Powell River Project Report 2012

Economic Viability of Woody Bioenergy Crops as a Potential Mine Reclamation Procedure

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Abstract: Planting woody biomass for energy production can be used as a mine reclamation procedure to satisfy the SMCRA and provide renewable energy for the United States. This study examines the productivity of woody biomass on previously mined lands using four species planted at two densities; one-half of the trees were fertilized in year two. This report summarizes the current and predicted volume of these species as well as the effect of planting density and fertilizer application. After four years, black locust has the highest volume of any treatment with the other species an order of magnitude behind. Black locust and sycamore trees have reached a point where it is clear that planting at lower density can increase per tree biomass. Future projections indicate planting at low density with fertilization will produce the greatest amount of biomass per tree.

Introduction and Justification of the Problem

Each year thousands of acres of Appalachian forests are mined for the coal that lies beneath them. Once mining is complete, this land is generally replanted as either forest or pasture. This research aims to determine if woody bioenergy crop production is a land use option that will provide positive economic benefits to land owners and environmental benefits to society while decreasing consumption of fossil fuels for electricity generation in Appalachia. A secondary goal for this research is to explore any incentives that exist to reclaim abandoned mine lands through bioenergy production while also determining if policy changes and financial incentives are necessary to encourage growth of bioenergy crops on these lands.

The Surface Mining Control and Reclamation Act (SMCRA) of 1977 requires all surface-mined lands to be restored at a minimum to "a condition capable of supporting the uses which it was capable of supporting prior to any mining, or higher or better uses of which there is reasonable likelihood (§515.b.2. 1265) (30U.S.C. 1977)." When a mine operator applies for a permit to extract coal from a parcel of land, they are required to submit a plan on how they intend to follow regulations of restoring the land to a usable state. Mine operators are also required to secure performance bonds for the duration of their operations and reclamation for an amount that would cover the completion of the reclamation plan outlined if the work had to be performed by a regulatory authority in the event of default (§509.a. 1295) (30U.S.C. 1977). The bonds are released once there has been established on "lands affected, a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area of land to be affected and capable of self-regeneration and plant succession at least equal in extent of cover to the natural vegetation of the area; except, that introduced species may be used in the revegetation process where desirable and necessary to achieve the approved post mining land use plan (§515.b.19 1269)(30U.S.C. 1977)". The quicker the mine operators are able to prove revegetation has occurred, the quicker they are able to retrieve their money tied up in performance bonds.

According to the Energy Information Administration (EIA) approximately 50% of electricity in the U.S. is generated by coal (DOE 2011). A small percentage of this could be replaced with biomass, utilizing existing infrastructure and potentially decreasing overall energy costs. The Annual Energy Outlook 2011 predicts "electricity generation from renewable sources grows by 72 percent [by 2035]…most of the growth in renewable electricity generation in the power sector consists of generation from wind and biomass facilities…Generation from biomass comes from both dedicated biomass plants and co-firing in coal plants. Its growth is driven by State RPS programs, the availability of low-cost feed stocks, and the federal renewable fuel standard, which results in significant cogeneration of electricity at plants producing biofuels" (DOE 2011). To provide a portion of the required amount of biomass to meet our growing energy demands, trees can be grown on reclaimed mine lands. By using mined lands to produce biomass, agriculture lands are not displaced and otherwise unproductive land becomes productive.

Potential economic benefits of cofiring biomass with coal include (1) it can be less expensive than alternative renewable energies, (2) increased customer base when they would prefer to purchase "green" power over fossil fuels, and (3) utilizing a waste that would otherwise incur a disposal cost (when scrap wood materials are used) (Hughes 2000). Biomass has an advantage over other renewable energy technologies in that it is 100% domestically produced, creating local jobs in a variety of industries. An additional benefit of using biomass from trees grown on reclaimed mines is the transportation system from the mine to the coal plant is already established. Often a coal plant will be in close proximity to a mine site; by cutting down on transportation costs, the cost of utilizing biomass for energy generation is reduced.

Replacing fossil fuels with renewable technologies can be good for the environment as well as the economy. A majority of biomass fuels pollute less than burning coal. "Biomass has virtually no sulfur (often less than 1/100 that of coal), low nitrogen (less than 1/5 that in coal), and low-ash content" (Hughes 2000). The majority of the world's carbon emissions come from generating electricity from coal. Burning wood instead of coal therefore greatly reduces the total amount of carbon emitted into the environment.

