Powell River Project Report 2014

Fertilizer and Density Treatment Effects on Woody Bioenergy Production on Mined Lands: Year Six Report

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Abstract

Planting woody biomass for energy production is investigated as a mine reclamation procedure to satisfy the SMCRA as an ongoing study at the Powell River Project. Annual re-measurement and analysis of three experimental biomass production sites on or adjacent to the Red River coal mine has been recast as an undergraduate research project. Currently examined are plantings of three tree species (Black locust, hybrid poplar, and American sycamore) planted at two densities, with and without fertilizer. Under nearly all species and density combinations, fertilized stands have significantly higher diameter and height growth, while density shows significant effects under few combinations of species and fertilizer regime. Findings further indicate that indicate that biomass growth continues to increase at an increasing rate after six years of growth on all sites and for all species.

Introduction

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 (30 U.S.C., 1977). Growing woody biomass as a post-mining land use may provide both environmental and economic benefits. Biomass can be burned alongside coal in existing power plants in small proportions with minimal plant upgrades, potentially reducing carbon emissions, as well as decreasing runoff and erosion, improving nutrient retention, and increasing carbon sequestration compared with reclamation to hayland/pasture (Brinks et al., 2011). In addition to hydrologic and soil benefits, forested areas (including woody biomass crops) can provide habitat for native plants and animals (Zipper et al., 2011a). Compared with long-rotation forestry options, growing short-rotation woody biomass may provide a quicker revenue turn-around, and may provide additional low cost rotations when coppicing practiced from stump sprouts following an initial rotation, or two.

Planting woody bioenergy crops on lands previously mined for coal has the potential to keep energy revenue coming from the land following coal extraction, thereby providing renewable energy and employment for Appalachian communities while restoring ecosystem services. Experimental sites on previously reclaimed mine lands were established in southwestern Virginia to determine biomass production potential. This report summarizes the first six years of growth data.

Methods

In spring of 2008, three experimental plots were established in the coal fields of Wise County, Virginia on the Powell River Project for examining opportunities to grow biomass on reclaimed mine lands as a potential post-mining land use (Figure 1). After mining, all three sites had been reclaimed with grasses and woody shrubs, and bond release had been achieved. To prepare the experiment for tree planting the land was ripped, creating furrows spaced approximately 2.5 meters apart. Five tree species were planted, including: hybrid poplar (*Populus trichocarpa* L. (Torr. And Gray ex Hook) x *Populus deltoids* (Bartr. Ex Marsh.) hybrid 52-225), American sycamore (*Platanus occidentalis)*, black locust (*Robinia pseudoacacia)*, and northern red oak (*Quercus rubra*) coupled with eastern cottonwood (*Populus deltoides*), along with a group of mixed hardwoods (black cherry (*Prunus serotina*), oaks (*Quercus* sp.), sugar maple (*Acer saccharum)*, American sycamore (*Platanus occidentalis)*, black locust (*Robinia pseudoacacia)*, ash species (*Fraxinus* sp.), and dogwoods (*Cornus* sp.)).

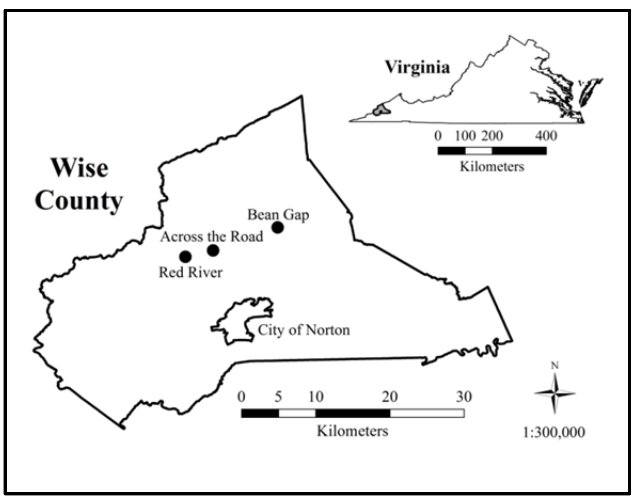

Figure 1: Biomass plots located in Wise County and context within Virginia.

