RESEARCH PROJECT SUMMARY

(1986 – 2016)

FOREST BIOMASS INNOVATION CENTER

MICHIGAN STATE UNIVERSITY
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Reported by:
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Executive Summary

Michigan State University's (MSU) Forest Biomass Innovation Center (FBIC) was established in 1986 to coordinate and centralize forestry research and extension activities in the Upper Peninsula. It was originally called the Upper Peninsula Tree Improvement Center but was renamed in 2011 to more accurately reflect the role it has assumed in promoting woody biomass crop screening, production system development, impacts analysis, supply chain logistics improvements, and outreach activities. The Center has six full-time staff members who support the research and extension activities of campus-based faculty, carry out independent research, and maintain MSU's 8,000 acres of research forest properties in the UP.

Activities at FBIC are supported primarily by MSU AgBioResearch and additionally by various Federal, State, and Corporate research grants. Administrative coordination is provided by MSU's Department of Forestry but faculty members of numerous departments depend on the Center's land, equipment, and staff for their projects. This ***infrastructure*** provides the foundation on which both applied and basic research projects are built as well as the platform for Extension activities.

Research in the early days of the Center concentrated on tree improvement of species important to the forest products and Christmas tree industries. A great deal of effort was also placed on understanding the issues that were preventing northern white-cedar regeneration in the region. The MDNR, USFS, and a local sportsman's group (UP Whitetails) were keen to understand this problem and provided financial support to our research. Gradually the research emphasis changed to center on rapidly growing species that were adaptable for Short Rotation Energy (SRE) Plantation systems.

Of the 112 research projects conducted on the Upper Peninsula Research Forests during the past 30 years, 59 have been completed and 53 more remain active. Many of these projects are under the direct supervision of the Center's manager, but others are directed by 17 campus-based faculty members from 6 departments within the College of Agriculture and Natural Resources.

In addition to supporting the work of MSU personnel and conducting independent research, the Center's director has participated and led several trans-disciplinary teams of university, state, regional, national, and international partners seeking to advance the sustainable use of woody biomass in the production of renewable energy and bioproducts. In this way, we hope to combine our resources with those of others to solve problems that are bigger than any one investigator or institution could do by itself.

FBIC is a relatively young research facility but has quickly become a valuable tool for the Department of Forestry, Michigan AgBioResearch, the College of Agriculture and Natural Resources, and Michigan State University. What will the next decade bring?

Introduction

Michigan State University began conducting forestry research in the Upper Peninsula in 1925 on property near the mouth of the Charlotte River south of Sault Ste. Marie that became the Dunbar Forest. The Jim Wells Forest, between Marquette and Munising, became part of the University's forest research land-base in 1943 and the Upper Peninsula Tree Improvement Center in Escanaba was added in 1986. Today these properties are managed from Escanaba. A brief history of each property follows:

The Dunbar Forest Experiment Station

Dunbar Forest is a 5,700-acre tract near Sault St. Marie. It is the University's largest and second oldest off-campus facility. It has been a part of the Department of Forestry's research, education, and demonstration program since 1925. From 1940 through the 1970s, this forest was extremely active with planting, tending, and harvesting research programs, a forest seedling nursery, and a field program for forestry and civil engineering students from the main campus. Activity at this forest now capitalizes on the value of the long-term genetics and silvicultural studies at the site. Driving time to Dunbar Forest is about five hours from the main campus in East Lansing and about four hours from the Upper Peninsula Tree Improvement Center in Escanaba.

The last resident manager of Dunbar Forest retired in the fall of 1990 and a decision was made to manage the property from Escanaba. Most of the equipment was transferred to the Escanaba location and a caretaker was engaged to watch the buildings and take care of the grounds at Dunbar. The old office building has been converted into a bunk house that can house up to five visiting researchers. It is regularly used by faculty, staff, and graduate students from MSU and other institutions and agencies. Staff from the Upper Peninsula Tree Improvement Center use the lodging facility when they work at this forest.

Together with regional resource managers, the faculty and staff of the Department of Forestry set priorities, start new research, and revitalize existing studies at Dunbar Forest. The long-term research projects at Dunbar Forest, its diversity of forest stands, and its location on the Saint Mary's River are valuable assets. The University is working to capitalize on these assets.

The Jim Wells Forest

Wells Forest is a 440-acre tract near Au Train that has been part of the University since 1943. Tax delinquent land was given to the University by the State of Michigan so that sound forest management could be shown to be a profitable activity. This property is undeveloped except for a rudimentary truck-road system. The Jim Wells Forest is about 2 hours from Escanaba by car. Researchers working at this forest can obtain lodging at the University's Upper Peninsula Experiment Station at Chatham, which is only 20 minutes from the site.

A management plan for this property was drafted by Maurice Day (Manager of Dunbar Forest) in 1946 and is still being followed today. Most of the forest was thinned under the supervision of Roy Skog (Extension forester in Marquette) in two phases throughout the 1950s and 1960s. A

poor timber market prevented the completion of this task on the southernmost part of the tract. Detailed inventory, harvest, and cost records were kept for this operation and a final report was issued in May 1964. A second inventory and round of thinning were begun in 1991 and was completed in 1998. A third round of thinning was completed in 2003 and all the American beech were removed in 2014. Sixty-two CFI (Continuous Forest Inventory) plots were installed in 1998 at the site to provide better growth and yield projections for this stand.

The Forest Biomass Innovation Center (FBIC)

FBIC (originally named the Upper Peninsula Tree Improvement Center) was established in 1986 when Michigan State University purchased an 840-acre beef farm in Escanaba, MI. This farm is located in an area where vast hardwood stands supplied charcoal to the region's pig iron furnaces in the mid-1800s. About 400 acres of these prime northern hardwoods were cleared around 1890 by one of the charcoal kiln supervisors and his brother. Together they established one of the first dairy farms in Delta County on the site that is now FBIC.

Local farmers claim that FBIC's farm fields are some of the best in the county, probably due to its fertile Onaway soils. The two brothers knew this because they were astute woodsmen. They chose the best forest in the area to clear for their farm. All of MSU's main forestry properties (Kellogg Forest, Russ Forest, Dunbar Forest, and FBIC) were abandoned farms. FBIC differs from the others in that it was not abandoned because it was on poor soils, but because of its remoteness from major agricultural markets. FBIC is, however, located directly in the heart of Michigan's thriving forest industry.

FBIC was expanded to its present size in 1987 when Mead Corporation donated an adjacent 880-acre tract of cedar swamp.

FBIC became a fully functioning Experiment Station in 1988 with the arrival of a resident manager. The first project established at FBIC was a forest genetics plantation of Douglas fir in 1986. The original name of the station was changed in 2011 to reflect a change in focus from tree improvement to woody biomass feedstock development and use. FBIC can be reached in seven hours by car from the main campus in East Lansing.

The staff at FBIC has grown to include a Resident Forester, an Operations Forester, a Forest Technician, a Research Technician, a secretary, and student interns. The Center also houses the office of the Extension Specialist for Forestry in the U.P.

This center is the focal point for Michigan State University's forestry research in the Upper Peninsula. It serves as the home base for the staff and equipment that are used to manage the Dunbar and Jim Wells Forests. Joint projects are frequently undertaken between staff at the Center and MSU's Department of Forestry, Department of Biosystems and Agricultural Engineering, Department of Crop and Soil Science, Department of Fisheries and Wildlife, Department of Horticulture, Department of Entomology, the Michigan State University Extension, the Michigan Department of Natural Resources, the Hiawatha National Forest, the Michigan Department of Agriculture, USDA Soil Conservation Service, and other groups (e.g., Society of American Foresters, USDA Resource Conservation and Development Forestry

Committee, The Cedar Action Group, UP Whitetails Association, and local school groups for demonstration, education, and research. Other university partners also include Michigan Technological University, The University of Wisconsin, The University of Minnesota, The State University of New York, College of Environmental Science and Forestry, Cornell University, Ohio State University, Iowa State University, The University of Washington, and Penn State University.

The document that follows provides a brief, yet comprehensive summary of the research projects that have been active on the Upper Peninsula Research Forests during the past 30 years (1986 – 2015). Some of these are legacy projects from earlier generations of researchers but most have been initiated during this 30-year interval. Some of the projects have been completed but many remain active today. When appropriate, the location of the project is mentioned along with the timeframe of the project and the principal investigator of the project. Areas are frequently identified using a code system (*e.g.* U08ac) that links the project to the GIS database maintained in the FBIC office.

Of the 112 research projects conducted on the Upper Peninsula Research Forests during the past 30 years, 59 have been completed and 53 more remain active. Many of these project are under the direct supervision of the Center's manager, but others are directed by 17 campus-based faculty members from 6 departments within the College of Agriculture and Natural Resources.

GHG, Carbon, & Ecological Service Studies

Kirtland Warbler Habitat Management Alternatives

(2015-2017) PI: Rothstein

Approximately 40,000 acres of jack pine are being managed to provide habitat for the federally endangered Kirtland Warbler in Michigan. Managing these young stands is expensive and the MDNR along with the US Forest Service are seeking new ways to reduce the expense of harvesting and replanting these stands while continuing to provide for the habitat requirements of this bird species. This project is designed to look at the feasibility and impacts of using trees that are no longer of use for the warbler for biomass feedstocks. A thorough assessment of environmental and financial impacts will be conducted.

Reduced Tillage Trial (1)

FBIC: U07u (2010-present) PI: Rothstein

An eight-acre plantation of several poplar hybrids (known as our "fiber farm") was harvested at FBIC in 2008 after 11 growing seasons. This plantation was replanted using the best yielding poplar clone from the first rotation (NM6) in 2010. Half of the plantation was established using a combination of herbicide application and mechanical tillage while the remainder received only herbicide weed control. Monitoring of GHG fluxes continued throughout the reestablishment period. Dr. Rothstein has two studies underway in this "son-of-fiber-farm." Both will examine the effects of previous land use and site preparation techniques on GHG fluxes and subsequent plant growth.