There are also environmental benefits on the front-end associated with planting trees on reclaimed mine sites and utilizing the biomass for energy production. Benefits include decreased runoff and erosion, nutrient retention and increased carbon sequestration (Brinks, Lhotka et al. (2011). Reforesting mine sites provides benefits to the ecosystem that the alternative reclamation, hayland/pasture, does not. In addition to hydrologic and soil benefits, forested areas can also provide habitat for native plants and animals (Zipper, Burger et al. 2011). As biomass increases market share and influences agriculture planting decisions, plant technology could progress to the point where faster-growing plants are continually replanted, resulting in a decrease in total emissions. In this case, carbon would be captured faster than it is emitted during burning biomass. "Demand for woody biomass to support renewable energy production could change sector dynamics by providing an additional revenue source, engendering new technology, fostering alternative harvesting and procurement strategies, and improving job security (John, Scott et al. 2011)."

Dominion Resources has invested in biomass power plants across the southwestern region. The Virginia City Hybrid Energy Center (VCHEC) began commercial operation in July 2012 after four years of construction. This facility peaks at 585-megawatts, enough electricity to power up 146,000 homes and uses up to 20% biomass. This will require an estimated 537,000 tons/year of biomass (Dominion 2012). Dominion was permitted to begin converting three 63 MW power plants to be 100% biomass-run fuel stations. These power stations will add an estimated 153 MW of biomass-only electricity to the Virginia grid by the end of 2013 (Dominion 2012). Dominion Resources also owns the largest biomass-only plant on the East Coast; an 83 MW plant in Hurt, VA.

The Pittsylvania power plant utilizes approximately 150 truckloads of wood waste every day, estimated at 3,300 tons (Dominion 2012). With these power plants online there is demand for biomass in the region; this study attempts to determine if it is economically feasible to use reclaimed mine lands planted with biomass to meet this demand.

There has been research conducted on growing woody biomass for energy production (DOE 2011) and on the economics of various reclamation procedures for mine lands (Baker 2008; Sullivan and Amacher 2009). Studies regarding the feasibility of using woody biomass as a reclamation procedure for active mine sites or as a viable option for reclamation of abandoned mine sites are limited (Brunner 2009; Brinks, Lhotka et al. 2011; Zipper, Evans et al. 2011). The economic viability of mine reclamation with woody biomass for energy production has also not been examined. This research aims to fill those gaps.

Objectives

The primary objectives of this study are to:

1. Investigate the production potential of biomass on mine sites
2. Use growth, yield and cost information to determine the economic viability of wood-based bioenergy as a potential post-mine land use
3. Identify policy barriers and incentives currently available for growing woody biomass for energy generation on mine lands and determine regulation changes that would make biomass an economically viable option
    a. At both the federal and state level
    b. For reclaiming abandoned mine lands

Methods

In spring of 2008, three experimental plots were set up in the coal fields of Wise County, Virginia on the Powell River Project for testing different tree species and treatments for growing biomass on reclaimed mine lands (Figure 1). After mining, all three sites had been reclaimed with grasses and woody shrubs. The coal companies achieved bond release, although the lands were left without potential to return to forest. To prepare the experiment for planting the land was ripped, creating furrows spaced approximately three meters apart. Five tree species (hybrid poplar, American sycamore, black locust, and northern red oak coupled with eastern cottonwood) along with a control group of mixed hardwoods (black cherry, oaks, sugar maple, American sycamore, black locust, ash species, and dogwoods) were planted. Each species was planted on each of the three sites at two different planting densities – high (3400 trees ha-1), and low (860 trees ha-1). The plots were further split so that each species at both densities received one of two treatments, either fertilization or no fertilization (no fertilization was applied to the mixed hardwood control group) (Zipper, Evans et al. 2011).

Tree growth for each species has been measured at either the beginning or end of every growing season since the sites were established. Height measurements were taken using calipers and a metric Philly rod. Height was determined as the height to the highest live bud; ground line diameter (GLD-basal diameter) was also measured. Measurements were recorded for each tree within the plot, roughly 700-800 stems of each species (eastern cottonwood and northern red oak counted toward one sample of 700-800). Oven-dry wood density was estimated for each species using the Global Wood Density Database (Zanne, Lopez-Gonzalez et al. 2009).