Each of the primary species (hybrid poplar, black locust and American sycamore) was planted on each of the three sites at two different planting densities – high (1.7 meter by 1.7 meter spacing, approximately 1375 trees/acre) and low (3.4 meter by 3.4 meter spacing, approximately 350 trees/acre). Red oak was planted at low density, and was also planted at high density spacing in combination with eastern cottonwood. The group of mixed hardwoods was planted only at low density, which is a typical planting density when reclaiming mines to forest. The plots were further split so that each species at both densities received one of two treatments, either fertilization or no fertilization (Zipper et al., 2011b). Fertilized trees received 118 ml of granular 19:19:19 in a 0.5 meter diameter surrounding the base of the tree in December 2009. All plots received a 2% glyphosate mix weed control at a 2 meter diameter around each tree, 2008-2010.

Tree growth for each species has been measured at either the beginning or end of every growing season since the sites were established. Diameter and height measurements were conducted using calipers and a Philly rod, respectively. Height is determined as the height to the highest live bud; and diameter was measured at ground line. Diameter and height are recorded for each tree within measured plots. Beginning with the sixth measurement (March 2014), undergraduate students are employed in plot re-measurements, providing an opportunity for students to engage in active research and gain familiarity with mine reclamation practices. Also beginning with the sixth measurement cycle, only the primary species (black locust, hybrid poplar, and American sycamore) are re-measured due to the poor performance of the mixed hardwoods and cottonwood on all sites.

Annual measurements are compiled, analyzed, and reported to the Powell River Project. Oven-dry wood density was estimated (Table 1) for each species using the Global Wood Density Database (Zanne et al., 2009). A biomass equation utilizing stem diameter and oven-dry wood density is used to estimate growth and give an estimate of dry woody biomass produced using each treatment. Biomass is estimated from an equation adapted from Clark III and Schroeder (1985), as follows:

$$biomass\ tons = a \times (ground\ line\ diameter^2)^b \times {}^{lbs}/_{ton} \times {}^{trees}/_{acre} \qquad (1)$$

Coefficients a and b are determined by tree species, adapted from Clark III and Schroeder (1985). These biomass per acre equations are derived from measurements of trees in larger size classes than the trees being considered here, yet is used as the best available for this application. Analysis is conducted to determine the effects of planting density and fertilizer on the various species across the three sites.

Table 1: Oven dry wood density (g/cm^3) for each species in trial as depicted by the Global Wood Density Database; source: Zanne et al. (2009).

Species	Oven dry wood density (g/cm^3)
black locust	0.60
hybrid poplar	0.34
American sycamore	0.46
red oak	0.56
cottonwood	0.47
hardwood species (other)	0.47

Results and Discussion

Tree diameter and height growth continue for all species through the sixth growing season, though the relative rate varies by species, fertilization regime, and planting density (Figures 1 – 4). Fertilized and unfertilized hybrid poplar have outstripped other species in both diameter and height growth rate when planted at the higher density (Figs. 1 and 3), and total height and diameter of hybrid poplar have now exceeded black locust on the higher density sites. Black locust (both fertilized and unfertilized) continues to show the largest diameters and heights when planted at the lower density, though it's growth rate appears to have slowed relative to the hybrid (Figs. 2 and 4).