Reduced Tillage Trial (2)

FBIC: U09o (2011-2012) PI: Rothstein

This study was designed to monitor the soil-to-atmosphere gas exchange after establishing a hybrid poplar SRE plantation in an old hay field to compare carbon cycling under 3 different treatments. The site was prepared by applying herbicides in 4'-wide bands throughout the plantation and then 1) the entire plot was cultivated to a depth of 6", 2) only the sprayed strips were cultivated, and 3) no cultivation was conducted. 10" unrooted cuttings of NM6 poplar were then planted in rows to form three replications of $1/10^{th}$ acre 72-tree rectangular plots.

USDA Carbon Cycling in Poplar & Willow

FBIC: U09n (2010-present) PI: Rothstein
Rhinelander, Wisconsin (2010-2015) PI: Mladenoff (UW)
Grand Rapids, Minnesota (2010-2015) PI: D'Amato (UMinn)

Established the 10-acre plantation on June 1, 2010 with poplar (NM6) with standard 8'x7' spacing (777 trees /acre), willow (Fish Creek) with standard double row spacing (5808 stems / acre) in randomized plots. Plots are 40M x 40M with 6M borders between the plots and around the perimeter. Used the Whitfield Tree planter to make slits in the ground, and hand planted the dormant stem cuttings using a large crew and measuring tapes to space the cuttings in each row. 4-blocks of 3 treatments - hay (Control), poplar (NM6), willow (Fish Creek) in randomized plots. Plots are 40M x 40M with 6M borders between the plots and around the perimeter. A companion plantation is in Rhinelander

GLBRC Land Conversion Impacts on GHG

Multiple Locations: PI: Rothstein & Mladenoff
Skandia X01 (2009-2015)
Brimley X02 (2009-2015)
Onaway X03 (2010-2015)
Lake City X04 (2010-2015)

SRE plantations on marginal lands should have far greater rates of feedstock production than existing forests and would allow forests to be utilized for carbon (C) sequestration, timber, recreation and other ecological services. This project seeks to quantify the impacts of SRE plantations on both C sequestration in soils and biomass, and emissions of greenhouse gases (GHGs) other than CO_2. We are using nine of FBIC's experimental willow and hybrid poplar plantations distributed throughout the region for intensive measurements of feedstock production, above- and below-ground C storage and GHG emissions as a function of initial site characteristics. These data will be used to parameterize, calibrate and validate process-based biogeochemical models and Life Cycle Assessments that predict feedstock production, C flows and GHG fluxes from SRE plantations across the range of soil and climate conditions of the region.

Arthropod Diversity in SRE Plantations

FBIC: U09n (2011-2013) PI: Landis

Doug Landis is investigating the differences in insect populations under developing poplar and willow SRE Plantations and comparing them to the populations in undeveloped pasture grass plots. FBIC staff trapped, collected, preserved, and delivered insects as part of a GLBRC project headed by Dr. Doug Landis (MSU) to determine how conversion of grassland habitats to poplar and willow short rotation woody biomass crops shape diversity, abundance and composition of functional groups of arthropods.

Controlling Carbonite Dynamics in SRE Plantations

FBIC: **U09t (2013-2014) PI: Rothstein**

Geochemical controls on soil C cycling are likely to be particularly important in soils containing inorganic C (carbonates). There is rising evidence that coupled organic – inorganic cycling processes play an important role in C cycling in soils of arid or semi-arid areas. The role of soil inorganic C (SIC) in temperate zone soil response to changing land cover has however not been extensively studied. This trial was designed to study the differences in soil gas exchange of carbon and nitrogen in converting an old hay field to a poplar plantation using 3 treatments; no site preparation, commercial standard site preparation (combination of herbicide and mechanical cultivation), and the standard site preparation with the addition of a nitrification inhibitor. The trial occupied 1 acre and contained 3 replications of 56-tree plots in which the 3 treatments were applied.

Balsam Fir – Sugar maple Shading Study

FBIC: various (1999-2000) PI: Kobe

Balsam fir and sugar maple seedlings easily regenerate in the shade of mature forests. This basic ecological study is being done to determine if the evergreen species can take advantage of the early and late parts of the growing season when the deciduous overstory species do not have their leaves. If so, this may give them a growth advantage and effect species composition in forests like ours if the global climate changes. The project combines the resources of Michigan State University's Department of Forestry and Princeton University. It began in the spring of 1999 and will continue for at least two years. A set of 166 fir and maple seedlings were part of the study. Shade structures were placed over half of the individuals in early spring and late fall to prevent them from photosynthesizing on mild days during those times. The unshaded trees are free to grow if they can. Seedling growth was assessed to determine the extent to which they were able to use the early and late portions of the growing season.

Growth, Yield, and Logistics Trials

Poplar Yield Trials

Fiber Farm

FBIC: (U07b) (1998-2008) PI: Miller

Aspen fiber is the leading agricultural crop in the UP and ranks 6th statewide. The goal of this project was to determine an optimal combination of clones and cultural methods for producing aspen-like fiber in a third of the time that natural stands require. The work was done with the close cooperation of Mead Corporation. This 8.4-acre plantation contained four clones of hybrid poplars, a seed source of hybrid aspen, and a seed source of hybrid larch was established at FBIC in the spring of 1998. Soil amendments (ash from wood-burning boilers), fertilizers, and weed control systems were tested in this plantation employing a split-plot randomized design. It was eventually harvested in the fall of 2008 after 11 growing seasons.

In addition to the original objectives for this trial it also served as the site for several additional research projects. Soil samples were collected from our short rotation hybrid poplar plantation by Dr. Fabio Sartori of Ohio State University. He is studying the variation in carbon sequestration beneath various poplar clones. Wood samples were collected from the same hybrid poplar plantation by Dr. Pascal Camdem and Josh Rawson of Michigan State University. They are investigating the effects of rapid growth on the physical properties of wood and wood fibers of various clones. Dr. David Rothstein installed plots in this plantation after it was harvested to monitor GHG exchange during the interval between harvest and second-rotation stand establishment. This second rotation has become known as the “Son of Fiber Farm” (U07u) and is being used to test reduced tillage methods for re-establishing poplar plantations.

Work done in this trial launched our subsequent investigations into Short Rotation Energy Plantation system development for poplars and willows.

Statewide Trial of Legacy Poplar Hybrids

FBIC: U08am (2009-present) PI: Miller
Skandia: X01b (2009-present) PI: Miller
Brimley: X02b (2009-2014) PI: Miller
Onaway: X03b (2010-2014) PI: Miller
Lake City: X04b (2010-present) PI: Miller
Albion: X05b (2011-present) PI: Miller

A series of large-plot yield trials of 16 legacy poplar hybrids were established at six sites throughout Michigan between 2009 and 2011. Poplar hybrids were chosen based on past performance in the Northeast and Lake States Regions, were established in 64-tree plots and replicated 5 times at each site. The number of clones included at each site varied depending on planting stock availability. Trees were planted in rows separated by 8’ and with 7’ between trees within the rows (resulting in 778 trees per acre). These plantations are measured annually and the intention is to harvest and weigh the trees at the end of the 6^{th} – 8^{th} growing season. These plantations are 5 to 7 acres each size (depending on the number of hybrids included) and have

been used for a variety of other research projects as mentioned elsewhere in this document.

The planting stock used in this network of trials were obtained from a variety of sources and assembled in "stool beds" at MSU's Tree Research Center in East Lansing. These beds have been rouged and augmented over time until they represent the largest collection of these legacy clones in the region. This is a unique resource.

10-clone Poplar Yield Trial

FBIC: U08at (2010-present) PI: Miller

Rooted mini-cuttings of 5 newer NRRI poplar clones, hardwood cuttings of 4 older poplar clones, and the *P. alba* hybrid [83XAA04] from McGovern, which had previously been identified to have good hardwood cutting rooting ability (see U07r & U07s below) were planted in 64-tree plots and replicated 4 times. Trees were planted in rows separated by 8' and with 7' between trees within the rows (resulting in 778 trees per acre) and occupy 2.8 acres.

2nd Generation Poplar Yield Trial

FBIC: U08az (2012-present) PI: Miller

This 2.2-acre trial represents the beginning of the second phase of our screening of poplar hybrids for use in Michigan SRE Plantations. The hybrids included in this yield trial are newer than those in our previous set of yield trials and have been selected on the basis of clonal trials conducted in MN and MI over the last decade. They are expected to demonstrate superior growth and pest resistance than the earlier hybrids. The test is also planted at a higher initial density with the expectation that rotations can be shortened and plantation economics improved. Dormant hardwood cuttings of 9 newer NRRI hybrids and 2 standard check hybrids were established in 100-tree plots and replicated 3 times. Trees were planted in rows separated by 7' and with 4' between trees within the rows (resulting in 1,555 trees per acre – twice the density of our previous poplar yield trials). A companion to this trial was established by NRRI in MN.

Populus Alba (AG15) Yield Trial

FBIC: U08be (2012-present) PI: Miller

A full-sib family (15xAG91) of a *P. alba* X *P. grandidentata* (*P.* x *rouleauiana*) hybrid that proved to be the best grower in the 1992 progeny test [U08m]. Branch cuttings from the best individual (AG15) in the progeny test (plantation U08m, Row 19, Column 41) were collected during the winter of 2008 and various methods for vegetatively propagating that tree were applied between 2008 and 2011. Eventually 75 copies (ramets) were produced and planted here in this 0.3-acre plantation to determine if the superior growth expressed by the parent tree is a genotypic or merely phenotypic phenomenon. The trial is composed of 25-tree plots (5 X 5 trees on 8' X 7' spacing) of AG15 and NM6 arranged in a randomized block design with 3 blocks.

Main Campus Short Rotation Energy Plantation

Lansing: X06a (2013-present) PI: Miller

This project occupies a 10.7-acre site along Sandhill Road of the extreme south edge of campus. It was established on May 16th, 2013 and includes 4 promising new clones and an NM6 control clone. The majority of the 8" dormant cuttings were planted on and 8'x5' spacing (7-acres), and 3-acres were established as a spacing trial, on 8'x 8', 8'x6', and 8'x4' spacings. This project was originally intended to supply wood chips to the Simon Power Plant, but that option has been withdrawn as a result of changes in university policy. This planting will serve now as an education and research tool for the Department of Forestry.