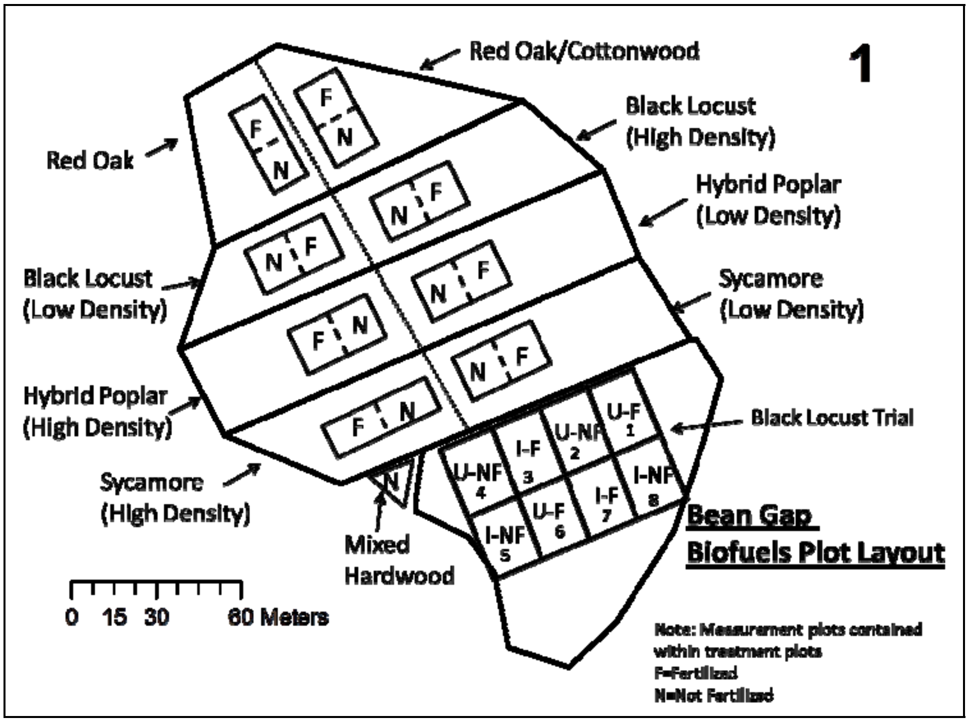

Figure 1: Plot diagram for the Bean Gap site, Wise County, Virginia.

Yearly reports have been compiled for the Powell River Project summarizing the experimental set up, research methods, and tree growth through the third growing season. The 2011 report for the Powell River Project, analyzing growing seasons one through three noted black locust has shown the greatest per-tree and per-hectare volume as well as per-hectare biomass. Hybrid poplar and sycamore follow black locust in growth while the red oak, cottonwood and mixed hardwood species are not showing favorable biomass growth at this time (Evans 2011). Continued monitoring of these trees is necessary to determine if growth patterns are sustained and to define when the optimal rotation for harvest is achieved. Currently the high density treatments have the greatest biomass per-ha for black locust, hybrid poplar and sycamore. The low density treatments have a higher per-tree biomass which at some point is expected to surpass the total biomass for the high density treatment (Evans 2011). If this happens prior to the optimal harvesting rotation age, it may be determined that planting at lower density is more cost efficient than higher density, or vice versa.

Continued growth measurements are needed to determine if current trends are sustainable over the harvest rotation as well as to determine the optimal harvest rotation. It is possible results from further collection could change current predictions. Additional collection and analysis will help determine the optimal rotation age for each species and which treatments are best for biomass growth.

The growth and yield model that will be used will be estimated using the following form (Sullivan, Aggett et al. 2005):

$$\ln(V) = B_0 + B_1 S + B_2 N + \frac{B_3}{A} + e$$

Where:
V = *total stand volume (m^3/ha)*
S = *site index*
N = *stand density at harvest (stems/ha)*
A = *stand age (years)*
e = *sample error*

These predictions will be used for economic analysis to determine net present value of biomass for each species and treatment. Net present value (NPV) uses the minimum rate of return from the best alternative investment to discount the value of all revenues and costs to the starting time period. This calculation allows for the value of time to be taken into consideration when making a decision. Net present value provides a direct comparison between opportunities as the difference between the present value of revenues and the present value of costs.

NPV = present value of revenues – present value of costs

NPV is calculated using the following general formula:

NPV = $$NPV = \sum_{t=0}^{T} \frac{P_t \times Q_t}{(1+r)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$

Where:

R_t = *price at time t ($)*

Q_t = *volume at time t (m^3/ha)*

C_t = *costs incurred at time t ($/ha)*

r= rate of return

t = rotation length (years)

T = harvest age (years)

