

Prior to the growing season, all the trees were tagged with an aluminum tag and the diameter at breast height marked with red paint so that the diameter would be taken at the same place each time. The diameter and heights were taken prior to the growing season and after the first growing season, so that changes in height and diameter could be assessed. Biomass was calculated in cubic meters from height and diameter measures prior to and after the growing season using a formula from the literature (Zabek, 2001).



Figure 26 Root mat of plots with vegetation management was dead, however annual vegetation had regrown (above). Plots without vegetation still had an established root mat that was utilizing nutrients from the upper soil layers.

In mid-August at the peak of the growing season, two foliar leaf samples were taken from four trees in each of the treatment plots to provide one composite sample for each treatment using the protocol previously described. The first fully expanded leaves at the top of the tree were sampled using a lift, which is usually 5-7 leaves down from the terminal leader. If you

sample leaves that are still actively expanding, the leaf will be receiving nutrients from the tree and give unrealistic value. If the leaf is not expanding it will be a net exporter of nutrients and values may be low. All samples were taken at mid-day. The sampling resulted in 12 total leaf samples that were analyzed for nitrogen, phosphorous and other nutrients by an independent lab.



Figure 27. Leaves selected for foliar sampling are taken from the terminal leader. Leaves 5-9 down from the top are selected.

Results:

Height, Diameter, and Biomass

The one-year height growth of all the treatments was significantly higher than the control.

However, only the vegetation/phosphorous treatment significantly increased diameter (Table 12).

None of the treatments significantly increased biomass compared to the control after one year.

Table 12. One year growth measures for each treatment.

One year change in:	Control	Vegetation Mgt	Phosphorous Additions	Vegetation/ Phosphorous
Height (meters)	2.22 ^a	2.66 ^b	2.54 ^b	2.71 ^b
Diameter (centimeters)	4.304 ^a	3.976 ^a	3.946 ^a	4.400 ^{ab}
Biomass (cubic meters)	0.025 ^a	0.025 ^a	0.025 ^a	0.027 ^a
Statistical analysis using mixed model repeated measures at P<0.05				

Foliar Nutrient Status

The low number of samples likely contributed to the lack of statistical significance (<0.05) for many of the measures such as %N, %P and micronutrients (Table 13). The N:P ratio was very significant, but since it was developed from other measures of N and P that were not significant, its relevance may be questionable. While significance may have been limited, trends in the data were telling. The vegetation/phosphorous treatment had the highest %N value at 4.0, which would be expected since the removal of vegetation and addition of P allowed improved uptake of the trees. A similar trend existed for %P, with the highest value found again for the vegetation/phosphorous treatment.

Table 13. Foliar nutrients for four year old hybrid poplar.

	Control	Vegetation Management	Phosphorous Amendment	Veg. Mgt/ Phos. Amd.	P Value significance<0.05
% N	3.6	3.6	3.7	4.0	0.55
%P	0.35	0.33	0.31	0.42	0.09
N:P ratio	10.4 ^b	10.9 ^{ab}	12.1 ^a	9.5 ^b	0.006
%K	2.1	2.0	2.0	2.4	0.10
%Mg	0.22	0.27	0.27	0.26	0.29
%Ca	0.75	0.93	0.94	0.76	0.19

Composite sample from 4 trees for each treatment sample.
 Statistical analysis using Tukey test

Perhaps the most relevant result was the ambient levels of N, P, and the N:P ratio found in the samples. They are representative of the maximum values found in the literature. Maximum growth of hybrid poplar under fertilized conditions is thought to occur at 3.6% foliar nitrogen and 0.42% foliar phosphorous. However, fast growth is known to occur at 2.5-3.5% foliar nitrogen and 0.25-0.40% foliar phosphorous. Foliar N:P ratios of above or below 9.5 usually coincide with differences in tree growth response to N and P applications. The values found in this study were at or above the levels that would usually result in significant increases in growth and biomass.

In this study, growth and diameter differences were found between the treatments, but not with biomass. The measurements will be taken again after the second growing season and additional differences may become significant.

Conclusions

At year four of the crop rotation, the deep row biosolids system does appear to provide the trees sufficient levels of nutrition, comparable to levels found in hybrid plantations fertilized with surface-applied biosolids and manures. The combined treatment of phosphorous amendment and vegetation management resulted in increases in height growth and diameter. However, another year's data is needed to better assess the long term effects on biomass and if the height and growth increases continue. If differences in growth and biomass are minor, then the cost of applying the treatments compared to the control may not be cost-effective.

Future Work

The data reported is only for the first year of the two year study. The vegetation management treatments will be reapplied with herbicide in March, 2005 and the foliar leaf samples and growth data taken later in 2005. It is hoped that treatment effects will become clearer at that point.

EFFECT OF VEGETATION MANAGEMENT AND PHOSPHOROUS AMENDMENTS ON GROWTH OF NEWLY PLANTED HYBRID POPLAR TREES

Maximizing the early growth and establishment of planted cuttings should allow the tree roots to reach the biosolids faster and result in faster utilization of the biosolids, which can decrease the rotation length, increasing the economic return on the property. At the very least, reducing competition through vegetation management and hastening plant establishment and root development with phosphorus amendments should improve plant health and, hence, survivability after the first year. Contrary to most forest ecosystems, the nutrient base of this deep row system is found underground in the biosolids trench. While the upper soil layers provide little in the way of available nutrients, they do provide the entry for surface water to reach the tree roots and can be critical in first year growth.

Research in hybrid poplar plantations has found that controlling surface vegetation during stand establishment can result in better growth (Thomas et. al, 2001). However, adding nutrients without controlling surface vegetation usually does not result in increased growth, because the additional nutrients and available water are taken up by the surface vegetation before the deeper tree roots can reach them.

The addition of nutrients that are limiting tree growth can result in significant increases in height and biomass accumulation. This has been found to be the case in phosphorous-limited soils in pine plantations on the coastal plain. Inspection of the trees in the deep row application system has indicated that phosphorous levels may be limiting the ability of the trees to uptake nitrogen, which results in higher growth rates. This study was initiated to address these questions for newly-established plantations.

Materials and Methods

Experimental Design

The experimental design and plot layout for this study is the same as that for the previous section that used already established 4-year old hybrid poplar trees. The only difference is that the treatments were randomly assigned and the physical location was adjacent to the study in previous section. Both studies were initiated within a few days of each other in March 2004.