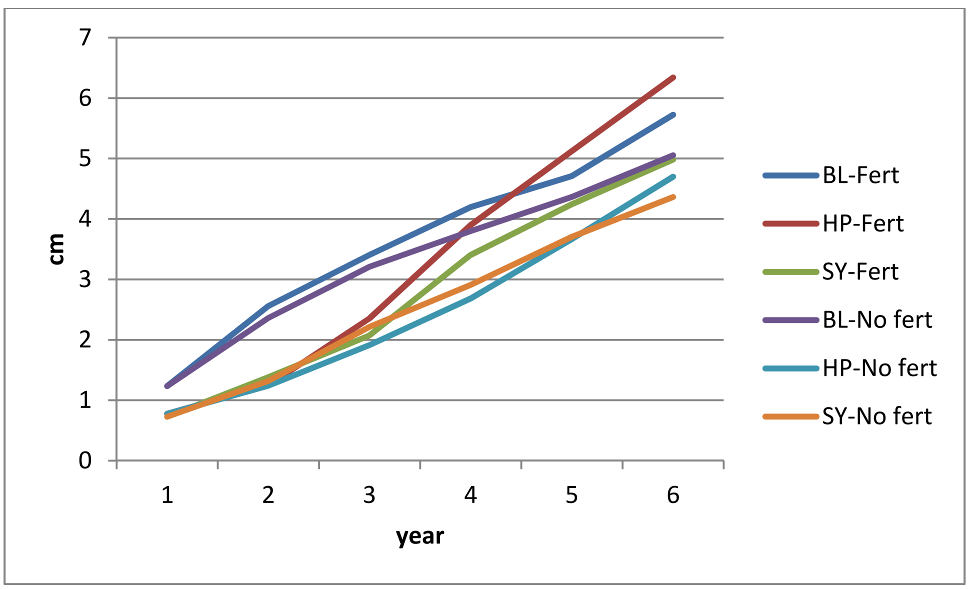

Figure 1: Mean tree diameter (cm) by year for fertilized (Fert) and unfertilized (No fert) black locust (BL), hybrid poplar (HP) and sycamore (SY) trees planted at high density.

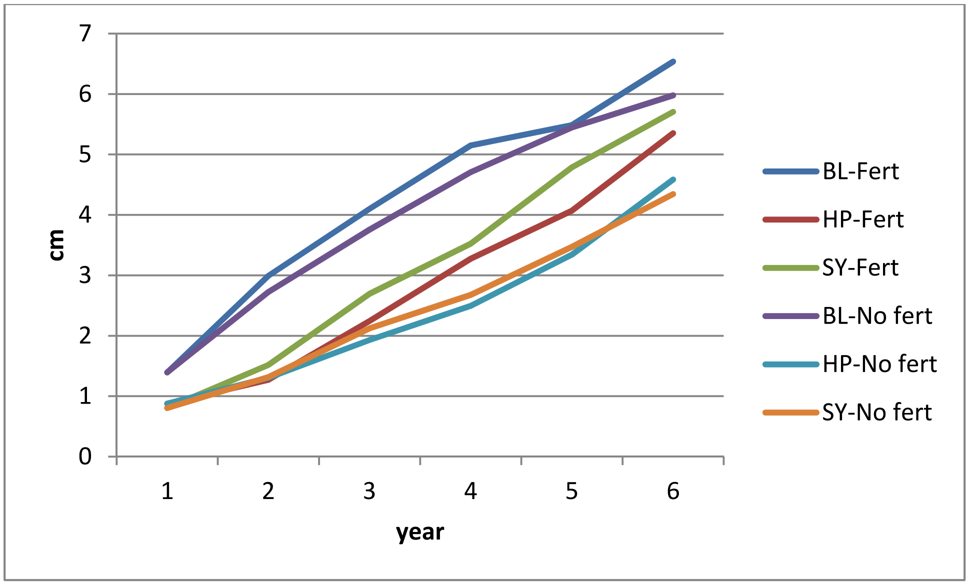

Figure 2: Mean tree diameter (cm) by year for fertilized (Fert) and unfertilized (No fert) black locust (BL), hybrid poplar (HP) and sycamore (SY) trees planted at low density.

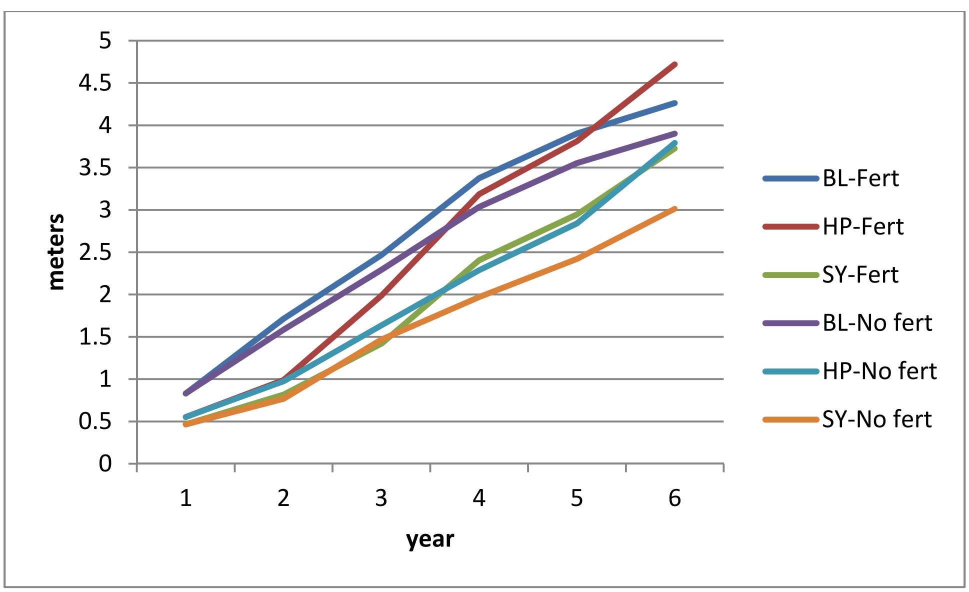

Figure 3: Mean tree height (cm) by year for fertilized (Fert) and unfertilized (No fert) black locust (BL), hybrid poplar (HP) and sycamore (SY) trees planted at high density.