Net present value only considers the opportunity costs of money tied up in the trees until the end of the first harvesting cycle. It is assumed that the land owner will keep the land in bioenergy production after the first harvest and capture future benefits. To estimate the value of infinite rotations, the land expectation value (LEV) must be calculated. The land expectation value takes into consideration the land on which the trees are growing and therefore calculates the opportunity cost of subsequent rotations. LEV is calculated as follows (using the same variables as in the NPV formula):

$$LEV = \frac{NPV\ (1+r)^T}{[(1+r)^T - 1]}$$

Utilizing current prices and future predictions of prices for woody biomass, along with costs of growing biomass on mined lands and growth projections, the potential viability of growing biomass for energy generation on reclaimed mine lands will be determined. A sensitivity analysis will be conducted to test the different species at varying prices, rotation age, discount rates and costs. Utilizing this cost information will highlight regulation changes which would be necessary across states to adopt planting trees for bioenergy as a common reclamation procedure. Finally, additional regulation changes required to encourage abandoned mines to be reclaimed for bioenergy production will be identified.

Preliminary Tree Growth Results

Data collected shows black locust trees are the fastest growing species regardless of treatment. Sycamore and hybrid poplar have similar growth patterns while the red oak and cottonwoods have accumulated the least amount of biomass thus far. Black locust, sycamore and hybrid poplar have all maintained similar survival rates (93%-103%) while the red oak species have 74% survival after four years and only 54% of the cottonwoods are still living and consequently are being measured (Figure 2).

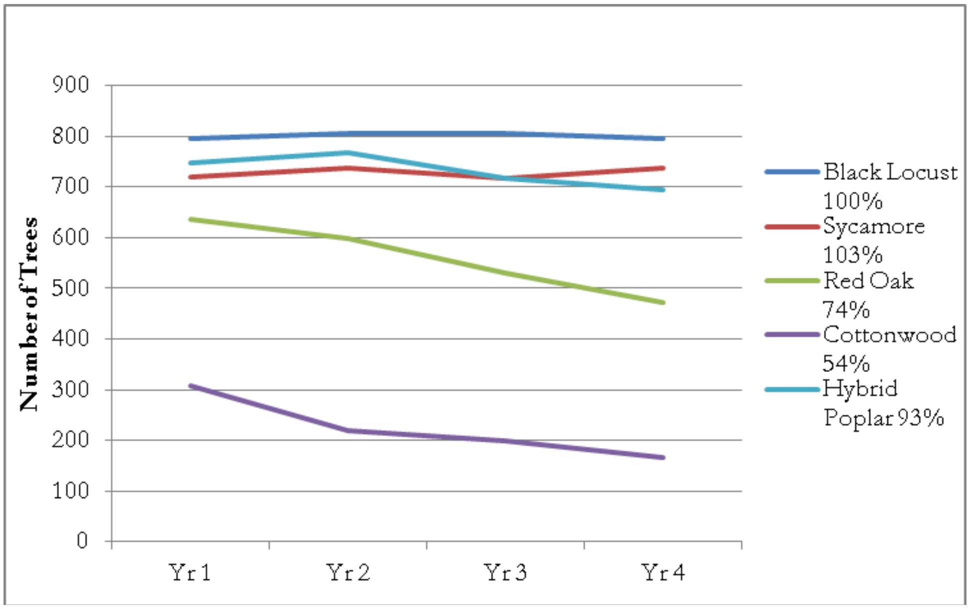

Figure 2: Survival by species at the end of each growing season.

For most species volume increased in the third year regardless of the addition of fertilizer; volume increased more rapidly for trees with fertilizer applied (Figures 3 and 4). Tree growth is measured as the individual biomass index (g/tree). Red oak is the only tree species that did not increase growth in the fourth season; while these trees still increased total biomass, the amount they grew by was less than in year three for the fertilized trees and less than in years two and three for the for the unfertilized trees.