Willow Yield Trials

Multi-rotation Willow & Poplar SRE Plantation Trial

FBIC: U08ac (2002-present) PI: Dickmann / Miller

12 willow hybrids and 2 poplar hybrids were planted here in 48-tree plots and replicated 5 times. Trees were planted on a 2' X 3' rectangular spacing resulting in density of 7,260 trees per acre. These have been harvested four times – the last time was in the fall of 2013. A companion replicate of this plantation was established in southern Michigan but mortality was excessive and that trial has been discontinued. This is a rare, long-term test of poplar and willow being grown together using the micro-rotation, high density management system. Willow annual growth increments lagged significantly behind poplar until the last harvest cycle, when certain willow clones began to equal the growth of poplar. Consequently poplar has out-yielded willow over the life of the plantation. Contradictory results have been reported from a similar, but unrelated, study in New York.

Failed Willow Clonal Yield Trial

FBIC: U07o (2007) PI: Miller

Willow hybrids showed promise in SRE Plantation systems so we at MSU developed a close working relationship with the willow biomass program at the State University of New York in order to expand the testing of these materials in Michigan. Testing of new hybrids developed in New York began in 2007 with this plantation. This 1.5-acre plantation was established on May 16th, 2007 on a hayfield at FBIC to test the performance test of 26 different willow clones for the Great Lakes Region. The plantation failed after two months. High mortality occurred, probably due to a combination of incorrect herbicide application and drought conditions following planting. Subsequent tests have been much more successful. We learn from failures.

Statewide Willow Yield Trial

FBIC: U08ah (2008-present) PI: Miller
Skandia: X01a (2009-present)
Brimley: X02a (2009-present)
Onaway: X03a (2010-2013)
Lake City: X04a (2010-present)
Albion: X05a (2011-present)

Large-plot yield trials of willow hybrids were established at six sites throughout Michigan between 2008 and 2011. These hybrids emerged as promising candidates from earlier work done in the state of New York. Cuttings were obtained from our partners at the State University of New York, College of Environmental Science and Forestry in Syracuse and subsequently from others at Cornell University and Double A Willows (the only commercial nursery licensed to produce these hybrids). The number of hybrids included at each site ranged from 26 to 20 depending on planting stock availability. Each plantation was established in a randomized block design with 4 blocks and 78-tree plots. Trees were spaced according to the New York protocol: pairs of rows separated by 2-1/2 feet were planted every 5 feet. Trees within the rows were separated by 2 feet. This yielded a planting density of 5,808 stools per acre. This provided access to the site by commercial willow harvesting equipment. Plantings ranged is size from 1 to 1.5 acres depending on the number of hybrids tested at that site. Measurements taken from these plots were confined to the center 18 stools to avoid plot edge effects. Trees were coppiced at the end of the first growing season and then harvested and biomass production recorded every three years thereafter. Numerous measurements were made in these plantings throughout their life.

Cornell Willow Hybrids Yield Trial

FBIC: U08bc (2012-present) PI: Miller

New willow hybrids are constantly being produced at the breeding program of Cornell University and we continue to collaborate to test these for adaptability in the Lake States. This 0.8-acre plantation was established on May 22nd, 2012 to test 24 of these newer clones. The test has a randomized block design with 4 blocks of 48-tree plots. The planting uses the double-row design employed in other willow yield trials throughout the region (5,808 stools/acre). The plots here are smaller than previous trials. Fewer border trees were employed in order to conserve precious planting stock. This trial is using 48-tree plots made up of 4-rows of 12-stools versus the standard 78-tree plot using 6-rows of 13-stools. The inner 16 stools are sampled leaving the remainder as borders.

Grass Yield Trials

Switchgrass Variety Trial

FBIC: U05e (2006-2009) PI: Minn / Kapp

Replicated plots of 9 switchgrass varieties were planted in 2006 by personnel from the Upper Peninsula Experiment Station's Crops Research Team. The test occupies 0.07 acres. Yields from these plots were calculated for three years (2007 through 2009). The plots remain but have been

unused since then. They are mowed each fall.

Miscanthus

FBIC: U08ak (2008-present) PI: Miller

Root segments of *Miscanthus giganteus* were donated to FBIC in 2008 and were planted in this 0.27-acre block at a rate of 5,000 segments per acre. The main purpose was to see if this biomass crop would survive the cold winters in the Escanaba area. Although survival was mediocre, the stand is beginning to develop now after 8 years. Growth is not impressive.

GLBRC Marginal Lands Study

FBIC: U05f (2013-present) PI: Thelan

This 8-acre study was established on 5/29/13 to test performance of 7 biomass crops (switchgrass, miscanthus, native grasses, prairie, old-field, undisturbed check, and hybrid poplar) on marginal land. This location is one of six sites intended to create a wider productivity gradient than that already established within the GLBRC network. Twenty-four 20 X 20 meter plots were established at FBIC in a randomized block design with 4 blocks.

Field Storage Impacts on Biomass Quality

In-Woods Storage of Logging Residue

FBIC (2012) PI: Pan

Logging residue (otherwise unmerchantable portions of trees cut in harvesting operations) are finding increased use in wood energy markets. These materials have moisture contents approaching 50% at the time of harvest. This water has no value and increases the weight of material as it is transported to end users. Moisture content can be reduced if residues are piled at the harvest site and allowed to air dry. This study was conducted to follow the change in heating value and wood quality as residues were stored in outdoor piles. This information is needed to complete a financial assessment of the benefits and cost of drying wood in this way.

Feedstock Changes Over Time in Chip Piles

FBIC (2013-2014) PI: Pan

The second phase of a project designed to determine the economics and effects on “logging residue” biomass storage techniques was begun during the summer of 2013 at FBIC. In this case, chipped logging residue was deposited in a pile. Samples were removed and analyzed from the pile regularly throughout a 12-month period to determine how wood moisture content and quality changed over time. This data was also instrumental in determining the financial benefits and costs of field drying of woody biomass.

Biomass Algorythm Improvements Estimate Improvement

TSALE Volume Equation Validation

2004 PI: MacFarlane

This study set out to improve the accuracy of predicted merchantable volume of standing trees in Michigan. Detailed cut tree measurements were collected from active forest harvesting operations in the UP and used to validate adjustments to the TSALE volume equation used by the Michigan DNR. FBIC staff helped to establish and test the protocols later used by student crews to collect project data.

FIA Biomass Equation Improvement Project

FBIC (2013-2014) PI: MacFarlane

The US Forest Service maintains an inventory of all forests in the United States and provides summaries and assessments of this information through the Forest Inventory Analysis (FIA) group. This project was initiated to obtain a better estimate of the biomass present in America's forests. The crew at FBIC assisted by collecting field data from numerous sugar maple and balsam fir trees. Detailed standing tree measurements along with measurements of dissected tree parts were provided to the campus-based researchers working on this project to improve the allometric equations for estimating biomass in standing trees of these species.

Norway Spruce & Red Pine Yield Study

FBIC: U09e (1992-present) PI: Carl Ramm

Red pine is widely planted for fiber production because of its high yields. Norway spruce may match or exceed red pine's yields on better sites, but has not been properly tested. This investigation is designed to compare the two species at FBIC. Two grub control pesticide treatments were also tested (together with a control group) during planting of this project in the spring of 1992. The plots were row-thinned in the winter of 2015. 130-tree rectangular plots of these two conifers were planted in 6 randomized blocks to determine the long-term yield characteristics of both. 3 insecticide treatments were applied to the seedlings prior to planting to assess effectiveness for grub control. Severe deer browse damage has occurred in this planting, so replanting was done in 1995.

Clearcut Reforestation Species Trial

Upper Peninsula Experiment Station (1982-present) PI: Miller

This 5-acre plantation was established at the Upper Peninsula Experiment Station at Chatham in a sugar maple stand that had been clearcut following storm damage in 1982. Quarter-acre blocks of fives species were planted in 1982 to test adaptability and compare yields of red oak, red pine, Kellogg hybrid pine, Japanese larch, and European larch. A report of growth during the first 14 years in this plantation was made in 1997.

Upland Hardwood Management by Selection Silviculture

Jim Wells Forest (1992-present) PI: Miller

The upland hardwoods at the Jim Wells Forest have been under management since the University obtained this property in 1943. The 440-acre tract has been thinned 4 times (1960, 1992, 2003, and 2013). The objectives of these thinnings were: 1) continue the process of improving the quality and size of the residual trees on the site, 2) encourage regeneration of desirable hardwood species and thus broaden the age class structure of the stand, and 3) generate a set of cost and yield figures similar to those obtained in the 1960s by Roy Skog. The most recent thinning (2013) has the objective to remove all the American beech from the forest before it is lost to beech scale disease.

Data collected over long periods from natural forest systems helps to quantify the effects of management activities such as thinning. Fifty-one Continuous Forest Inventory (CFI) plots were established in 1996 at the Jim Wells Forest, where periodic thinning is taking place. Tree growth in these plots was measured in 1996, 2001, 2006, and 2014. A system to precisely and efficiently map the location of each tree within the plots was also developed and implemented. University researchers can use the growth and spatial data from trees in these plots to model and understand forest growth in response to thinning.

Jack Pine Budworm Growth Reduction Study

2002 PI: McCullough

The growth reduction caused by Jack pine budworm was quantified in this MDNR-funded study. Stem segments collected from the Eastern UP were brought to FBIC where they were prepared and analyzed with specialty scanning equipment and software (WINDENDRO) at the Center.