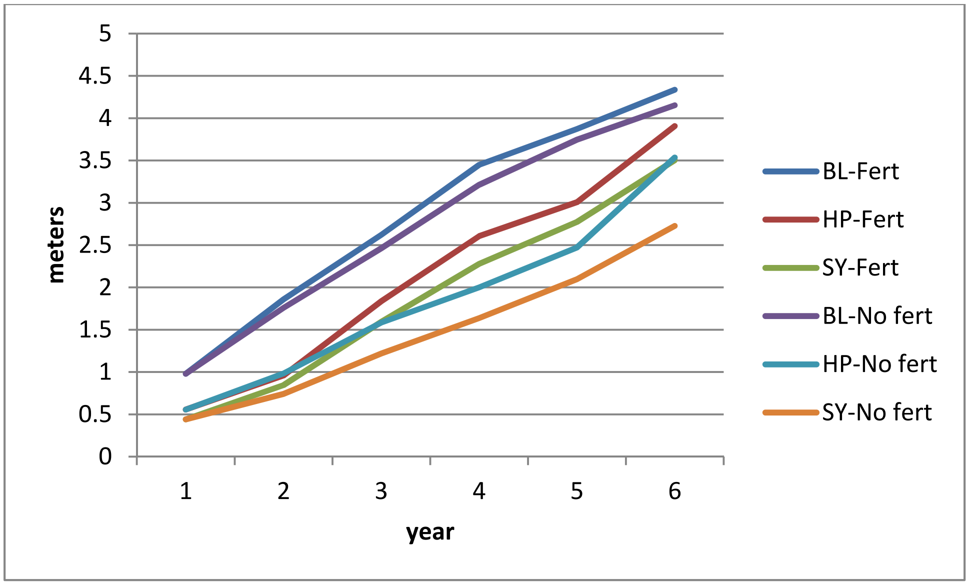

Figure 4: Mean tree height (cm) by year for fertilized (Fert) and unfertilized (No fert) black locust (BL), hybrid poplar (HP) and sycamore (SY) trees planted at low density.

Differences in total tree diameter and height in the sixth season were examined more closely in regard to the effect of treatment (Tables 2 and 3). Fertilization appears to have the most significant effect on diameter and height growth, with the difference between mean diameters and heights being significant ($\alpha=0.05$) between fertilization regime in every combination of species and planting density, except black locust planted at a lower density (Table 2). Fertilization resulted in higher diameter and height at the sixth year in all cases. Planting density is shown to be significant only in diameter growth, with significant ($\alpha=0.05$) differences only seen in half of those cases (Table 3). Where significant, diameters are all smaller when trees are planted at the higher density.

Table 2. Fertilizer effect on mean diameter (cm) and height (m) for black locust, hybrid poplar, and American sycamore for high density and low density plots on all sites after six growing seasons by planting density.

			diameter (cm)		height (m)	
			mean	std dev.	mean	std dev.
black locust						
	high density planting					
		fertilized	**5.75**	1.83	**4.31**	1.06
		unfertilized	**5.15**	1.80	**4.00**	1.10
	low density planting					
		fertilized	**6.61**	1.66	4.39	0.90
		unfertilized	**6.00**	1.68	4.18	1.08
hybrid poplar						
	high density planting					
		fertilized	**6.84**	2.87	**5.17**	2.24
		unfertilized	**4.97**	2.53	**4.12**	2.21
	low density planting					
		fertilized	**6.58**	2.57	**4.89**	1.90
		unfertilized	**5.24**	2.45	**3.98**	1.48
American sycamore						
	high density planting					
		fertilized	**4.98**	2.18	**3.73**	1.50
		unfertilized	**4.14**	1.76	**2.84**	1.17
	low density planting					
		fertilized	**5.93**	2.91	**3.69**	1.66
		unfertilized	**4.41**	1.82	**2.83**	1.11