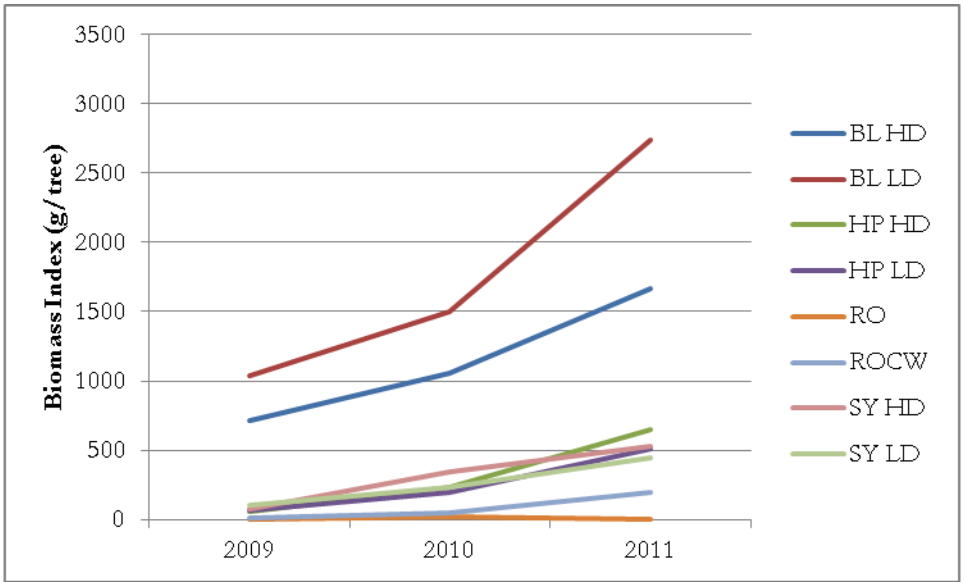

Figure 3: Current annual increment change in volume for unfertilized trees.

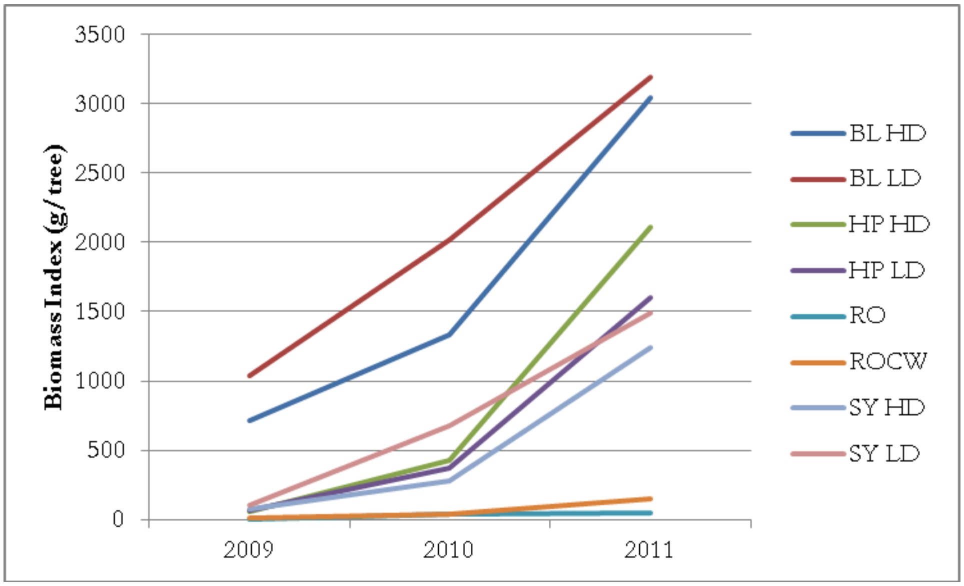

Figure 4: Current annual increment change in volume for fertilized trees.

The black locust, hybrid poplar, and sycamore trees have (on average) all achieved a "free to grow" status and are above the competitive herbaceous vegetation and out of primary deer browsing height as of the 2011 growing season (Evans 2011).

	Stocking (tree ha^{-1}) NF **(F)**	Mean Height NF **(F)** (cm)	Volume Index NF **(F)** (cm^3 tree^{-1})	Biomass Index NF **(F)** (g tree^{-1})
Block 1 (Across the Road)				
Black Locust (HD)	2834 **(3157)**	257 **(301)**	3490 **(5366)**	2094 **(3219)**
Black Locust (LD)	1249 **(904)**	268 **(284)**	4803 **(6314)**	2882 **(3789)**
Hybrid Poplar (HD)	1722 **(1091)**	222 **(250)**	1795 **(3104)**	610 **(1055)**
Hybrid Poplar (LD)	431 **(517)**	135 **(163)**	729 **(707)**	248 **(240)**
Mixed Hardwood	880	69	105	49
Red Oak	1435 **(1435)**	56 **(75)**	58 **(144)**	32 **(80)**
Red Oak/Cottonwood	1119 **(1406)**	73 **(82)**	109 **(88)**	51 **(41)**
Sycamore (HD)	3502 **(3186)**	135 **(192)**	753 **(1402)**	347 **(645)**
Sycamore (LD)	746 **(804)**	104 **(123)**	443 **(630)**	204 **(290)**

Table 1: Year four stocking, mean height, volume and biomass index for example site

For all species the fertilized treatment resulted in a higher mean biomass index per hectare regardless of whether the trees were planted at high or low density (Figure 5).