Forestry Genetics Trials

Section *Aigeiros* Hybrid Poplar Trials

Legacy Poplar Hybrid Clonal Trial

FBIC: U08ab (2001-2009) PI: Dickmann

This 2.7-acre plantation was established on May 17th, 2001 as part of a network of plantings in the Lake States designed to test legacy poplar hybrids for adaptability, growth, and disease resistance. The trail used a randomized block design with 5 blocks of 60 taxa in single-tree plots on 10'x10' spacing. The USFS was the originating agency. Growth data from this plantation and stem samples were taken from this plantation and several other similar plantations in Wisconsin and Minnesota and delivered to researchers at Iowa State University for analysis. A report written by William Headlee was published describing differences in wood characteristics.

56-clone Hybrid Poplar Clonal Trial

FBIC: U08aj (2008-present) PI: Miller

2008 NRRI Poplar Clonal Trial [U08aj] – This is the first in a series of poplar clonal trials we are conducting in cooperation with University of Minnesota's Natural Resources Research Institute. Clones chosen for testing in these regional field trials showed potential after 3 to 4 years in progeny trials in a nursery in Minnesota. In this test, 56 NRRI poplar clones were planted in single-tree plots and replicated 6 times. Cuttings were established in this 0.3-acre plantation with 8' between rows and with 5' between cuttings within the rows. Planting stock was produced in Minnesota as rooted mini-cuttings. Mini-cuttings are short stem sections that are then placed in greenhouses under conditions that favor root and shoot development. These rooted mini-cuttings are hardened-off to prepare them for field planting in a manner similar to containerized seedlings. This and other clonal trials will provide information vital to the selection of clones for more intensive testing in poplar yield trials. Traits of particular interest include growth rate, climatic adaptability, and pest resistance.

70-clone Hybrid Poplar Clonal Trials (2009)

FBIC: U08ao (2009-present) PI: Miller
Skandia: X01c (2009-2014) PI: Miller
Brimley: X02c (2009-2014) PI: Miller

A set of 70 poplar hybrids from the NRRI Minnesota breeding program was obtained for testing at three sites in Michigan in the spring of 2009. Planting stock was received as rooted, actively growing, mini cuttings in greenhouse containers. The planting design was the same for each site and was composed of 6 randomized blocks of 70-clones in single-tree plots spaced 7-ft apart within rows spaced 8-ft apart. Each planting occupied about 0.5 acres. We have had poor luck with these mini-cuttings when planted on satellite research sites away from Escanaba where caring for them is more difficult. The only planting in this set that has survived well enough to produce useful data is the FBIC test (U08ao).

70-clone Hybrid Poplar Clonal Trials (2010)

Onaway: X03c (2010-2013) PI: Miller
Lake City X04c (2010-2014)

A set of 70 poplar hybrids from the NRRI Minnesota breeding program was obtained for testing at two sites in Michigan in the spring of 2010. These hybrids were similar to the set established the previous year in FBIC, Skandia, and Brimley. Planting stock was again received as rooted, actively growing, mini cuttings in greenhouse containers. The planting design was the same for each site as in the previous year and was composed of 6 randomized blocks of 70-clones in single-tree plots spaced 7-ft apart within rows spaced 8-ft apart. Each planting occupied about 0.5 acres. We have had poor luck with these mini-cuttings when planted on satellite research sites away from Escanaba where caring for them is more difficult. Consequently, both of these trials have poor survival and have been abandoned.

41-clone Hybrid Poplar Clonal Trial

FBIC: U08bd (2012-present) PI: Miller

Dormant hardwood cuttings of 39 newer NRRI poplar hybrids and 2 check clones were established here in single-tree plots, replicated 6 times. Cuttings were established with 8' between rows and with 6' between cuttings within the rows. The test occupies approximately 0.3 acres.

Section *Leuce* Hybrid Poplar Trials

Populus Alba Clonal Test of 83XAA04

FBIC: U08as (2010-present) PI: Miller

Members of a full-sib *Populus alba* family (83XAA04) developed by McGovern had previously shown good growth [U07m] and the potential to reproduce from un-rooted hardwood cuttings [U07r]. 15 superior individuals from this full-sib family were identified in nursery beds at MSU's Tree Research Center. Dormant hardwood cuttings of these individuals were planted here on May 14th, 2010 in this clonal trial along with a control hybrid of NM6. 2-tree (ramet) plots are replicated 4 times on an 8' X 7' rectangular spacing. Within-family variability of rooting and growth will be determined from this 0.14-acre plantation.

White Poplar and Aspen Hybrid Progeny Test

FBIC: U07m (2005-present) PI: Miller

This is a 0.6-acre full-sib progeny test of 10 poplar hybrids from the section *Populus* along with an NM6 check clone. Hybrids were made by McGovern. Rooted seedlings were planted in 4-tree row plots (full-sibs), replicated six times, on 9' X 9' spacing. The poplar clone NM6 was included in each block for comparison.

1992 White Poplar and Aspen Progeny Trial

FBIC: U08m (1992-present) PI: Miller

This 1-acre test includes full-sib progeny of 58 hybrids of various poplars from the section *Populus*. Controlled pollinations were made by Pat McGovern. Rooted seedlings were planted in 3-tree row plots, replicated 4 times on 8' X 8' square spacing. One particularly outstanding family was identified and vegetatively propagated for further testing. Clones of individuals from this superior family are being tested in U08be.

1994 White Poplar and Aspen Progeny Trial

FBIC: U08p (1994-present) PI: Miller

This 0.6-acre plantation includes full-sib progeny test of 19 hybrids of various poplars (especially *P. alba and P. x smithii*) from the section *Populus*. Hybrids were made by McGovern. Rooted seedlings were planted in 4 single-tree plots per block, replicated four times on 8' X 8' square spacing.

Hybrid Aspen/Alba Clonal Archive

FBIC: U07l (1999-present) PI: Miller / Wycoff

10 clones of poplar hybrids from the section *Populus* are archived here in 16-tree, square, un-replicated plots on 9' X 9' square spacing. The hybrids were produced by the University of Minnesota's Aspen/Larch Genetics Cooperative and chosen as promising for Michigan conditions by Gary Wycoff of Mead Paper (no longer in existence). This 0.6-acre planting is pruned and maintained as an archive of these unique genetic materials.

Silver Maple Rangewide Progeny Test

Dunbar: X07a (2011-present) PI: Keathley

Silver maple has potential as a SRE Plantation species. Open pollinated silver maple seed was collected in the spring of 2010 from twenty-two seed sources from Michigan, New York, Pennsylvania, Vermont, New Hampshire, Massachusetts, Connecticut, and Ontario. These seed were sown and grown in the tree nursery at MSU's Tree Research Center. Seedlings were lifted and outplanted as 1-0 dormant bareroot seedlings at Dunbar Forest and at the Sandhill property on the main campus. Each planting was a randomized block design with 6 blocks of 4-tree linear plots. Rows are 8' apart and seedlings are 6' apart within the rows.

Height and diameter growth of trees in both plantations are annually measured, and data on timing of spring bud-break as well as dormancy onset was also collected for the northern site in 2012. Initial indications are that this species is well adapted to SRE Plantation culture in Michigan and grows well.

Larch Species and Progeny Trials

MICHCOTIP Larch Species Provenance Trials

MICHCOTIP-85-12 in Brampton (1985-1995) PI: Hanover
MICHCOTIP-85.17 Manton/DNR
MICHCOTIP-85.18 Gwinn/DNR
MICHCOTIP-85.19 Cooks/Mead
MICHCOTIP-85.20 Brampton/Mead

An extensive collection of European, Asian, and North American larch seedlots was assembled by MICHCOTIP. Greenhouse-grown, containerized seedlings were outplanted throughout Michigan in the spring of 1985 at sites that included the five Upper Peninsula sites listed above. A complete set of materials was established by MSU personnel at Brampton and sub-sets of these seedlots were shared with cooperators who established the remaining four trials. FBIC personnel maintained and measured all of the trials for a decade. Eventually the DNR and Mead Paper lost interest in these tests.

European Larch Hybrid Progeny Trial

FBIC: U07n (2006-present) PI: Miller / David

This trial was a cooperative effort between MSU, MeadWestvaco, and the University of Minnesota's Aspen/Larch Cooperative. Partial funding for this third test came from MeadWestvaco. Progeny from 28 full-sib families of European larch (recently created by the University of Minnesota's Aspen Larch Cooperative breeding program) were planted on May 10th, 2006 in a randomized block design in 15 blocks of 2-tree plots on 10' square spacing. The test occupies 2.5 acres.

Eastern Red Cedar Rangewide Progeny Test

FBIC: U08f (1989-present) PI: Hanover

This 2-acre plantation of 100 half-sib seedlots from throughout the eastern United States was established at FBIC in 1989. The plantation is a randomized block design with 4 blocks, 4-tree row plots planted on 8' X 6' spacing. The plantation is one of three established by MICHCOTIP and the USDA Soil Conservation Service to test the genetic variability of this species under a range of conditions. Of principle interest, is the species' adaptability for use in wind and snow breaks. Measurements of this and two other plantings were made in 1993 by MSU and SCS personnel.

Kellogg White Spruce Seed Orchard Progeny Test

FBIC: U08j (1989-present) PI: Hanover

This 2.5-acre test plantation of 170 half-sib families was established in 1992 at FBIC. It is testing parents in a seed orchard at the Bergener Farm (part of the Kellogg Biological Station). Information from this planting will be used to rogue the Kellogg seed orchard to improve the quality of the seed produced there. This is a randomized block design with 3 blocks, 3 single-tree plots per block, established on an 8' X 8' spacing. This plantation was row-thinned in 2015.

Wellston Jack Pine Seed Orchard Progeny Test

FBIC: U08n and U08s (1994-present) PI: Hanover

This is a 1994 test plantation of 124 half-sib Jack pine half- and full-sib seedlots collected from parents in a progeny test near Wellston, MI (MSFG-P-80.21). Data from this planting will guide roguing of MSFG-P-94.01 at Brighton, MI (a seed orchard of this same material). The planting is a randomized block design with 5 blocks (2 are in U08n and 3 are in U08s) with 4 single-tree plots per block. Together this test occupies 3.2 acres. This plantation was row-thinned in 2015.