Significant ($\alpha = 0.05$) differences between fertilized and unfertilized means shown in bold

Table 3. Planting density effect on mean diameter (cm) and height (m) for black locust, hybrid poplar, and American sycamore for fertilized and unfertilized plots on all sites after six growing seasons by planting density.

			diameter (cm)		height (m)	
			mean	std dev.	mean	std dev.
black locust						
	fertilized					
		high density planting	**5.75**	1.83	4.31	1.06
		low density planting	**6.61**	1.66	4.39	0.90
	unfertilized					
		high density planting	**5.15**	1.80	4.00	1.10
		low density planting	**6.00**	1.68	4.18	1.08
hybrid poplar						
	fertilized					
		high density planting	6.84	2.87	5.17	2.24
		low density planting	6.58	2.57	4.89	1.90
	unfertilized					
		high density planting	4.97	2.53	4.12	2.21
		low density planting	5.24	2.45	3.98	1.48
American sycamore						
	fertilized					
		high density planting	**4.98**	2.18	3.73	1.50
		low density planting	**5.93**	2.91	3.69	1.66
	unfertilized					
		high density planting	4.14	1.76	2.84	1.17
		low density planting	4.41	1.82	2.83	1.11

Significant ($\alpha = 0.05$) differences between high density and low density means shown in bold

Survival continues to remain high, especially for the black locust and hybrid poplar (Figure 5). American sycamore numbers continued a relatively steep decline through the sixth growing season, although the rate of decline seems to have slowed somewhat from the previous year.

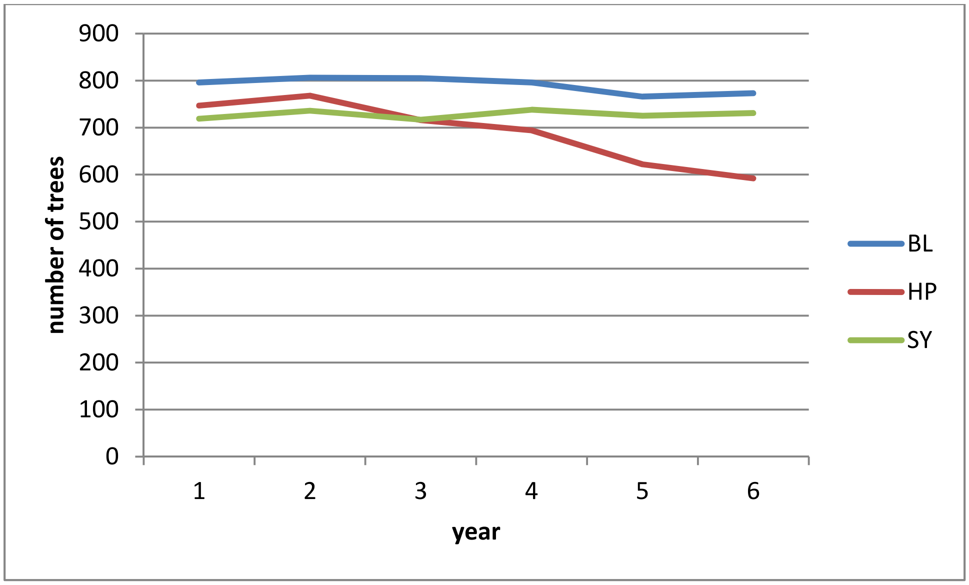

Figure 5: Tree survival over six years by species with sites combined; black locust (BL), hybrid poplar (HP), and American sycamore (SY). (Note: Slight increases in number of stems seen between some years may result from difficulty finding or correctly identifying all trees, especially at younger ages.)

Estimated biomass after six growing season ranges from 22.61 tons per acre for fertilized black locust planted at high density to 2.94 tons per acre for unfertilized sycamore planted at low density (Figures 6 and 7, and Table 4). Overall, black locust still yields the highest overall volume at six years, regardless of treatment, but current growth rates of the other species appear to be comparable, if not slightly higher, for fertilized hybrid poplar and sycamore.