Application of Treatment

The application of treatments did vary from other studies because the site was newly graded with no vegetation present. The rows were subsoiled using the operational technique to provide a regular 10-foot spacing for the cuttings (Figure 28). Cuttings were planted by hand at the intersection of the subsoiled rows. The phosphorous amendment was applied using commercial corn starter (N-P-K, 0-48-0). It was applied immediately after planting by sprinkling it in the subsoiling trench on four sides of the planted cuttings the prescribed rate of phosphorus (0.6 cups per cutting total).

Since many of the cuttings had begun to leaf out when planted it was not possible to use Goal herbicide to control the vegetation, which would damage leafed out cuttings. Therefore, Pendulum®, a pre-emergent herbicide, was sprayed immediately after planting using a backpack sprayer in three-foot strips on each side of the cuttings. Pendulum® has no effect on vegetation present, but since the site was newly graded, no vegetation was present to control. It was only fairly effective after the end of one growing season. The gravelly soil at the surface likely contributed to this lack of efficacy.



Figure 28. Newly planted plots, showing subsoiling trenches made by the bulldozer.

In mid-August, at the peak of the growing season, foliar leaf samples were collected using the protocol described. However, all the trees were severely browsed (Figure 29) and the collection of 6 leaves per plot was difficult in some cases. Leaves were taken from terminal leaders with little or no browsing. All samples were taken at mid-day when the trees were actively growing. The sampling resulted in 12 total leaf samples that were analyzed for nitrogen, phosphorous and other nutrients by an independent lab. Unfortunately, the leaf samples were so small in volume that there was not sufficient biomass to measure nitrogen on one of the composite plot samples. This resulted in only two measures for %N on the vegetation management plots, making statistical analysis impossible for %N.



Figure 29 Severe deer browsing.

Results and Discussion

The severity of the deer browsing made the use of height and diameter data unreliable as indicators of treatment effect. These metrics were collected so that they can be used in the analysis of second year data, however, they are not included in this report. Browsing caused many of the small trees to appear more like bushes after the first year, which can cause the lack of a central leader to continue growth the second year. Therefore, in March 2005, the trees were pruned so that one central leader would be expressed.

Foliar Nutrient Status

The low number of samples likely contributed to the lack of statistical significance (<0.05) for any of the nutrient measures (Table 14). The vegetation/phosphorous treatment had the highest %N value at 3.47, which would be expected since the removal of vegetation and addition of P allowed improved uptake of the trees. A similar trend was not found for %P in the vegetation/phosphorous treatment.

The most informative result of this analysis is the ambient levels of N, P, and the N:P ratios for the treatments. They are representative of the values found in the literature for fertilized trees that exhibit fast or maximum growth. Maximum growth of hybrid poplar under fertilized conditions is thought to occur at 3.6% foliar nitrogen and 0.42% foliar phosphorous. However, fast growth is known to occur at 2.5-3.5% foliar nitrogen and 0.25-0.40% foliar phosphorous. Foliar N:P ratios of above or below 9.5 usually coincide with differences in tree growth response to N and P applications. The values found in this study are at or above the levels that would suggest significant increases in growth and biomass.

Table 14. Foliar nutrient levels by treatment for one-year old hybrid poplar.

	Control	Vegetation Management	Phosphorous Amendment	Veg. Mgt/ Phos Amend	P Value sig<0.05
% N	3.17	3.29 **	2.94	3.47	-----
%P	0.29	0.31	0.31	0.28	0.45
N:P ratio	10.9	10.6	9.5	12.4	----
%K	2.4	2.3	2.1	2.4	0.51
%Mg	0.19	0.18	0.20	0.23	0.13
%Ca	1.0	1.1	1.2	1.1	0.12

Composite sample from 4 trees for each treatment sample.

Statistical analysis using Tukey test

** only two values instead of three

Conclusions

The deep row biosolids system does appear to provide the trees levels of nutrition comparable to fertilized plantations, even during the first growing season. The effects of phosphorous amendments, vegetation management, and combined phosphorous and vegetation management on height and diameter growth could not be determined in this study due to the impact of deer browsing. While deer fencing would have solved this problem, the intent of the study was to mimic operational conditions. Growth measurements and nutrients samples will be taken after the second growing season to determine if significant treatment effects occur as the stems grow out of the reach of deer. Results of this research will help to determine if the vegetation and phosphorous treatments actually result in significant growth impacts. If differences are minor, then the cost of applying the treatments compared to the control may not be cost-effective.

FIVE YEAR HYBRID POPLAR CLONAL TRIALS

The purpose of this study was to test a variety of hybrid poplar clones to see which perform best using deep row application on abandoned gravel spoils in this region. The lack of nutrients in the existing soil after mining combined with the biosolids that may contain as much as 20 percent lime to meet regulatory requirements, creates a unique mix of conditions. The clone used in the initial plantings at the ERCO tree farm was HP308, but problems with cottonwood beetle, slow growth, and the changing makeup of biosolids required experimentation with new clones.

Experiment Design

Table 15 Layout of different clonal trials.

DN 17	OP 367	DN 5		120' 120' 120'	Main Road
DN 82	HP 308	DN 70	184-411		
50-197	NM 6	DN 34	15-029		
100'	100'	100'	100'		

In Section 5 of the ERCO tree farm (Figure 6) an area of 400' by 360' was set aside for a planting of different hybrid poplar clones to test their growth and survival under the unique conditions of the site. The design and layout of the clone trial was developed by Mike VanHam of Sylvis Environmental in British Columbia, Canada, a private consultant who is retained by ERCO, Inc. Table 15 shows the clones that were randomly assigned to each area. There was no effort to create smaller replicated plots which would have provided better statistical rigor to the design. The test plots were divided into 11 equal sized blocks, which were 100 feet by 120 feet. Cuttings were planted on a 10-foot spacing, so that each block contained 120 trees.

Table 16 Source and type of hybrid poplar clones.

Source and Type of Hybrid Poplar Clones	
Source Nursery	Type of Clone
Iasca	NM 6
Iasca	DN5
Iasca	DN17
Iasca	DN34
Iasca	DN70
Iasca	DN182
Iasca	OP 367
Iasca	184-411
Iasca	15-29
Iasca	50-197
ERCO	HP 308

The eleven clones were selected based on recommendations by Sylvis Environmental, Inc. The source nursery and type of clone are provided in Table 16. Only the thickest and best looking planting stock was planted. The planting stock consisted of a cut branch stem about one foot long and 1/2 inch in diameter. During the month of April, the cuttings were planted firmly into the ground with the top bud showing. The vegetation competition between the rows was controlled by periodic mowing .