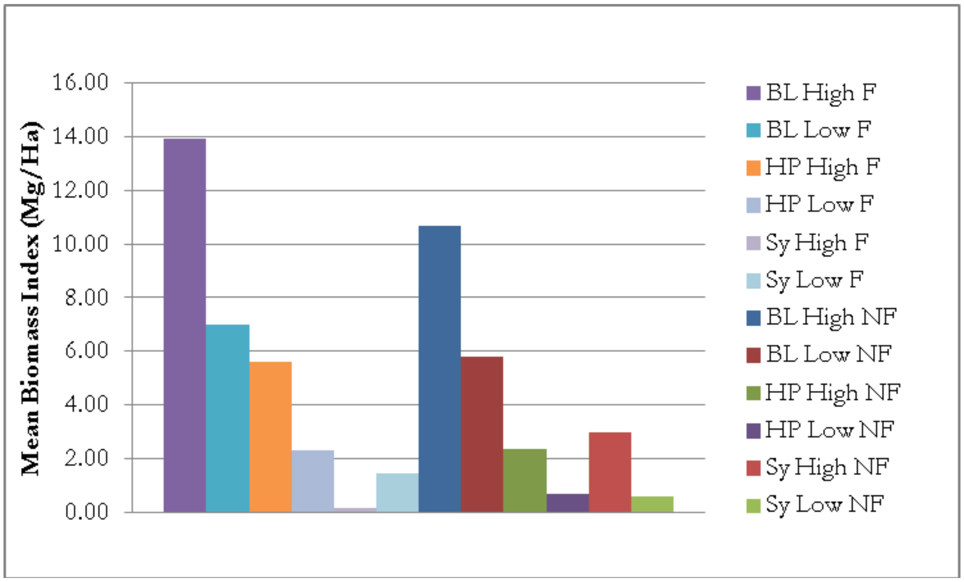

Figure 5: Effects of planting density, species and fertilization on biomass index over the full study period; the leftmost columns are fertilized trees and right columns are unfertilized.

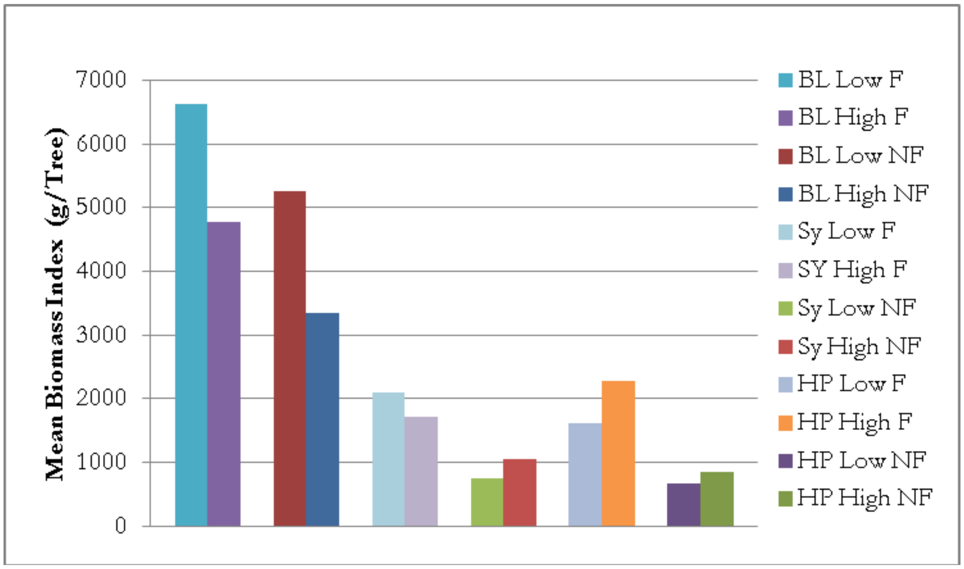

Figure 6: Effects of planting density, fertilization and species on biomass index per tree over the full study period.

Black locust trees have reached a point in their growth where volume is impacted by planting density. Black locust trees in both the fertilized and unfertilized treatments have higher per tree biomass indices when they are planted at low density versus high density (5251 vs. 3336 for unfertilized and 6626 vs. 4765 for fertilized trees) (Figure 6). The fertilized sycamore trees have reached a similar state where growth is inhibited by proximity of the trees. The low density fertilized sycamores have greater individual biomass than the high density plots (2090 and 1708, respectively). The other tree species are not at this state in their growth. Per hectare biomass volume is larger for high density plots for all species.

In the year three PRP report there were no statistical differences found between fertilized and unfertilized plots. Growing season four shows that there is a statistical difference between fertilized and unfertilized plots. This could be because at year three (only the second year after fertilizer was applied) the trees with fertilizer hadn’t utilized all the fertilizer potential while this past growing season saw more substantial growth from the fertilized trees than the unfertilized trees.