Table 4: Mean biomass (tons/acre) by year, planting density, species, and fertilization regime.

	year					
High Density	**1**	**2**	**3**	**4**	**5**	**6**
black locust - Fert	0.87	4.10	7.68	12.23	14.30	22.61
black locust - No fert	0.87	4.06	7.67	10.74	14.05	20.09
hybrid poplar - Fert	0.11	0.31	1.69	5.73	10.84	18.22
hybrid poplar - No fert	0.11	0.37	1.18	2.74	5.92	10.70
American sycamore - Fert	0.09	0.45	1.26	4.84	9.23	13.02
American sycamore - No fert	0.09	0.45	1.69	3.69	7.33	11.34
Low Density	**1**	**2**	**3**	**4**	**5**	**6**
black locust - Fert	0.43	2.13	4.41	6.86	8.63	9.92
black locust - No fert	0.43	2.02	3.94	6.20	7.47	10.30
hybrid poplar - Fert	0.06	0.18	0.72	2.24	3.77	6.57
hybrid poplar - No fert	0.06	0.16	0.39	0.84	1.91	4.04
American sycamore - Fert	0.04	0.22	0.86	2.00	4.53	7.20
American sycamore - No fert	0.04	0.12	0.42	0.74	1.44	2.94

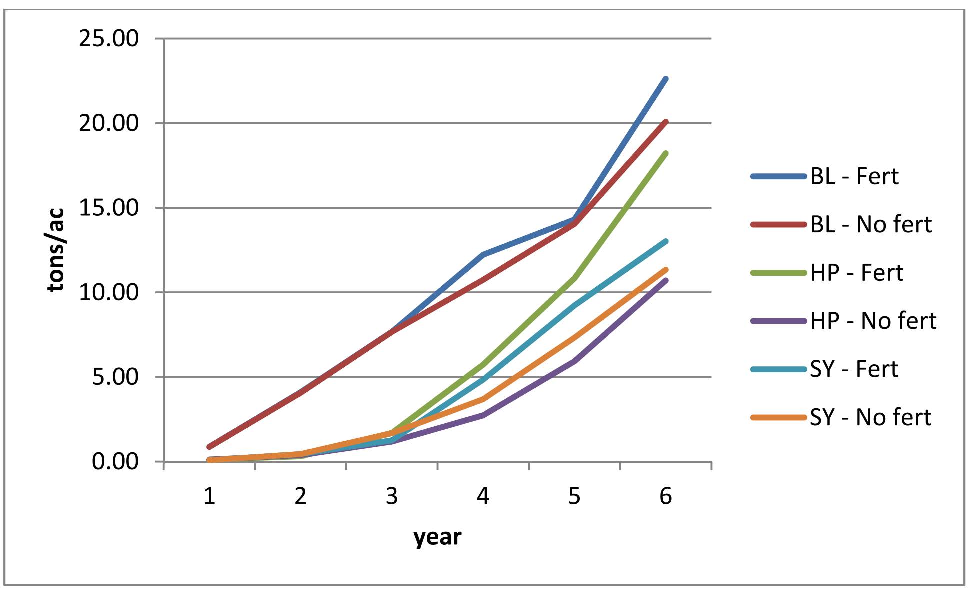

Figure 6: Mean biomass (tons/acre) by year, species, and fertilizer regime when planted at high density; black locust (BL), hybrid poplar (HP), and American sycamore (SY).