The total tree height after each growing season was measured using a telescoping pole and/or a handheld instrument. Survival was assessed after the first and second growing season. The data were entered and analyzed using SAS (Statistical Analysis System). Initial analysis of the data distribution indicated that using the square of the height measurements provided a better data distribution for analysis. All the data are reported in Table 17 with graphs made to highlight single characteristics of height growth and survival.

Results

Survival

Survival after the second growing season was greater than 90% for three clones with three other clones in the 80-90% range (Figure 30). These clones in order of survival percentage were: OP367 (96%); DN70 (94%); DN5 (93%); DN82 (88%); NM6 (87%);

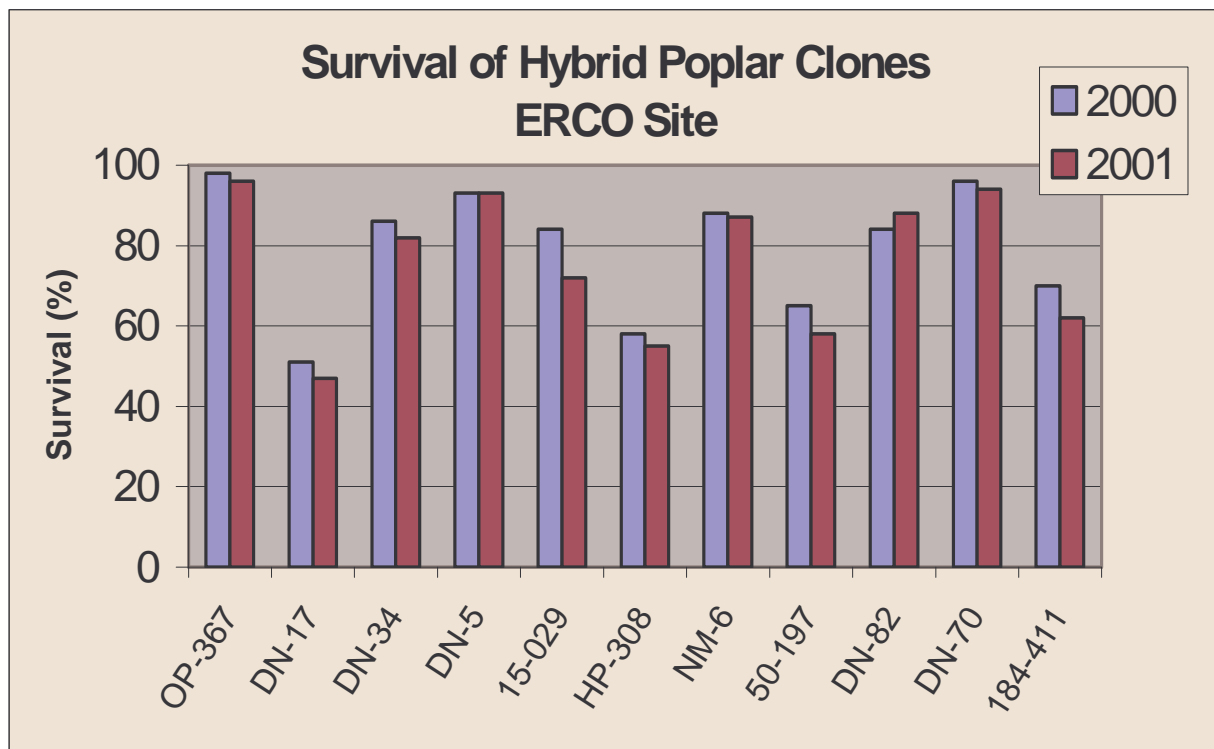


Figure 30. Percent survival for each of 11 hybrid poplar clones during 2000 and 2001. One hundred percent represents 120 trees.

and DN34 (82%). The survival of clone 15-029 at 70% was lower than the others, but should receive some consideration due to its good performance in total height measures. The survival of other clones were under 80%, which would indicate they are not well adapted to survive in this environment. It is possible that deer browsing may have had an impact on survival since some clones may be more favored than other, however, since fencing to

exclude deer is not operationally possible, clones used must be able to survive browsing pressure early on.

Total and Annual Height Growth

After four growing seasons, both the OP-367 and DN-17 clones were significantly taller than the other clones (933 and 833 cm. respectively), but not significantly different from each other (Figure 31). Throughout the four year period, OP367 consistently had the best height growth, with it being significantly taller than all the other clones after the end of year 1 and year 2.