Projected Results

Height and diameter measurements were used with the growth and yield model mentioned previously to predict future tree growth patterns. The trees follow the expected pattern of fast growth in their youth with increases in volume tapering off in later years (Figure 7). Every treatment of black locust out-competes all other species by an order of magnitude with low density sycamore and hybrid poplar trees next in line (Figure 8).

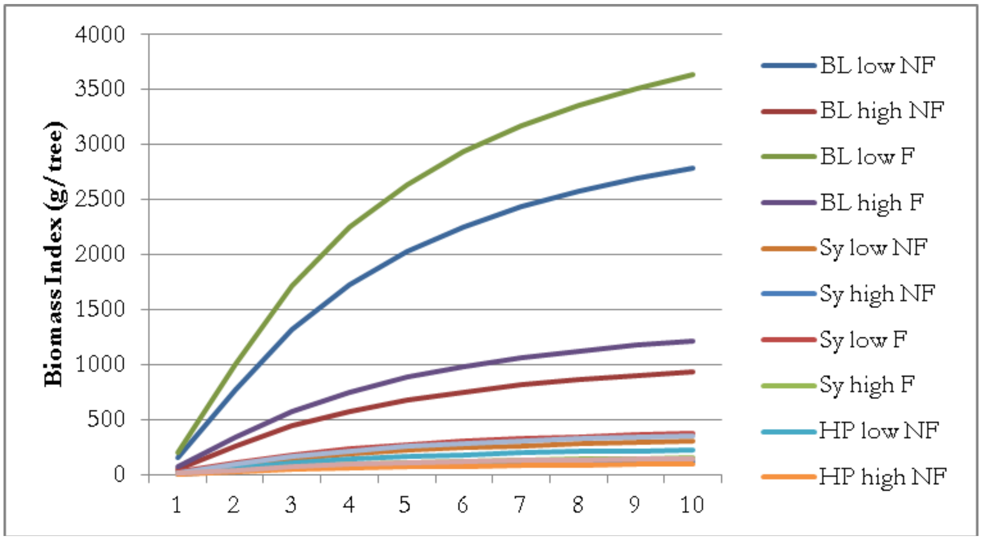

Figure 7: Treatment and species comparison for each species across all sites as projected using 4 years of measured growth data.

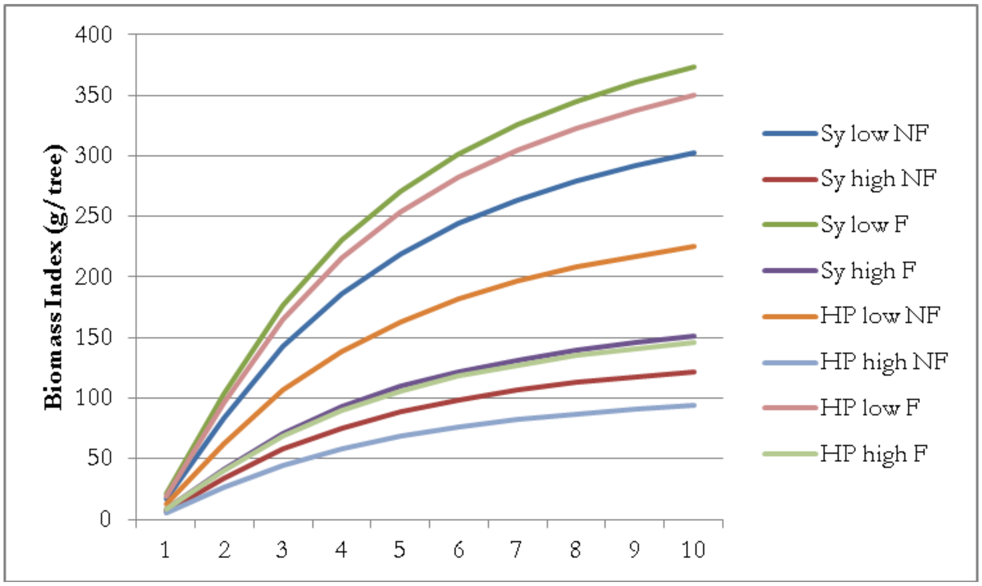

Figure 8: Treatment and species comparison across all sites "zoomed-in" from Figure 7.