Advanced-Generation White Spruce Progeny Test of Selected Sources

FBIC: U09a (1989-present) PI: Hanover

Hans Nienstadt of the Forest Service Forestry Sciences Lab in Rhinelander assembled and grew the "best" selections of white spruce from Minnesota, Wisconsin, Michigan, and Ontario tree improvement programs to create this fourth-generation progeny test. The 4-acre plantation of 170 half-sib seedlots was established at FBIC in 1989 and is one of 5 plantings across the northern

Lake States. It is a randomized block design with 4 blocks and 3 single-tree plots per block. After several years of mortality from white grub damage, the plantation was consolidated to half its original size. This 3.3-acre planting will produce improved, locally adapted seed. This plantation was row-thinned in 2015.

1989 Black Locust Progeny Test

FBIC: U08g (1989-1992) PI:Miller

A half-acre test of 40 half-sib families of black locust, selected from a rangewide progeny test in Lower Michigan, was established at FBIC in 1989. Previous work with black locust showed that it could be adapted and grow well in extremely cold areas of Michigan. Placing these trees in the Upper Peninsula was intended to subject them to cold stresses that occur infrequently in Lower Michigan, thus reducing the time required to screen them for their responses. Winter damage to these trees was severe the first year and continued for several years after that. The test was abandoned in 1992.

1992 Black Locust Progeny Test

FBIC: U08l (1992-1995) PI: Miller

Following the failure of the 1989 black locust progeny test, a larger 2-acre test of 160 half-sib families of black locust selected from the same rangewide progeny test in Lower Michigan was established at FBIC in 1992. It was hoped that the families in this new test would show cold tolerance. Winter damage to these trees was severe the first several years and this test was abandoned in 1995. Don’t grow black locust in the U.P.

Christmas Tree Related Projects

White, Blue, & Tri-hybrid Spruce Progeny Test

FBIC: U08c (1998-present) PI: Hanover

This 4-acre plantation was established on May 05, 1988 at FBIC to test half-sib seedlots of Spartan Spruce (interspecies hybrids of white and blue spruce) along with various tri-species-hybrids to screen various crosses for cold tolerance in the U.P. It is a randomized block design with 3 blocks; 141spartan, 44 white, 35 blue, 27 tri-hybrid seedlots; 4-tree row plots; 8x8' spacing. This plantation was row-thinned in 2015.

Douglas-fir Elevation Transect Progeny Test

FBIC: U08k (1992-2014) PI: Hanover

This 1.4-acre planting of 91 half-sib Douglas-fir seedlots (collected along elevational transects within the Lincoln National Forest in New Mexico) was established at FBIC in 1992. The test was designed to examine genetic differences and to screen the seedlots as candidate Christmas tree sources. Seedlings had poor root/shoot ratios when planted and mortality was high during the first year in the field. Subsequent losses to winter injury left so few survivors that the test has been abandoned. Swiss needlecast disease heavily infected this plantation over the years. The surviving trees were finally removed in 2014.

Scotch Pine Shearing Response Uniformity Study

FBIC: U08i (1989-1995) PI: Bloese

The uniformity of seedlings in growth, color, and response to shearing is important to Christmas tree growers. This 1-acre test of 57 scotch pine seedlots was established at FBIC in 1989 to measure and demonstrate variation among closely related seedlings. All seed came from a single plantation or seed orchard. Half this planting has been sheared annually and the other half has been allowed to grow freely. A preliminary assessment of the tree response to shearing was recorded in the fall of 1995. This project has revealed some differences in bud development that have not been reported by other investigators.

Scotch Pine Christmas Tree Variety Demonstration

FBIC: U08q (1994-2004) PI: Koelling

A 3-acre planting of 33 commercial varieties of Scotch pine were planted in 1994 on 6’ X 8’ spacings to simulate a commercial Christmas tree operation. 5 more commercial varieties were added the following year (1995) bringing the total to 38. Each variety was represented by two rows of 34 trees each and is being managed using commercial Christmas tree production techniques. The planting demonstrated the performance potential of these varieties in the Upper Peninsula was a focal point for workshops for local Christmas tree growers. Signs identified the varieties to visitors and a virtual tour of the planting was available on our web site.

True Fir Variety Demonstration

FBIC: U08ae (1995-present) PI: Koelling

A small trial containing “true firs” (*Abies* sp.) was established in 1995. True firs are gaining popularity among Christmas tree purchases and testing them for adaptability in the Upper Peninsula was important. Double rows containing 34 trees each of Nikko fir, Korean fir, balsam fir, and Fraser fir were planted.

Silvicultural Trials

Enhanced Rooting of Section Leuce Poplars Using Endophytes

FBIC: U08bi (2015) PI: Miller / Doty

Dr. Sharon Doty (University of Washington) has observed improved rooting of certain hybrid poplar hardwood cuttings when treated with endophyte mixtures in greenhouse trials. This mixture will be applied to several promising, but recalcitrant hybrid poplar clones in field trials at FBIC to determine if rooting success can be improved.

Poplar Spacing Trial

FBIC: U08ag (2008-present) PI: Miller

Quantifying the relationship between initial planting density, crown architecture, tree growth rate, change in mean annual biomass increment, and financial return on investment is poorly understood for short rotation energy plantations. A preliminary study of seven hybrid poplar

clones planted at three initial spacings was begun at FBIC in 2008. The trees were harvested in the fall of 2014 and biomass yields computed for all study plots. Stumps will be allowed to re-sprout and the second rotation performance will be monitored.

The trial occupies approximately 8 acres. Yield plots are approximately 1/10-acre each and contain varying numbers of trees, depending on the planting spacing. Trees in the center of each plot were measured and sampled, leaving a 2-row border to eliminate edge effects. Plantation density was varied by adjusting the spacing of trees within rows that were 8' apart. Spacings were 8' X 5' (1,089 TPA), 8' X 6' (907 TPA), and 8' X 7' (770 TPA). The planting was arranged in a randomized block design with 5 blocks.

Heterogeneous 6-hybrid poplar Test

FBIC: U08au (2010-present) PI: Miller

SRE Plantations are usually established in mono-clonal units as is often the case in agricultural systems. Multiple clones must be employed to reduce the risk of losing an entire planting, but it is not clear if there might be advantages to using multiple mono-clonal blocks or to using completely heterogeneous mixtures of clones. Inter-tree competition effects and impacts on disease and pest populations are unknown. A random heterogeneous mixture of 6 poplar clones was planted in this 1-acre test to begin to observe the differences that may exist between mono-clonal and heterogeneous plantings.

Poplar Response to Post-Planting Nitrogen Application

Installed in 3 existing poplar yield trials. (2012-2014) PI: Rothstein

Optimal nutrient management in SRE Plantations can have significant effects on the environmental impacts and economic returns from these systems. A preliminary study was begun here using existing poplar yield studies to determine the effects of a single rate of nitrogen fertilizer on a range of poplar clones planted over a range of sites. 100 kg/ha of nitrogen was applied (in the form of urea) to the plots of 5 poplar clones in 2 of the five blocks at each of three poplar yield trials located at FBIC [U08am-2009], Skandia [X01b-2009], and Brimley [X02b-2009

Poplar Response to Time-Release Fertilizer Application

FBIC: U08bh (2015-2016) PI: Miller

Most of the SRE Plantation research projects in Michigan have been conducted without the addition of fertilizer or irrigation. This has provided base-line yield information over a range of sites. This study will be one of the first to explore the impact of fertilizer on poplar growth. Various formulations and rates of a time-release balanced fertilizer will be applied to two poplar hybrids at the time of planting and again in the second growing season. We will follow the growth response of both the poplar and the weeds on the site during the first two growing seasons to determine the effectiveness of these treatments.

Two-stage Aspen Establishment Trial

FBIC: U07q (2008-present) PI: Miller

Aspen is native and well adapted to conditions in Michigan. Hybrids have demonstrated improved growth over native families but can only be initially propagated from seedlings. Aspen seedlings are difficult and expensive to establish so this trial is designed to test the merits of a 2-stage approach. Seedlings of an aspen hybrid (*P. tremuloides* X *tremula*) from the Aspen/Larch Genetics Cooperative (ID code = #XT-Ta-1-01) were planted on 19' centers in 2008 (120 seedlings per acre) in this 1.3-acre test. The trees that grew were cut in the winter of 2011 after 4 growing seasons and sprouts from the established root systems are now re-growing. We will determine whether a well-stocked stand can be produced in this manner.

Populus Alba Field Rooting Trial

FBIC: U07r & s (2009-present) PI: Miller

White poplar and aspen hybrids do not normally reproduce well from hardwood stem cuttings making them more expensive to establish than other poplar hybrids. The *P. alba* hybrid being tested here (McGovern # 83XAA04) showed superior growth in a progeny test [U07m] and demonstrated better-than-average rooting ability in greenhouse trials. Rooted and unrooted cuttings were prepared and 90 of each were planted in 0.16-acre blocks at FBIC on June 19th, 2009. 87% of the rooted cuttings [U07s] and 80% of the un-rooted cuttings [U07r] survived the first year. This is an encouraging result and we will continue to monitor survival and growth of both plantings.

Regenerating Aspen Despite Buckthorn

FBIC: U10a (2001-present) PI: Miller

The woody invasive species "buckthorn" has become established widely throughout the Lake States. Its aggressive ability to occupy sites threatens the regeneration of many native species including quacking aspen. The understory of a mature aspen stand at FBIC was removed with a brush mower and spouts were later treated with glyphosate in an attempt to kill the buckthorn. The overstory was removed later and that aspen allowed to resprout. Plots were established and periodically remeasured to gage the success of these treatment in discouraging the buckthorn and favoring the aspen regeneration. A report was prepared after six years. Although expensive, the treatment was successful in re-establishing the aspen stand.

Red Pine Management

The four red pine thinning & spacing studies described below have been instrumental in the development and updating of the US Forest Service's Red Pine Management Guide. This is the document that forms the basis for red pine management through the US. Data from these trials is unique in this era of computer growth modeling studies. It offers one of the only ways to ground these models in reality.