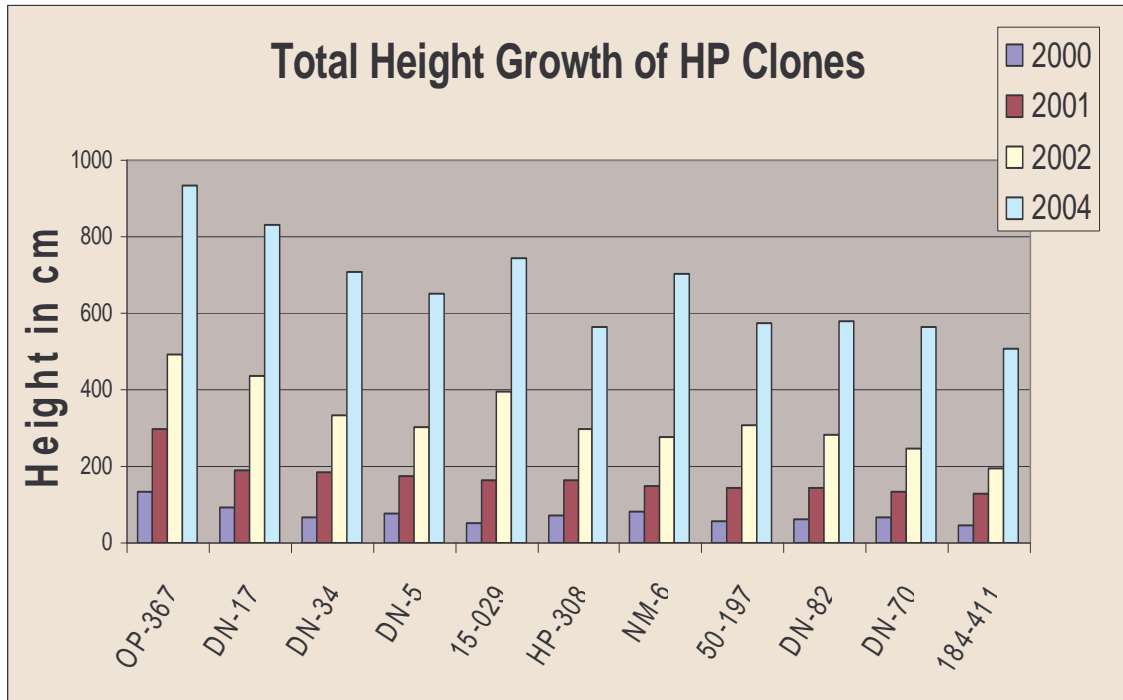


Figure 31. Total average height for each of 11 hybrid poplar clones, 2000-2004. Bars for years 2000 and 2001 represent an average of 120, while years 2002 and 2004 represent an average of 40 randomly selected trees.

After five years, DN17 maintained its place as the second tallest clone in terms of total height growth. The five tallest clones after the fifth year were: OP367 (933 cm); DN17 (833 cm); 15-029 (743 cm); DN34 (708 cm); and NM6 (701 cm).

Annual Height Growth

OP-367 consistently demonstrated superior annual height growth compared to the other clones except for DN-17 and 15-029, which had better annual growth in year 2-3 (Figure 32). The height growth of OP-367 in the second year was 165 cm., 50 cm. more than the next best performer DN17, with 115 cm. By the fifth year, OP367 had an annual height growth of 439 cm., which was only slightly higher than NM6 at 422 cm. However, NM6 performed poorly in the previous years.

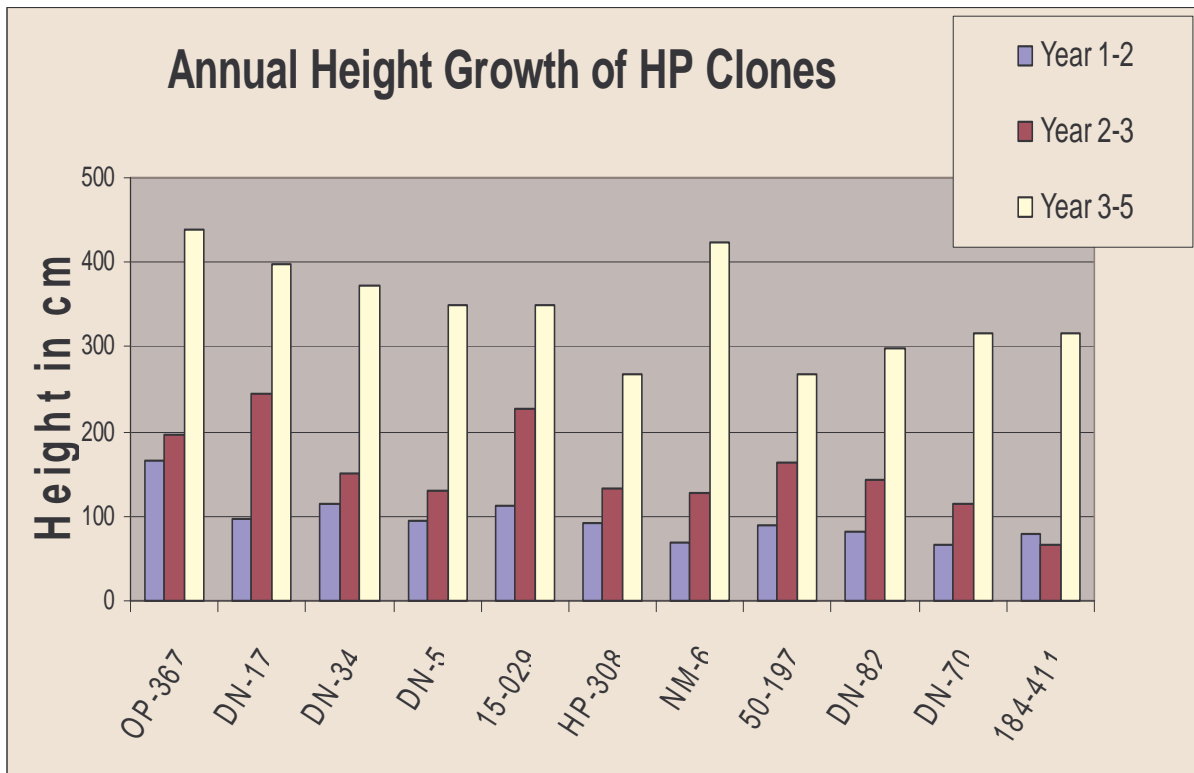


Figure 32 Annual height put on by each of 11 hybrid poplar clones.

Conclusions

After five years, the OP367 clone was the superior performer of all the clones tested for survival and total height. The DN-17 clones had the next highest height growth after five years, but its survival was poor at 47% after two years. It is unclear if deer browsing or site conditions may have been responsible for this lower survival, but its superior height growth makes it worth further consideration. The DN-34 clone also had excellent survival and acceptable height growth which warrants further consideration.

Some clones have been determined to be unacceptable due to problems with insects and disease or form, although they may have good survival and height growth. OP-367 was not only the best performer but lacked any serious insect or disease problem. Although OP-367 had the highest survival at 96%, there were two other clones (DN70 & DN5) that had survival over 90%. However, the very poor height growth of these clones indicates they are not desirable choices for this site, regardless of the good survival.

In contrast, the poor survival of DN17 (47%) is a concern since it was a superior performer in height growth. More analysis needs to be done to determine if deer browsing may have impacted the survival or if the lack of irrigation may have impacted survival. Field notes indicated that deer had caused serious mortality on some clones. When a stem was damaged by deer browsing or rubbing it typically died back to the base. In many cases these stems died, impacting overall survival. For those stems that did grow, the lower heights could also impact the overall mean height of the entire block.

Table 17 - Overall height, survival and growth measures for clonal varieties.

