crops in the US by relying on published scientific literature. Additional use of yield values reported in recent presentations and "gray" literature increase our understanding of the current SRWC yield potential but often do not provide enough information to use the values in assessments or mapping. This paper summarizes the types and sources of woody crop yield information available, discusses its limitations, and speculates on current woody crop yield potentials in the US.

Keywords: short rotation woody crops, SRWC, yield potential, growth curves, maximum mean annual increment

*WrightLink Consulting, 111 Cross Winds Cove Rd. Ten Mile, TN 378980, USA; Phone: +1 (865) 288-9463. Email: wrightlld@gmail.com

Subject Area: Production Systems **Preferred Presentation Format: Oral or Poster**

Challenges to mapping yields and modeling production of woody crops

Laurence M. Eaton[1]*, Lynn L. Wright[2], Robert D. Perlack[1], Matt H. Langholtz[1,] Chad Hellwinckel[3]
[1]Oak Ridge National Laboratory, Oak Ridge, TN
[2]Wrightlink Consulting, Oak Ridge, TN
[3]University of Tennessee, Knoxville, TN

Estimating potential US supply of woody resources hinges on understanding potential yields and costs at various spatial scales. Woody crop biomass yields are affected by a number of endogenous and exogenous factors. Genetics are important for determining potential biomass for fuels and power, as well as site conditions, weather, and cultural management of the crops themselves. We examine a these growth factors from a recently completed national database of historical published and unpublished yields to support economic modeling. Costs are developed from management practices and present or near-future harvesting technologies. Yield, cost, and projected demand (i.e. expected biomass price) are combined to generate expected returns of these alternative land uses, which compete with traditional crops in future market scenarios. POLYSYS, an agricultural simulation model, is used to estimate the relative competitiveness of woody crops and the potential for woody crops to displace conventional crops and pasture. The outcomes of these scenarios are presented at various spatial scales to estimate future market equilibriums of biomass.
Keywords: economic analysis, GIS
*** corresponding author:**
Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 27831
Phone: +1-865-574-7358; email: eatonlm@ornl.gov
Subject area: 1) Production systems

Short rotation yields of pure and mixed family plots of loblolly pine

C. Dana Nelson*, Kurt H.Johnsen, John Butnor, Larry H. Lott, G. Sam Foster, Warren L. Nance

U.S. Forest Service, Southern and Rocky Mountain Research Stations

Mixed and pure family plots of 10 fast growing half-sib families of loblolly pine (*Pinus taeda* L.) were planted in replicated experiments at two close spacings on two sites in the south central Gulf region. Plots sizes were 70 trees (10 x 7 tree blocks) with three complete replications per spacing per site. Tree spacings were 1 x 2 and 2 x 2 meters (~2000 and ~1000 TPA, respectively) and individual tree measurements were made at ages 5, 10 and 15 years. Mixed plots consisted of paired families randomized in 75/25 and 25/75 ratios of trees planted as well as all families in randomized rows and all families in random mixes. Stem volume yield differences among treatments (family composition X plot type) appeared more significant at closer spacing (1 x 2 m) than wider spacing (2 x 2 m), and family composition was the strongest factor, over mixed vs. pure plots and ratios within mixed plots. By age 10 the wider spacing plots were yielding at or near to the closer spacing plots. We will evaluate these trials for their potential to inform land managers of silvicultural options for loblolly pine short rotation culture.

Keywords: southern pines, biomass, biofuel, genetics, close spacing

*** corresponding author:**
Southern Institute of Forest Genetics, 23332 Success Road, Saucier, MS 39574, USA;
Phone: +1 (228) 832-2747; Email: dananelson@fs.fed.us

Topic Area: 1. Production Systems

Short Rotation Woody Crops Research at the University of Illinois

Gary J. Kling*, Thomas B. Voigt, Michael C. Dietze, David S. LeBauer, Sarah C. Davis, Evan H. Delucia, Stephen P. Long, J. Ryan Stewart, and Anthony Bratsch

Energy Biosciences Institute, University of Illinois at Urbana Champaign

Short rotation woody crop research was initiated by the Energy Biosciences Institute at the University of Illinois Urbana-Champaign in Spring 2010 on our 320 acre second-generation energy farm. The woody crop studies encompass 4 hectares and are side-by-side with trials of perennial grasses, forbs, and first generation energy crops, corn and soybeans, providing a unique opportunity to compare yields and ecosystem services of both woody and herbaceous crops. These new trials include evaluations of novel woody plant species and germplasm obtained from partnerships with the US Forest Service-Rhinelander (USFS-R), the University of Minnesota (UM), the State University of New York (SUNY), and Iowa State University (ISU). Research includes replicated plots with 23 clones of *Populus* from the USFS-R, 70 clones of *Populus* from UM, 6 clones of *Populus* from ISU, and 20 clones of *Salix* from SUNY. In the novel woody plant trial, the species include *Acer rubrum, Acer saccharinum, Alnus incana tenuifolia, Betula nigra, Castanea dentata x C. mollissima, Catalpa speciosa, Celtis occidentalis, Cornus sanguinea, Corylus americana, Cotinus obovatus, Ilex decidua, Liquidambar styraciflua, Liriodendron tulipifera, Maclura pomifera, Platanus occidentalis, Prunus serotina, Pterocarya stenoptera, Rhus copallinum, Robinia pseudoacacia* and *Quercus coccinea*. Data collection includes measurements of plant height, shoot length, initial dieback, height of bud scars, diameter at base, DBH, leaf numbers, leaf area, biomass produced, soil chemistry, coppice stem density, and photosynthetic efficiency.

Keywords: *Acer rubrum, Acer saccharinum, Alnus incana tenuifolia, Betula nigra, Castanea dentata x C. mollissima, Catalpa speciosa, Celtis occidentalis, Cornus sanguinea, Corylus americana, Cotinus obovatus,* hybrid poplar, hybrid willow, *Ilex decidua, Liquidambar styraciflua, Liriodendron tulipifera, Maclura pomifera,* novel woody plants, *Platanus occidentalis, Populus, Prunus serotina, Pterocarya stenoptera, Rhus copallinum, Robinia pseudoacacia and Quercus coccinea, Salix,* tree evaluation

*corresponding author:

University of Illinois, 1201 S. Dorner Dr., Urbana, IL 61801, USA

Phone: +1 (217) 333-3363; Email: gkling@illinois.edu

Subject Area: 4. Regional Feedstock Partnerships