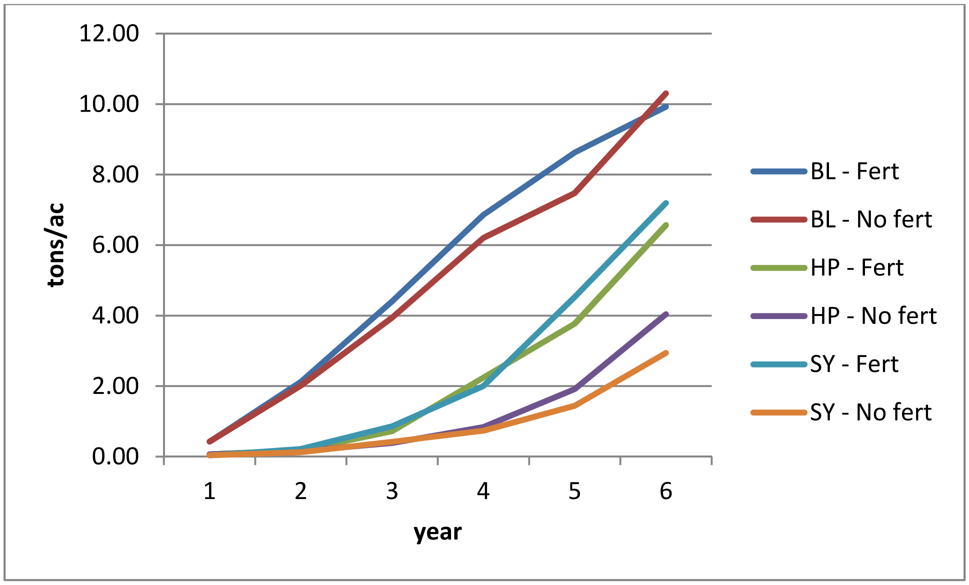

Figure 7: Mean biomass (tons/acre) by year, species, and fertilizer regime when planted at low density; black locust (BL), hybrid poplar (HP), and American sycamore (SY).

Future Work

Funding has been received to continue measurement of the black locust, hybrid poplar, and American sycamore for an additional year, to be conducted during tree dormancy between the end of the 2014 growing season and the beginning of the 2015 growing season. Again, undergraduate students will be employed to provide undergraduate research opportunities. The long term outlook, provided that sufficient funding is available, is to continue annual measurement of the existing plots through the tenth growing season. After ten years, we hope to be able to harvest the existing timber, and allow regeneration to occur through coppice. A harvest will help us better understand biomass yield and properties, and consequently its suitability and value in actual biomass markets as they exist at that time. Coppice regeneration likely will have a substantive impact on the economics of biomass plantations on mined lands, and having the opportunity to follow the growth and properties of this additional source of value will be invaluable in understanding the viability of biomass as a post mining land use into the future.

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Summary Data

Year six average diameter, height, and biomass index by site, species, and treatment.

No Fertilizer	ATR tree diam. (cm)	BG tree diam. (cm)	RR tree diam. (cm)	mean tree diam. (cm)	ATR tree height (m)	BG tree height (m)	RR tree height (m)	mean tree height (m)	mean Biomass Index per Tree (g/tree)
Black Locust (High Density)	4.63	4.43	6.11	5.06	3.35	3.56	4.79	3.90	7707.11
Black Locust (Low Density)	5.35	5.93	6.66	5.98	3.37	4.12	4.97	4.15	10612.71
Hybrid Poplar (High Density)	4.28	6.17	3.64	4.70	3.22	5.57	2.59	3.79	5217.21
Hybrid Poplar (Low Density)	2.52	5.04	6.20	4.59	2.15	3.67	4.78	3.54	4525.93
Sycamore (High Density)	2.76	4.94	5.39	4.36	1.78	3.48	3.78	3.01	3874.34
Sycamore (Low Density)	2.31	5.53	5.19	4.34	1.55	3.67	2.96	2.73	3303.38
Fertilizer	ATR tree diam. (cm)	BG tree diam. (cm)	RR tree diam. (cm)	mean tree diam. (cm)	ATR tree height (m)	BG tree height (m)	RR tree height (m)	mean tree height (m)	mean Biomass Index per Tree (g/tree)
Black Locust (High Density) F	5.52	4.92	6.73	5.72	3.80	3.88	5.10	4.26	10311.40
Black Locust (Low Density) F	6.30	6.90	6.41	6.54	3.74	4.37	4.90	4.34	12573.28
Hybrid Poplar (High Density) F	4.88	8.42	5.73	6.34	3.50	6.69	3.97	4.72	10265.64
Hybrid Poplar (Low Density) F	2.60	5.48	7.98	5.35	1.79	3.68	6.25	3.91	6992.99
Sycamore (High Density) F	3.13	4.82	6.99	4.98	2.26	3.55	5.37	3.73	6383.31
Sycamore (Low Density) F	2.22	7.80	7.10	5.71	1.60	4.99	3.92	3.50	8780.49

Mean biomass (tons/acre) by year, fertilization regime, species and planting density.

	year					
No Fertilizer	**1**	**2**	**3**	**4**	**5**	**6**
black Locust (High Density)	0.87	4.06	7.67	10.74	14.05	20.09
black Locust (Low Density)	0.43	2.02	3.94	6.20	7.47	10.30
hybrid Poplar (High Density)	0.11	0.37	1.18	2.74	5.92	10.70
hybrid Poplar (Low Density)	0.06	0.16	0.39	0.84	1.91	4.04
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