1953 Red Pine Thinning Study

Red pine management research began at the Dunbar Forest shortly after the station was established in 1925. In 1953, six thinning treatments were imposed on a red pine plantation that was originally planted in 1927 at Dunbar forest. These treatments were based on a thinning system known as the “Percent-of-Height” thinning method. Trees were thinned to provide growing space equivalent to 16, 18, 20, 22, and 24% of the total height of the trees. An unthinned control treatment was also begun. Measurements were taken and the planting was re-thinned in 1956, 1959, 1962, 1965, 1968, 1971, 1981, 1992, and 2002. Today this trial continues and provides a location for classroom instruction and demonstration of red pine management alternatives. These trees now are among the largest at the Dunbar Forest, and certainly the most impressive.

1962 Red Pine Thinning

Thinning plots were established in a 1938 plantation of red pine near Trout Lake on the Hiawatha National Forest in 1962. 16 thinning treatments were chosen for this test. Measurements were taken and the planting was re-thinned in 1965, 1969, 1976, 1982, 1992, and 2002.

1968 Red Pine Spacing Trial

Spacing trials differ from thinning trials in that spacing is set at the time of planting and then trees are allowed to grow for a period of time without thinning. Thinning trials establish a desired spacing or basal area and are repeatedly thinned to retain that goal over the life of the plantation.

A 1962 plantation of red pine near Pickford, MI on the Lake Superior State Forest (in an area known as "Rockview") was chosen for a spacing trial in 1968. The trees had not yet closed their canopy, so inter-tree competition had not yet begun. Five densities (between 220 trees and 820 trees per acre) were established as treatments. Tenth-acre plots were established of each treatment in a randomized block design with 4 blocks. Diameter and height were measured in 1986 and 1996 and a paper was prepared that summarized the results after 34 years of growth. Plots were measured again in 2006.

1971 Red Pine Spacing Trial

A plantation of red pine immediately adjacent to the one described above was planted at six densities in 1971. Diameter and height were measured in 1996. Trees were planted at six densities (363 to 726 trees per acre) in tenth-acre plots arranged in a randomized block with 4 blocks. This plantation was measured in 1996 and results were included in the same report mentioned above. It was also measured again in 2006.

White Pine Spacing Study

FBIC: U09e (1998-present) PI: McCollough

White pine is a valuable saw timber species in Michigan but its value can be significantly reduced if trees do not recover quickly from attacks by the white pine weevil. This insect kills the terminal leader which causes a lateral branch to bend upwards to become the new leader – leaving a crook in the stem. White pine was planted here at three spacings (6’x6’ [1210 TPA], 7’x7’ [890 TPA], and 8’x8’ [680 TPA]) to see if higher densities would force more rapid recovery

from weevil attack. This 30-acre plantation is composed of 1.6-acre plots arranged in a randomized block design with 4 blocks.

White pine also suffers from a killing disease; white pine blister rust. The USFS has a seed orchard of white pine near Oconto, WI that they consider to have resistance to this disease. We planted each plot so that 25% of the trees along one side were from this seed source while the remaining trees were nursery-run Michigan seed sources.

Unfortunately, there has been no outbreak of either white pine weevil or white pine blister rust in this plantation since its establishment. Good for the trees, but bad for the entomologists and pathologists. The entire plantation was row-thinned during the winter of 2014 and continues to be monitored.

Upland Hardwood Regeneration in Pastured Woodlots

FBIC: U06b (1992- 2014) PI: Miller

Many woodlots in the Upper Peninsula of Michigan have been pastured or are in areas with extremely high deer populations. Regeneration of hardwoods on these sites has been difficult, and sometimes impossible due to the intense competition from pasture vegetation and over browsing. A study was initiated in 1992 in a 25-acre upland hardwood woodlot at FBIC to quantify the impacts of deer browsing and sod competition on hardwood regeneration after a cutting. Following a thinning to a residual basal area of 60 sq. ft, the stand was subdivided into three sod control treatments (herbicide, mechanical, and control). Half the area was fenced with electric deer exclosures. The result was a split-plot randomized block design with three blocks. Seedling establishment and growth will be monitored over time.

Windbreak Species Effectiveness Trial

FBIC: U07d (1991-1993) PI: Miller

A study was established at FBIC in the spring of 1991, in cooperation with the USDA Soil Conservation Service, to test various windbreak shrub species for adaptability to Upper Peninsula weather conditions. The open land at FBIC mandates some type of windbreaks to reduce snow accumulations, and this project offered benefits to both the research and demonstration mission of FBIC and to the physical plant needs.

Thirteen species of shrubs and four species of trees were selected based on their efficacy in windbreaks in other regions. Five replications of 5-tree row plots were planted in 1991. Deer browsing became a severe problem during the first growing season. Protective netting was placed over all seedlings but most species never recovered from the initial browsing. The browse damage was compounded by a high white grub population in the area. Together both reduced the vigor of the test trees to the extent that the project had to be abandoned.

Tree Shelter Effects on Cedar Growth

FBIC: U08v (1990-present) PI: Miller

Several tree species have been shown to exhibit greater survival and early growth when planted in plastic tube tree shelters (see Red Oak Tree Shelter Study above). A preliminary study was

conducted during the summer of 1989 that led to the establishment, in 1990, of a tree shelter test for northern white-cedar on three sites. One hundred trees were planted on each of two sites: one at FBIC and the other on state land. Each site has 50 trees in 4' Tubex shelters and 50 unsheltered trees. Another group of 25 trees were planted nearby inside an 8'-tall woven wire fence. All the trees that were not inside the woven wire fence have perished and those that remain provide a vivid example of what must be done to regenerate cedar.

Tree Shelter Effects on Red Oak Regeneration

FBIC: U09b (1990-1997) PI: Lantagne

Red oak is a valuable species for both timber and wildlife. Its presence in U.P. hardwood stands has diminished with harvesting. Overcoming regeneration problems of this valuable species is important for the region. A test was established at FBIC to determine the effects of tree shelters on red oak. No differences in survival were seen during the first growing season, but trees in shelters grew 60% taller than those without shelters but tree damage became apparent after that. 2nd, 4th, and 6th-year growing season data were summarized. One clear conclusion has been that Tubex tubes, when installed according to 1990 manufacturer's recommendations, caused excessive winter injury to red oak after the first growing season. Also clear is that the netting installed to prevent blue bird death, as recommended by the manufacturer, caused severe terminal deformity. A summary of results from the test appears on our web site.

Red Pine Seedling Type/Planting Time Trial

FBIC: U09i (1990-1992) PI: Miller

Questions remain about which type of seedling (bare root or container grown) is the best to use, and whether spring or fall planting produces better survival. A test was begun at FBIC in cooperation with the Michigan DNR and Mead Corporation in 1990 to examine these questions.

The original plan called for five types of red pine seedlings to be planted during both the spring and fall of each of three successive years, beginning in 1990. By the fall of 1991, after half the test had been planted, the white grub population on the test site had increased and killed more than 80% of the trees. Mead Corp. and the MDNR both experienced similar problems. An insect census of this site during the spring of 1992 found an excess of 1.3 grubs per cubic foot of soil (0.5 is considered high). The project was abandoned as a result.

Herbicide Trials

Triploid Aspen Herbicide Sensitivity Trial

FBIC U08u (1990-1991) PI: Schultz

Regenerating genetically improved aspen is a difficult task that involves extensive site preparation and tending. A study was initiated in 1990 to test the sensitivity of 570 triploid, hybrid aspen seedlings planted into areas treated with common site preparation herbicides (Arsenol, Oust, and Accord plus Oust). There were three planting sites in the Upper Peninsula, two on Mead Corp. land and one at FBIC. Each planting was a split-plot randomized block design with two main plot treatments (mechanical scarification and no scarification) and four

split-plot treatments (three herbicide treatments and one control). The herbicides were reapplied in 1991 and final survival and growth was measured at the end of that growing season. First-year data, summarized in Paul Schultz's thesis, showed triploid aspen to be severely damaged by Arsenol but benefited by Oust plus Accord.

Herbicide Sensitivity Trial for Fiber Farm Species

FBIC: U07c (1998) PI: Miller

Controlling weed competition in Fiber Farming systems is both critical for success and difficult. The crop species grown in these plantations tend to be sensitive to most commercial herbicides and often require repeated, expensive mechanical cultivation to exclude weeds. Six herbicides were tested on poplars, aspen, and larch in 1998 at FBIC. Crop tolerance to these chemicals was determined at various application rates and at different growth stages. This test established that Clopyralid, imazaquin, sethoxydim, and fluazifop can all be safely applied to newly planted, actively growing poplars, aspens, and larches in Upper Michigan. None of these herbicides had adverse effects on the survival or the growth of the crop trees at the end of the first growing season in the field. Prodiamine is not suitable for use as a pre-emergence herbicide in first-year hybrid poplar plantations. Three quarters of all poplar cuttings treated with this chemical died and those that survived grew poorly in relation to mechanically weeded control cuttings. Unrooted cuttings of hybrid poplar treated with oxyfluorfen survived and grew as well as mechanically weeded trees in Upper Michigan.

Pendulum & Scepter Herbicide Trial for Hybrid Poplar

FBIC: U08t (1999-2000) PI: Miller

An integral part of any short rotation woody crop production system is the exclusion of weeds from the developing trees. A two-year test of imazaquin and pendimethalin was established in the spring of 1999 in a plantation of two hybrid poplar clones. The study will determine the effects of these two herbicides when applied at various rates on tree growth and weed control. Results from this test will be directly applied to our Fiber Farming demonstration area. This work is partially supported by BASF/American Cyanamid. A second, identical, study was established in East Lansing in 1999 to compliment this test.