Clone	Survival Rate (%)		Total Height (cm)				Height Growth yr. 1 – 2	Height Growth yr. 2-3	Height Growth yr. 3-5
	2000	2001	2000	2001	2002	2004			
OP-367	98	96	131	297	494	933	165	197	439
DN-17	51	47	92	190	434	833	98	244	399
DN-34	86	82	69	184	334	708	115	150	374
DN-5	93	93	78	172	303	652	94	131	349
15-029	84	72	53	166	393	743	113	227	350
HP-308	58	55	72	165	297	566	93	133	268
NM-6	88	87	81	150	278	701	69	129	422
50-197	65	58	56	145	309	577	89	164	268
DN-82	84	88	60	141	283	582	81	142	299
DN-70	96	94	67	134	248	564	67	114	316
184-411	70	62	46	126	193	509	80	67	317

Future Work

No diameter measures had been taken for the clonal variety plots through the 2004 growing season, so no biomass measurements could be calculated. Diameters will be measured for the 2005 growing season and biomass calculated. Visual observations indicate that the OP-367 clones will outperform the other clones.

**HYPOTHETICAL BUSINESS SCENARIO FOR DEEP ROW BIOSOLID
APPLICATION FOR A FORESTRY OPERATION**

Experimental Design

The deep row biosolid application beneficial use technique at ERCO is an operational business that has functioned under a research permit from the Maryland Department of Environment since 1983. There are no other comparable operations anywhere in the world so the development of an economic analysis required using information obtained from ERCO, but it is not representative of the ERCO operation itself. Commonly accepted machine rates per hour and production rates per person were used to determine costs based on reasonable assumptions. The objective was to determine how different factors affect the profitability of this enterprise, given the present market.

Methods

Interviews were carried out with the manager of the ERCO operation to determine reasonable production rates and logistical guidelines in the analysis. Custom rate hourly equipment costs for bulldozers and backhoes were used to determine total costs based on the number of hours estimated for their use. As application rates increased assumptions were made on equipment needs and hours required.

The amount of land required under various alternative application rates was determined based on the research being carried out in this project.

Results and Discussion

Business Resources

The economic analysis first identified the business resources required under three headings (Table 17): 1) land & buildings; 2) site development; and 3) equipment and personnel. This would enable the determination of costs associated with each expense.

Production

The analysis intended to look at the income generated under the different application rates that were part of the research study: 4000, 8000, and 12,000 lbs of nitrogen (N) per acre for the six-year rotation. The existing ERCO operation presently operates near the 4000 lbs of nitrogen rate. First, it was necessary to calculate exactly how many wet tons per acre were required to reach the nitrogen application rates in the study. It is important to note that the wet tons per acre required to reach target N levels depends directly on the percent nitrogen found in the biosolids. In this case the average was about 1.2% (wet weight basis) using lime-stabilized biosolids that are currently available. If the percent N were to decrease, it would require more wet tons per acre to reach the same N application rate - likewise, fewer tons per acre with a higher percent N. Based on the results from the water quality portion of this work (Table 6), the nitrogen concentration is very consistent and not likely to change. However, if the process at the wastewater treatment plant were to change, then a change in the biosolids nitrogen content would be anticipated.

Field experience indicates that applying the 2351 wet tons per acres associated with the 12,000 lbs N/acre is the highest volume that can be physically applied using the deep row technique as presently done due to operational and equipment limitations. Therefore, while

higher rates of N beyond the 12,000 lbs N per acre are possible, it would only occur if the percent N of the biosolids used were increased, not by physically applying more than 2351 wet tons per acre.

To reach the three application rates per acre, it was necessary to use operational information to determine how much application would take place in a normal week given the abilities of equipment and personnel. This was determined by figuring the average number of wet tons per truck (18 wet tons), times the number of loads per day, and the number of work days per week. This information was used later when estimating equipment and personnel needs and their associated costs under the different scenarios.

Land Requirements

An important aspect of deep row application is the land requirements. Since one application is made every rotation, there must be adequate land available during the rotation length before reapplication is needed. In our scenario we used a rotation length of 7 years on a 125 acre land base. However, if the rotation length can be reduced by improving the growth of the trees through better vegetation management, phosphorous amendments, or other means, this would reduce the rotation length and have a significant impact on land requirements and/or application rate that could be sustained. Likewise, if rotation length is increased, it will increase the land base required by 17.3 acres for each additional year. Rotation length was kept constant for this analysis until other research information provides better information.

In this analysis, it was assumed that the site is only 125 acres, which worked out to 121 acres in this case. Hence, 17.3 acres per year are required using a 7 year rotation, regardless of the application rate. The only factor changing is the amount applied per acre.

Financial Projection – Income and Expenses

This project attempted to estimate annual income and expenses based on the expense factors identified and the present income structure of the industry (Table 18). The \$25 per wet ton received for application of the biosolids does not include the cost of trucking to the site, which may be figured into actual contracts in a number of ways.

The main expenses that change with the higher application rates are equipment operators, and dozer and excavator equipment costs. Many of the other costs are not significantly impacted by higher application rates. The general trend in equipment operator needs is that an additional equipment operator is needed when you go to the next higher application rate.

The bottom line of this analysis is the profit, calculated as annual income minus annual expenses. At the lower application rate the operation makes little profit (\$4,075), however, profits increase dramatically at the 8000 lbs N rate to \$208,325. At the highest application rate of 12,000 lbs N the profit almost doubles to \$412,575.

What this analysis clarifies is that if the higher application rates are environmentally feasible, then the profit potential would likely attract others into the industry. It is important to note that the higher profits at the higher rates would not likely be sustained as more competitors entered the industry and market competition would likely reduce profits.

Some Highly Variable Costs

The values provided for taxes, permits & assessments, tree harvesting, opportunity cost per year are included at their actual cost, but may be reduced as indicated below:

- Taxes – many gravel spoils are taxed as commercial properties, however, because this type of operation is considered a tree farm, it is eligible for a woodland assessment, which would reduce the taxes to about \$1-2 per acre. However, a forest stewardship plan must be developed and implemented (Kays and Schultz, 2003).

- Monitoring costs – since the present deep row application is operated under a research permit, the monitoring costs depend upon what the Maryland Department of Environment determines is needed. Once research is completed it is likely that draft COMAR regulations can be developed so that actual monitoring costs can be known by those considering the enterprise.
- Permits and assessment fees – similar comments as provided for monitoring.
- Tree harvesting – one of the objectives of the current research is to make it possible to grow a tree suitable for pulp production in the rotation time so that a commercial harvester could take the trees at a break-even cost. Presently, harvesters are paid to chip the trees on site which is expensive.
- Opportunity cost – this is the value this land could bring if used for other purposes. This value can be changed depending upon the business operation.