Differences in the sites are statistically significant and the Red River site produces a greater amount of biomass (per tree and per hectare). Across the Road is the least productive site (Figure 9). On a per-tree basis planting at low density is the most productive treatment; fertilizer is second (Figure 10). Fertilized trees planted at low density grow more rapidly than any other treatment or combination of treatments. We do not currently have enough data to determine if there is a threshold where the effects of one treatment overcomes another and produces a greater amount of biomass.

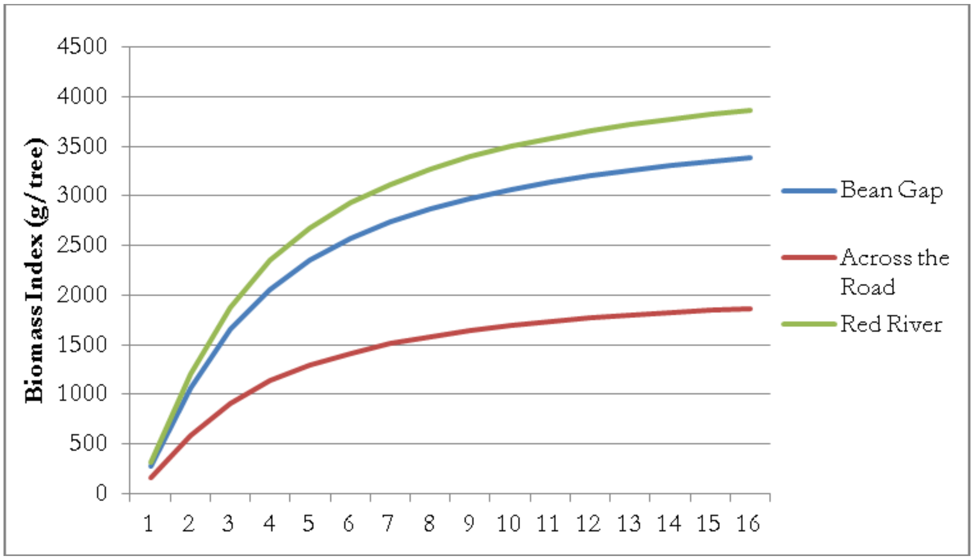

Figure 9: Each site performs differently; the most productive species and treatment combination, black locust, is compared across different site locations.

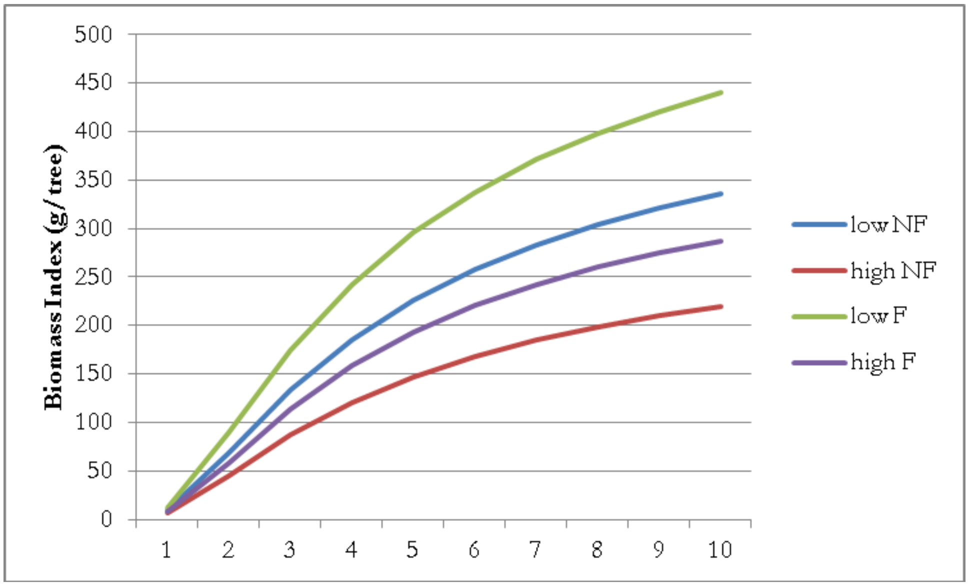

Figure 10: Combination of all tree species across all sites; planting at low density produces the greatest biomass index per tree regardless of species or location.

What Comes Next

Data collected from the planted biomass trials provide the basis for estimating growth and yield models; continued measurement will strengthen these models. The models will be used in conjunction with cost information to determine net present value and financial viability of growing bioenergy products on mined lands. Analysis of current policy will help determine if changes are needed to encourage adoption of growing bioenergy crops as a reclamation procedure on active mine lands. Further analysis will determine policy changes necessary and any financial incentives that could be implemented for reclamation to occur on abandoned mine lands.

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