Herbicide Effectiveness Trial for Willow Hybrids

FBIC: U07p (2007) PI: Miller

This .14-acre plantation was established on May 30, 2007. 10 treatments consisting of a control with no weed control, another control with mechanical control to keep the cuttings weed free, and 4 herbicides at two different rates each. Simazine, Goal, Pendulum, and Sceptor were all used at a single dose and at a double dosage to test their effect on weed control and willow cutting performance. Three different willow taxa were used (SX67, SX61, and SV1).

Goal, Simazine, & Solicam Herbicide Effectiveness on Willow

FBIC: U08ai (2008) PI: Miller

This .2-acre plantation was established on May 28, 2008 at FBIC to evaluate the effect of Goal, Simazine, and Solicam at various levels on two hybrid willows (Tully Champion & Sherburne). Herbicide treatments were compared with mechanical weed control and with no weed control treatments.

Multi-site Sureguard & Solicam Herbicide Trial on Willow

FBIC: U08an & U08ap (2009) PI: Miller
Skandia: X01d (2009)

0.3-acre plantations were established in June of 2009 at FBIC and Skandia to test the effectiveness and safety of several Sureguard and Solicam treatments and controls on 3 willow clones (Fish Creek, Tully Champion, and Sherburne). Rates include 1X, 2X, 3X, and 4X the labeled rate. Mechanically weeded and untreated controls were also included. The test was designed as a split-plot randomized block design with 3 blocks, 10 main plots, 3 sub-plots, and 10-tree plots.

Comprehensive Herbicide Trial on Willow Hybrids

FBIC: U08ar (2010) PI: Miller

This 2-acre plantation was established on June 16, 2010 to test 30 herbicide treatments on 7 willow clones. Various rates of 8 pre-emergence and 5 post-emergence herbicides were compared to mechanically weeded and unweeded controls. The herbicides tested included: Goal 2XL, Galigan 2E, Princep 4L, Prowl H2O, Dual Magnum, Solicam DF, Chateau, Karmex, Stinger, Fusilade DX, Poast, Assure II, and Permit. Willow clones tested included SV1, SX61, SX64, Fish Creek, Tully Champion, Millbrook, and Sherburne. The test was designed as a split-plot randomized block design with 4 blocks containing 30 main plots, and 7 sub-plots of 6-tree plots.

Herbicide Effects on Spruce Survival Under Drought Conditions

FBIC: U08c (1988) PI: Miller

A plantation of spruce transplants was established at FBIC in the spring of 1988. A severe drought followed planting. The inadvertent lack of weed control in two rows of this plantation provided data that shows the profound effect of weed control under stress conditions. Average survival with good weed control was 98% but only 24% where no weed control was applied. A report of these results was prepared and distributed.

White-Cedar Research

Enhancing Cedar Regeneration By pH Adjustment

FBIC: (1987-1990) PI: Miller

Germination of northern white-cedar has been shown to improve as pH increases from 5.0 to 8.0 under laboratory conditions. In 1987 the DNR in Escanaba applied lime to some test plots in a harvested cedar stand to determine the effects on regeneration. Lime was applied at 0, 1, 1.5, and 2 tons per acre. Seed germination data from these plots was analyzed by FBIC personnel. Initially, seedlings were more abundant in heavily limed plots than the un-limed control plots, but the reverse was true after only three years.

A second liming study was begun by FBIC personnel in 1989 on a scarified swamp site to repeat the DNR experiment under more controlled conditions. Lime was applied at 0, 1, 2, and 4 tons-per-acre in a randomized block design. pH measurements were taken on the site in the spring (just before lime was applied) and again in the fall (3 months after liming). Liming did not increase the pH in any plot and in fact, the pH decreased for all treatments during the year.

A third liming investigation was begun on these same plots in 1990, to better understand what was happening on this site. This time lime was applied at rates of 0, 3, 6, and 9 tons-per-acre. pH levels were determined before lime application in the spring and at three additional times throughout the growing season. Similar pH series were also measured at four other swamp sites in the area. Liming did not affect pH in the first growing season although it was applied at exceptionally high rates. pH also varied over the growing season at all sites.

We have concluded from this work that the buffering capacity of these organic soils prevents us from economically changing their pH with lime. We also learned that pH varies within a site and throughout the growing season. This means that many soil samples must be taken to describe surface pH accurately on these sites.

Fencing Effects on Regenerating Northern White-Cedar Stands

FBIC (1990-present) PI: Miller

Animal damage to young northern white-cedar is believed to be one principle deterrent to the successful regeneration of the species. Guidelines were developed for erecting deer exclosure fences for research plots under the auspices of the CEDAR Action Group. The CEDAR Action Group is a committee of 40 resource managers, land owners, and sportsmen formed to coordinate cedar management, information, and research. This group is coordinated through FBIC. Fences that conform to these guidelines are being built by members of the committee in several Delta County locations and in northern Lower Michigan. A network of exclosures over a wide range of sites will eventually exist, in which the effects of deer browsing on wetland forest regeneration can be quantified.

One design involves enclosing an area of at least 3,800 sq. ft. with a woven wire fence that is 8’

tall. This design is statistically acceptable for monitoring the development of sapling size trees. Three sites in Delta County were fenced and are monitored by FBIC staff using this design.

Another design was developed for monitoring seedling regeneration only. Because seedling studies can be done in small plots, these fences are small, cheap, and easily built. The seedling plot fence design includes a 10' circle of 5' tall woven wire held in place by "t" posts. The DNR has been installing fences like this for several years. FBIC personnel installed 33 of these fences during the summer of 1995 in small clearcuts in cedar stands throughout the central U.P. (see Cedar Stand Origin Study below).

Individual Tree Shelter Effects on Cedar Growth

FBIC (1990-present) PI: Miller

Several tree species have been shown to exhibit greater survival and early growth when planted in plastic tube tree shelters (see Red Oak Tree Shelter Study above). A preliminary study was conducted during the summer of 1989 that led to the establishment, in 1990, of a tree shelter test for northern white-cedar on three sites. One hundred trees were planted on each of two sites: one at FBIC and the other on state land. Each site has 50 trees in 4' Tubex shelters and 50 unsheltered trees. Another group of 25 trees were planted nearby inside an 8'-tall woven wire fence.

At FBIC, seedlings in tubes grew 30% taller than those outside the tubes during the first growing season but survival was unaffected. Since then, the unprotected trees have been browsed and those in the tubes have had winter injury. The result is that the trees in nearby fences are now nearly 40% taller than those in the tubes. All trees on the FBIC site, except those in the fence, have not increased in height since the first growing season.

Strip Clearcut Regeneration Study

FBIC (1994) PI: Pregitzer / Miller

Many cedar stands fail to regenerate following standard prescriptions for strip cutting. Three successfully regenerated strip cuts were examined during the summer of 1994 to determine the sequence of their regeneration. Each strip was sampled across and along its axis with nine plots. Ages of all stems greater than 1 foot tall were determined. Height growth of all stems greater than 6.5 foot tall was also studied.

Each strip had individual trees that had regenerated at the time of the cutting and so were as old as the cutting itself (approx. 30 years). However, most of the individuals regenerated after the cutting so the young stands are all-aged. The oldest individuals in the stands are dominant in height.

This work shows that strip cuts in cedar stands require extended periods to become fully stocked. It also shows the futility of one-time direct-seedlings in cedar cuts as an artificial regeneration technique. A summary of this work appears in Forest Ecology and Management.

Cedar Ecology and Hydrology Research Area

FBIC (1993-1994) PI: Miller

A 1,100 acre area at FBIC has been identified as a wetland watershed. The site is bounded by uplands and drains through an identifiable stream channel. This site offers a particularly unique opportunity to monitor, study, and describe the dynamics of these cedar swamps over a long period. A great deal of time has been spent in providing access and defining this area. Nearly 3 miles of old logging trails have been reopened for winter access. Twenty monitor wells have been established throughout the site including a stream monitoring station on Portage Creek. A baseline survey has been conducted to establish horizontal and vertical reference points throughout the site.

Snowpack Monitoring in an FBIC Swamp: The depth and water equivalent of the snowpack in the cedar research area described above was monitored throughout the winter of 1992-1993. Four samples at each of 20 monitoring points were sampled with an 8" snow corer designed at FBIC. Snow depths and densities varied wildly even among closely spaced sites with similar overstory conditions. Recommendations for future sampling in this swamp have been drawn from the experience of this preliminary study.

Cedar Stand Origin Study

FBIC (1993-1995) PI: Pregizer / Miller

As current management of cedar fails to reliably regenerate cutover stands, our most recent research approach to the problem focuses on describing how mature cedar forests in the U.P. became established in the first place. By discovering how these older forests got started (e.g., by fire or windstorm), and by examining their development over time, we can better "imitate" nature when we try to create our own new cedar forests. Our study involved a detailed examination of tree rings from over one thousand trees from swamps in the region. By examining these rings and trees we can piece together the age of the stand and how it developed and grew over the last 300 years or so. A summary of this work appears in the Canadian Journal of Forest Research.

Patch-Clearcut Regeneration Study

FBIC (1993-1995) PI: Pregitzer / Miller

The cedar stand origin study (above) has provided a set of thirty-three 1/40th-acre clearcut patches (37’ diameter) in 11 different cedar swamps throughout the central U.P. With the DNR and USFS we have constructed small (10’ diameter x 5’ tall) wire deer exclosures and installed a groundwater monitor well in each of these plots. This network of plots is the most extensive sample of cedar sites in Michigan. It will be monitored over the next ten years to determine the effects of various factors on the regeneration of cedar at these sites.

Seed Shelter Study

FBIC (1993-1996) PI: Miller

Scattering cedar seed into cut-over areas has long been done to increase the number of cedar seedlings. Some recent evidence shows that regeneration of clearcut strips can take from four to 30 consecutive seed years. This means that most of the tens of thousands of seeds that fall on the ground each year in cedar stands must fail to germinate or must dry out and perish. If managers

are going to spend money sowing seed, it makes sense to give these seeds a better chance at survival than their "wild" counterparts.