Other Considerations

Presently, biosolids may be trucked long distances (hundred of miles) for application to farm fields or disposal in landfills. The sites for deep row application are within 40 miles of most treatment facilities and would dramatically reduce trucking and the associated pollution from emissions, wear and tear on highways, accidents, and noise associated with truck traffic. In addition, the deep row application with trees has desirable environmental benefits associated with the reclamation of gravel spoil, improved wildlife habitat, the production of forest products, carbon sequestration, improved water quality, and the general attributes of open space and working lands. These are external costs that are not incorporated into a financial analysis for any one enterprise, but real costs none the less to local, state, and federal governments, that is, the taxpayer.

Table 18 Hypothetical business scenario for deep row biosolid application with trees.

Dale Johnson, Farm Management Specialist
 Jonathan Kays, Natural Resource Specialist
 University of Maryland Cooperative Extension

Business resources

Land & Bulidings

125 acres gravel spoil
 Office trailer
 Storage trailer

Site development

Well
 Electricity
 Telephone
 Geological assessment
 Well monitoring
 Erosion and sediment control/site grading
 Permits

Equipment

Bulldozer
 Backhoe
 Pickup
 Pickup
 ATV
 Scale

Human

Equipment operators
 Manager

Production

Application rates per acre
 855 wet tons per acre 4000 lbs N
 1710 wet tons per acre 8000 lbs N
 2351 wet tons per acre 12000 lbs N

Application rates per week

18 wet tons per load, 3 loads per day, 5 days a week	285
18 wet tons per load, 6 loads per day, 5 days a week	570
18 wet tons per load, 9 loads per day, 5 days a week	855

Application rate per acre	855	1710	2351
Application rate per week	285	570	855
Acres need per week	0.33	0.33	0.33
Acres needed per year	17.3	17.3	17.3
Years per rotation	7	7	7
Acres per rotation	121	121	121

Table 19 Financial projection.

Annual income			
Application rate per week	285	570	855
Price/wet ton	25	25	25
Income per year (line 1 x line 2 x 52 weeks per year)	370,500	741,000	1,111,500
Forest product income			
Annual expenses			
Manager	60,000	70,000	80,000
Equipment operator 1	50,000	50,000	50,000
Equipment operator 2		50,000	50,000
Equipment operator 3			50,000
Office trailer, \$200 month	2,400	2,400	2,400
Storage trailer, \$150 month	1,800	1,800	1,800
Dozer \$75/hour, 5 hours/day, 250 days	93,750	187,500	281,250
Excavator \$75/hour, 2 hours/day, 250 days	12,500	25,000	37,500
Service vehicles 40,000 miles/year, \$0.35/mile	14,000	14,000	14,000
ATV	1,500	1,500	1,500
Taxes, residential assessment, \$75/acre, 125 acres	9,375	9,375	9,375
Utilities, \$100/month	1,200	1,200	1,200
Insurance	15,000	15,000	15,000
Monitoring, 4/year	6,000	6,000	6,000
Wells, cost recovery # Years	500	500	500
Permits & assessment	4,000	4,000	4,000
Professional improvement	2,000	2,000	2,000
Tree planting, 17 acres/year, \$600/acre includes cuttings	10,200	10,200	10,200
Tree harvesting, 17 acres/year, \$1,000/acre	17,000	17,000	17,000
Lime 5 ton/acre, 18 acres, \$30/ton	2,700	2,700	2,700
Opportunity cost of land, \$500/acre/year	62,500	62,500	62,500
Total expenses (Total of lines 7...27)	366,425	532,675	698,925
Income - expenses (line 3 - line 28)	4,075	208,325	412,575

* indicates costs that may be highly variable depending location & circumstances

Other considerations

Trucking costs \$1/mile	Biosolid sustainability
Trucking emission reduction	Forest renewable resources
Carbon sequestration	Reclamation
Open space/working land	Noise, Truck Traffic
Wildlife habitat	Water quality

**EDUCATION OF STATE AND LOCAL ENVIRONMENTAL PROFESSIONALS
ABOUT THE USE OF DEEP-ROW BIOSOLID APPLICATIONS**

One-day field days were held in early October during each year of the project: 2002, 2003, and 2004. The format of the field days included a morning session at the Prince George's County Cooperative Extension office where a project overview and research results were shared. This was followed by a field session at the ERCO site to demonstrate the deep row technique and showcase the research. Each of these annual sessions was attended by about 35-50 professionals and informed citizens from industry, state agencies, universities, and others. Participants were not only from Maryland but from Virginia, Pennsylvania and West Virginia, as well.



Figure 33. Steve Gerwin speaking to tour group (October 2003).



Figure 34. Eric Flamino explains the deep row process to a group of professional foresters.

Exit surveys and interviews of attendees confirmed the positive value of these field days, which have consistently resulted in an expanded network of interested clientele, project ideas, and funding sources. Deep row projects or plans for the installation of projects are pending in British Columbia, Virginia, and Pennsylvania, and are a direct result of the annual field tours or other tours of the property. During the last workshop held in October 2004, a CD-Rom was made that included all the powerpoint presentations. A copy of that CD was provided to WSSC and other project sponsors. Individuals and groups continue to visit the site on a regular basis.