Small seed shelters are commercially available and used for other species like spruces and pines in Canada. We successfully tested three shelters recently using cedar seeds on bucket-mounded sites. Nearly twice as many cedar seeds germinated and grew in the least expensive of these shelters than in unsheltered control plots. These shelters are compressed peat pots, like those used in gardening, with their bottoms removed. They only cost two cents each and may be well worth the cost.

Cedar Microsite Hydrology Study

FBIC (1993-1995) PI: Hart

We often think about cedar as a swamp species that prefers wet soils, but this study shows that cedar seedlings can only survive when they are growing above the high water level. Other species like balsam fir and tag alder occupy sites where the water is too high for cedar.

A 30-year-old strip cut in a cedar swamp at FBIC was studied. Cedar regeneration was abundant at one end of this 600-foot-long strip and absent at the other. This disparity in regeneration could not be explained by differential animal pressure or other gross site features. Cedar seedlings were found only on mounds (or hummocks) that protruded above the seasonal high water table at the site. The number of cedar seedlings was strongly correlated with the number of mounds.

It is postulated that drainage changes at this site (due to road and railroad grade building) changed the water table enough to submerge the suitable mounds at one end of this strip. This effect has wide-spread implications for cedar stands in the U.P. Surveying the number of available "micro-sites" before making any regeneration cuts in cedar stands is advisable. A summary of this work appears in the Canadian Journal of Forest Research.

Swamp Scarification Study

FBIC (1986-present) PI: Miller

Two cut-over cedar swamps in Delta County were treated with a roto-tiller-like machine called the "American Ranger" in 1988. These sites have regenerated almost completely to sedges and cattails following this scarification. We now know that these former cedar stands can no longer support cedar seedlings because they are too wet. The treatment eliminated all the high spots so that the whole area was submerged in the spring. This work and the study mentioned above lead us to conclude that successful cedar regeneration will depend on increasing the number of dry microsites using a technique like "bucket mounding" or by lowering the water table.

Bob's Lake Study

FBIC (1993-1995) PI: Miller

An in-depth review of Thomas Nelson's 1939 work in a cedar swamp near Bob's Lake (Marquette County) was conducted and summarized by Rod Chimner, Mike Zuidema, and Ray Miller. We reviewed the conclusions Nelson made in 1951 (inadequate cedar regeneration was taking place on the site and cedar that did regenerate was being removed entirely by browsing deer) and found the same situation now. Stem analysis of the stand showed that cedar had been regenerating on this site from 1761 through about 1925 but that no cedar had regenerated during the last 70 years. We were surprised to find cedar of many ages on this site. This means that the trees regenerated over a long time (200 years or more) rather than all at once after a large disturbance. Cedar stopped regenerating at Bob's Lake soon after the adjacent upland areas were logged. The remaining trees in the swamp began to grow faster after upland logging.

Jamestown Slough Case Study

FBIC (1993) PI: Miller

This minor study was conducted to provide information and materials about a cedar stand in Manistique for use in an outdoor education facility being developed for school children. A set of basal disks was removed from all trees in a transect through the stand. These disks were sanded and their ages were determined at FBIC. A summary of the stand's species and age structure was prepared and returned with the disks to the Manistique facility for use by the school children. This project provides an additional data point to the study of cedar stand age structures described earlier. Cedar here ranged in age from 130 years-old to 55 years-old.

Biomass Production Plantations

Plantations of poplar and willow have periodically been established at FBIC to provide future locations for research and demonstration of the management systems being investigated in other designed studies. These production blocks are established whenever planting stock, space, funds, and time are available. This is done to provide options for future research that cannot be foreseen. At this writing there are 20 acres of these production blocks at FBIC.

Poplar

2011 "NM6" Poplar Production Block (U09p)
This is a 2.8-acre block of NM6 poplar established on June 14th, 2011 with 8' between the rows and 4' between trees within the rows (~1,400 trees per acre).

2011 High Density "NM6" Poplar Production Block (U08aw)
This is a 0.25-acre plantation of NM6 planted at 5,800 cuttings per acre (using the ESF double-row design).

2012 "NM6" Poplar Production Block (U09r)
This is a 3.7-acre block of NM6 poplar established on May 1st, 2012 with 8' between the rows and 4' between trees within the rows (~1,400 trees per acre).

Mixed Poplar and Willow

2009 High Density Willow & Poplar Production Block (U08aq)
Extra cuttings of 13 poplar clones (0.1-acres) and 20 willow clones (0.7-acres) were planted on July 16th, 2009 using the ESF double-row spacing (5,808 stools/acre).

2010 Mixed Poplar Production Block (U08bb)
Cuttings of 1 willow clone and 13 known and mapped poplar clones left over from other tests were established here in row pairs using the ESF double-row spacing (5,808 stools/acre). Cuttings of each clone were planted contiguously within rows.

Willow

2010 "Tully Champion" Willow Production Block (U07t)
This is a 2.6-acre block of Tully Champion willow from ESF. It is planted using the ESF standard double-row spacing (5,808 stools/acre).

2010 Mixed willow Production Block (U08av)
This 1.4-acre willow production planting was established on July 14th, 2010 at FBIC. Planted leftover hardwood cuttings of willow from the 2010 planting season using the ESF double-row design (5,808 cuttings per acre). 8 willow clones are planted in 30-rowpairs that are about 300-ft long. 1.4-acres (225-ft EW by 264-ft NS) ESF standard double row spacing for production demonstration

2010 Mixed Willow Production Block (U08ba)
This planting occupies 0.4 acres and contains cuttings of 13 willow clones left over from other tests. They are established here in row pairs using the ESF double-row spacing. Cuttings of each clone were planted contiguously within rows.

2011 "Fabius" Willow Production Block (U09q) – abandoned.
This is a 3.2-acre block of a single willow clone (Fabius) from ESF. It is planted using the ESF standard double-row spacing but excess mortality forced (due to weed competition and deer browsing) us to abandon it.

2012 "Millbrook" Willow Production Block (U08bf)
This 0.25-acre block of a single willow clone (Millbrook) from ESF. It is planted using the ESF standard double-row spacing.

2012 "Millbrook" Willow Production Block (U09s)
This is a 3.5-acre block of a single willow clone (Millbrook) from ESF. It is planted using the ESF standard double-row spacing.

Statewide Wood Energy Team

(2015-2018) PI: Miller / Potter-Witter / Gasteyer

Increasing the use of Michigan's wood resources can contribute to a more secure and renewable energy future and improve our rural economies. This increase must be integrated into the existing agriculture and forestry sectors of our economy. This $385,000 joint project with majority funding from the US Forest Service and Michigan's DNR will form a *"Statewide Wood Energy Team for Michigan"* that will strive to increase the level of comfort that Michigan communities and stakeholders have with wood energy systems. In this way we hope to overcome the existing reluctance to adopt these technologies. This in turn will expand markets for low-value wood and lead to expanded opportunities for forest management and for sustaining rural economies. We will seek to integrate these new markets with existing forest products industry supply chains. Throughout, we intend to support systems that are environmentally, economically, and socially sustainable and beneficial.

Specifically this project seeks to:

1. Assess woody biomass supplies, energy infrastructure, and community readiness,
2. Develop the resources needed to raise awareness and reduce anxiety surrounding the use of wood energy in Michigan,
3. Engage stakeholders in discussions that address concerns that presently limit the expansion of this energy source, and
4. Support the installation of one or more demonstration wood energy systems in Michigan that produce heat, power, combined heat and power (CHP), and/or district heating and cooling at the institutional or small community scale.

Forest Biomass Statewide Collaboration Center

(2009-2011) PI: Miller / Shonnard / LaCourt

The FBSCC was formed as a $1.6 million project funded by the US Department of Energy. A team composed of scientists from Michigan State University (MSU) and Michigan Technological University (MTU) assembled to better understand, document, and improve systems for using forest-based biomass feedstocks in the production of energy products within Michigan. Work was funded by a grant from the U.S. Department of Energy (DOE) and administered by the Michigan Economic Development Corporation (MEDC). The project began in March of 2009 and concluded in September of 2011.

The goal of the project was to improve the forest feedstock supply infrastructure to sustainably provide woody biomass for biofuel production in Michigan over the long-term. Work was divided into four broad areas:

- TASK A: Develop a Forest-Based Biomass Assessment for Michigan – Define forest-based feedstock inventory, availability, and the potential of forest-based feedstock to support state and federal renewable energy goals while maintaining current uses.

- TASK B: Improve Harvesting, Processing and Transportation Systems – Identify and develop cost, energy, and carbon efficient harvesting, processing and transportation systems.
- TASK C: Improve Forest Feedstock Productivity and Sustainability – Identify and develop sustainable feedstock production systems through the establishment and monitoring of a statewide network of field trials in forests and energy plantations.
- TASK D: Engage Stakeholders – Increase understanding of forest biomass production systems for biofuels by a broad range of stakeholders.

These primary tasks were divided into sub-tasks, each led by a Principle Investigator from one of the two universities. Coordination among the nineteen sub-tasks was provided by a Steering Committee composed of Dr. Donna LaCourt (MEDC), Dr. David Shonnard (MTU), and Dr. Raymond Miller (MSU). Quarterly progress reports have been submitted every three months through MEDC to DOE since July, 2010. A comprehensive understanding of the entire project is obtained when this report is combined with the companion report simultaneously generated by MTU scientists.

Feedstock Supply Chain Center of Energy Excellence

(2009-2012) PI: Miller / Shonnard / LaCourt

The Feedstock Supply Chain Center of Energy Excellence was a Michigan-funded project with a narrow focus: to examine the forest-to-gate processes for a biofuel refinery planned by Frontier Renewable Resources in Kinross, Michigan. The research focuses on the area within a 150-mile radius of Kinross and on the supply of pulpwood logs, which will be the principle feedstock for this refinery. This project was geared towards determining the biomass needs and supply chain improvements for this facility, owned by the company Frontier Renewable Resources. Collaborators for this research include Michigan State University, Michigan Technological University, the Michigan Economic Development Corporation, and Frontier Renewable Resources. There were eight separate sub-projects and numerous collaborators in this $2 million project.