REFERENCES

- Aschmann, S.G. 1988. Effects of municipal sewage sludge application on a mixed hardwood forest in Maryland. Ph.D. Dissertation. University of Maryland, College Park, MD.
- Bear, J. 1972. Dynamics of Fluids in Porous Media. American Elsevier Publishing Co., New York, NY.
- Brady, N.C. and R.R. Weil. 2002. The Nature and Properties of Soil, 13th edition. Pearson Education, Inc., Upper Saddle River, New Jersey.
- Burken, J. and J.L. Schnoor. 1998. Predictive relationships for uptake of organic contaminants by hybrid poplar trees, *Environmental Science and Technology*, Vol. 32, pp. 3379-3385.
- Chaney, R.L., S.B. Hornick, and P.W. Simon. 1977. Heavy metal relationships during land utilization of sewage sludge in the Northeast. P. 283-314. *In* Land as a waste management alternative. Proc. 1976 Cornell Agric. Waste Mgt. Conf., Ithaca, N.Y. Ann Arbor Science Publishers, Inc., Ann Arbor, Mich.
- Clapp, C.E., R.H. Dowdy, D.R. Linden, W.E. Larson, C.M. Hormann, K.E. Smith, T.R. Halbach, H.H. Cheng, R.C. Polta. 1994. Chapter 20: Crop yields, nutrient uptake, soil and water quality during 20 years. *In: Sewage Sludge: Land Utilization and the Environment*. Clapp, C.E., W.E. Larson, and R.H. Dowdy, editors. SSSA Miscellaneous Publication. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America, Inc.
- Cole, D.W., C.L. Henry, W.L. Nutter, Eds. 1986. The forest alternative for treatment and utilization of municipal and industrial wastes. Proceedings of the Forest Land Applications Symposium, June 25-28, 1985, Seattle, WA. University of Washington Press, Seattle, WA.
- ENR. 1997. Landfills: bay area expansion stalled. *Engineering Record*. Vol. 238(14):15.
- ERCO. 2000. Beneficial reuse tree farm: Annual Report. Report to MDE pursuant to permit requirements. ERCO, Inc., Glen Burnie, MD 21061.
- Felton, G.K. 1995. Temporal variation of soil hydraulic properties on MSW-amended mine soils. *Trans. ASAE* 38(3):775-782.
- Felton, G.K. and M. Ali. 1992. Hydraulic parameter response to incorporated organic matter in the B horizon. *Trans. ASAE* 35(4):1153-1160.
- Ferro, A., J. Chard, R. Kjelgren, B. Chard, D. Turner, T. Montague. 2001. Groundwater capture using hybrid poplar trees: evaluation of a system in Ogden, Utah, *International Journal of Phytoremediation*, Vol. 3, No. 1, pp. 87-104.

- Flamino, P.D. and F.R. Gouin. 1988. Biomass production on disturbed soils amended with undigested limed sewage sludge by the “deep-row” method. Federal EPA Grant fund proposal. University of Maryland, College Park, MD.
- Freeze, R.A. and J.A. Cherry. 1979. Groundwater. Prentice-Hall, Inc. Englewood Cliffs, NJ.
- Gouin, F.R. 1994. Informal assessment of ERCO project.
- Granato, T.C., and R.I. Pietz. 1992. Chapter 9: Sludge Application to Dedicated Beneficial Reuse Sites. From: Municipal Sewage Sludge Management: Processing, Utilization, and Disposal. C. Lue-Hing, D.R. Zenz, R. Kuchenrither, editors. Water Quality Management Library, Volume 4. Technomic Publishing Company, Inc. Lancaster, PA.
- Gshwind and Pietz, 1992. Chapter 10: Application of Municipal Sewage Sludge to Soil Reclamation Sites. From: Municipal Sewage Sludge Management: Processing, Utilization, and Disposal. C. Lue-Hing, D.R. Zenz, R. Kuchenrither, editors. Water Quality Management Library, Volume 4. Technomic Publishing Company, Inc. Lancaster, PA.
- Hansen, E.A. 1994. A guide for determining when to fertilize hybrid poplar plantations. Res. Pap. NC-319. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station.
- Hansen, E.A. and D.N. Tolsted. 1985. Nitrogen sources and fertilization rates affect growth of hybrid poplar. In: Proc. Fifth Central Hardwood Forest Conf., J.O.Dawson and K.A. Majerus (eds). Dept. Forestry, University of Illinois, Urbana-Champaign, IL.
- Heilman, P.E., R.F. Stettler, D.P. Hanley, R.W. Carkner. 1995. High yield hybrid poplar plantations in the Pacific Northwest. Pacific Northwest Regional Extension Publication 356.
- Kays, J. S., & V. M. Schultz. (2003). Tax Considerations for Forest Landowners. (Fact Sheet 630). College Park, MD: UMCP, MCE.
- Kays, J.S., G.K. Felton, and E.J. Flamino. 1999. Deep-row application of biosolids to grow forest crops on mine spoils: potential utilization for the Baltimore, MD - Washington, D.C. Metro area. In Proceedings of the Water Environment Federation/Association of Wastewater Operators Joint Residuals and Biosolids Management Conference. January 27-30, 1999. Charlotte, NC: Water Environment Research Federation.
- Kays, J.S., G. Felton, E. Flamino and P.D. Flamino. 1997. Use of deep-row biosolid applications to grow forest trees: a case study, In: The Forest Alternative: Principles and Practices of Residual Use. Preliminary Proceedings. C.L. Henry (ed.). University of Washington, Seattle, WA.

- Kays, J.S. 1996. Use of deep-row biosolid applications to grow forest trees and reclaim wildlife habitat: a case study, Profitable Agriculture and a Clean Environment, University of Maryland Cooperative Extension Service, College Park, MD.
- Licht, L. A. 1990. Poplar tree buffer strips grown in riparian zones for biomass production and nonpoint source pollution control. Ph.D. Dissertation. University of Iowa. University Microfilms International (UMI) Dissertation Services, Ann Arbor, MI (order number 9112446).
- Lindau, C.W., W.H. Patrick Jr., R.D. Delaune, K.R. Reddy, P.K. Bollich. 1988. Entrapment of Nitrogen-15 dinitrogen during soil denitrification. *Soil Sci. Soc. Am. J.*, 52:538-540.
- Lue-Hing, et al., 1992. Municipal Sewage Sludge Management: Processing, Utilization, and Disposal. C. Lue-Hing, D.R. Zenz, R. Kuchenrither, editors. Water Quality Management Library, Volume 4. Technomic Publishing Company, Inc. Lancaster, PA.
- Maryland Department of Environment. 1997. 1995 sewage sludge utilization in Maryland. Annapolis, MD.
- MDE. 1998. 1996 sewage sludge utilization in Maryland," Maryland Department of Environment, Design and Certification Division, Baltimore, MD.
- Mitchell, D.S., A.C. Edwards, R.C. Ferrier. 2000. Changes in fluxes of N and P in water draining a stand of Scots pine treated with sewage sludge. *Forest and Ecology and Management* 139: 203-213.
- National Agroforestry Center. 2000. Working trees for treating waste. Publication NPS 00-0254. USDA National Agroforestry Center, University of Lincoln, Lincoln, NE.
- Newman, L.A., X. Wang, I.A. Muiznieks, G. Ekuan, M. Ruszaj, R. Cortelucci, D. Domroes, G. Karscig, T. Newman, R.S. Crampton, R.A. Hashmonay, M.G. Yost, P.E. Heilman, J. Dufey, M.P. Gordon, D.E. Strand. 1999. Remediation of trichloroethylene in an artificial aquifer with trees: a controlled field study, *Environmental Science and Technology*, Vol. 33, pp. 2257-2265.
- Outwater, A.B. 1994. Reuse of Sludge and Minor Wastewater Residuals. CRC Press, Inc. Boca Raton, Florida.
- Patrick, W.H. and S. Gotoh. 1974. The role of oxygen in nitrogen loss from flooded soils. *Soil Science* 118(2):78-81.
- Pepperman, R.E. 1995. Report on the ERCO, Inc. Tree Farm Biosolids Benifical Reuse System. Environmental Group Services, Inc., Baltimore, Md. pp74.
- Pivetz, B. E., 2001. Phytoremediation of contaminated soil and ground water at hazardous waste sites, EPA ORD Ground Water Issue, EPA/540/S-01/500.

- Purkable, T.L. 1988. Effect of composed sewage sludge on water quality and hybrid poplar growth. M.S. Thesis, University of Maryland, College Park, MD.
- Quinn, J.J., M.C. Negri, R.R. Hinchman, L.P. Moss, J.B. Wozniak, E.G. Gatliff. 2001. Predicting the effect of deep-rooted hybrid poplars on the groundwater flow system at a large-scale phytoremediation site, *International Journal of Phytoremediation*, Vol. 3, No. 1, pp. 41-60.
- Ritter, W.F. and L. Bergstrom. 2001. Chapter 3: Nitrogen and Water Quality. From: Agricultural Nonpoint Source Pollution: Watershed management and hydrology. W.F. Ritter and A. Shirmohammadi, editors. CRC Press LLC, Boca Raton, Florida.
- Shepherd, M.A. 1996. Factors affecting nitrate leaching from sewage sludges applied to a sandy soil in arable agriculture. *Agriculture, Ecosystems and Environment* 58: 171-185.
- Sikora, L.J., W.D. Burge and J.E. Jones. 1982. Monitoring of a municipal sludge entrenchment site. *J. Environ. Qual.* 11(2): 321-326.
- Sikora, L.J. R.L. Chaney, N.H. Frankos, and C.M. Murray. 1980. Metal uptake by crops grown over entrenched sewage sludge. *J. Agri. & Food Chem.* 28(6):1281-1285.
- Sikora, L.J. and D. Colacicco. 1980. Entrenchment of sewage sludge - a disposal use alternative. *Civil Engineering - ASCE* 80-82.
- Sikora, L.J. and D. Colacicco. 1979(a). Methods used and costs associated with entrenchment of sewage sludge. P. 169-174. *In* Natl. Conf. On Municipal and Industrial Sludge. Composting-material handling. Information Transfer, Inc., Rockville, Md., in cooperation with USDA-ARS.
- Sikora, L.J., C.M. Murray, N.H. Frankos, and J.M. Walker. 1979(b). Effects of trenching undigested lime-stabilized sludge. *J. Water Pollut. Control Federation* 51(7): 1841-1849.
- Sopper, W.E. 1995. Temporal variation of soil hydraulic properties on MSW-amended mine soils. *Trans. ASAE* 38(3):775-782. Sopper, W.E., Eds. 1993. *Municipal sludge use in land reclamation*. Lewis Publishers, Anne Arbor, MI.
- Taylor, J.M., E. Epstein, W.D. Burge, R.L. Chaney, J.D. Menzies, and L.J. Sikora. 1978. Chemical and biological phenomena observed with sewage sludge in simulated soil trenches. *J. Environ. Qual.* 7(4): 477-482.
- Thomas, K. D., W.J. Reid, and P.G. Comeau. 2001. Vegetation management using polyethylene mulch mats and glyphosate herbicide in a coastal British Columbia hybrid polar plantation: Four-year growth response. *Western Journal of Applied Forestry*, 1 January 2001, vol. 16, no. 1, pp. 26-30(5)

- Tompkins, M.D. 1983. Prince Georges County Ground-Water Information: Well Records, Chemical-Quality Data, Pumpage, Appropriation Data, Observation Well Records, and Well Logs. Maryland Geological Survey Water Resources Basic Data Report No. 13.pp160.
- USEPA. 1994b. Chapter 3: Surface Disposal of Biosolids. From: A Plain English Guide to the EPA Part 503 Biosolids Rule, EPA/832/R-93/003.
- US Environmental Protection Agency. 1994a. A Plain English Guide to the EPA Part 503 Biosolids Rule. EPA/832R-93/003. Washington DC. Available at: <http://www.epa.gov/OW-OWM.html/mtb/biosolids/503pe/index.htm>. Cpt 2.
- Van Ham, M.D. 1999. ERCO Tree Farm Foliar and Soils Analysis Summary. October 1999. Sylvis, Inc, Vancouver, BC.
- Van Ham, M., L. Lee, and B. McLean. 2000. Pit to park: Gravel mine reclamation using biosolids. In: Planning for End Uses in Mine Reclamation –Proceedings of the Twenty-Fourth Annual British Columbia Mine Reclamation Symposium, Williams Lake, BC. GVRD, Vancouver, BC: 38-51. Available online at: www.nutrifor.com/publications.html.
- Walker, J.M. 1974. Trench incorporation of sewage sludge. From: *Proceedings of the National Conference on Municipal Sludge Management*, Allegheny County, PA. Information Trans., Inc. Washington, D.C.
- Wilson, J.M. and W.B. Fleck. 1990. Geology and Hydrologic Assessment of Coastal Plain Aquifers in the Waldorf Area, Charles County, Maryland. Maryland Geological Survey, Report of Investigation No. 53. Baltimore, MD.pp138.
- Wilson, N. 1995. Soil Water and Ground Water Sampling. CRC Press. Boca Raton, FL.
- Zabek, L.M. 1995. Optimum Fertilization of Hybrid Poplar Plantations in Coastal British Columbia. M.Sc. thesis. University of British Columbia, Vancouver BC.
- Zabek, L.M. 2001. Nutrition and Fertilization Response: A Case Study Using Hybrid Poplar. Ph.D. Dissertation. University of British Columbia, Vancouver BC.