5.3.0 STRATEGIC FEEDSTOCK PRODUCTION ANALYSIS FOR WMC

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ACRONYMS AND SYMBOLS

1. AFRI: Agriculture and Food Research Initiative
2. DBH: Diameter at breast-height
3. DxM: P. deltoides x P. maximowiczii
4. DxN: P. deltoides x P. nigra
5. DxT: P. deltoides x P. trichocarpa
6. Dx(TD): P. deltoides x (P. trichocarpa x P. deltoides)
7. NARA: Northwest Advanced Renewables Alliance
8. NC: North Central region
9. NxM: P. nigra x P. maximowiczii
10. NxT: P. nigra x P. trichocarpa
11. PNW: Pacific Northwest region
12. TxD: P. trichocarpa x P. deltoides
13. (TD)xD: (P. trichocarpa x P. deltoides) x P. deltoides
14. TxN: P. trichocarpa x P. nigra

5.3.1 EXECUTIVE SUMMARY

GreenWood Resources studied the opportunity for poplar biomass plantations to supplement the supply of biomass originating as logging and thinning residues from coniferous stands in western Montana. Approximately 40,000 acres of agricultural and pastoral ground with annual precipitation rates of 25 to 40 inches were identified within 75 miles of potential refinery locations in Columbia Falls and Missoula. Silvicultural prescriptions and mean annual biomass increments (MAI) were projected for plantations stocked at 1,450 stems per acre and managed for five consecutive four-year coppice cycles following an initial two-year planted cycle. MAI projections varied between 2.8 and 4.9 bone dry tons per acre per year dependent on site quality and whether irrigation is applied. (MAI projections as well as varietal selections were based on a replicated varietal trial managed by GreenWood Resources and Flathead Valley Community College at Kalispell.) The economics of the opportunity were modeled for four scenarios defined as combinations of site quality and management intensity. The base case scenario - 10,000 acre development on sites of reasonable site quality and managed with intensive cultivation without irrigation – showed a break even price is $115 per bone dry ton. This pricing is higher than longstanding poplar programs in the Pacific Northwest, a consequence the region’s limited precipitation and modest growth rates; irrigation will be required on most sites. However, the more appropriate pricing level is the weighted average price refineries will pay when their biomass supply originates as logging residuals blended with the plantation supply. While the plantation component may be the higher-cost one, it represents an indispensable constituent as a strategic foundation: Dedicated biomass plantations will reduce supply and pricing uncertainties associated with the inevitable cyclicality in the housing market that drives the availability of residuals remaining after trees are cut and processed for sawlogs. In order for NARA refineries to secure requisite financing, their feedstock supply portfolios may require purpose-grown energy plantations as a necessary addition to logging residuals.

5.3.2 INTRODUCTION AND BACKGROUND

5.3.2.1 History of Poplar Plantation Development

Planting poplar in the Pacific Northwest began in 1893 when the Willamette Pulp and Paper Company established 1,000 acres of black cottonwood (P. trichocarpa) plantations in the vicinity of West Linn, Oregon over a twenty-year period, reportedly the first artificial forest regeneration program in the United States (Priaulx 1952). Testing of hybrid varieties of poplar was then initiated in Washington in 1938 and 1939 by the U. S. Forest Service; a second effort of hybrid testing by Crown Zellerbach Corporation followed in 1947 (Beeman 1947). More recently through the 1980s and 1990s, the establishment of industrial poplar plantations in the Pacific Northwest repeatedly occurred as a strategic response to constraints in the regional supply of hardwood fiber for premium grades of communication papers. Five pulp and paper companies with significant investments in the Pacific Northwest undertook the development of these operations that are now recognized as the forerunners of today's poplar bioenergy plantation industry.

The recent history of the Pacific Northwest's poplar industry can be looked at as having a developmental period during 1984 – 1999 followed by a second period during 2000 – 2007 that saw a divestiture of assets and their reorganizations into a new ownership structure. The developmental period began as an effort to forestall forecasted shortages in the region's sole commercial hardwood species, red alder (Alnus rubra) through the establishment of poplar plantations as a replacement supply of short fibers (i.e. less than a millimeter in length). In 1982- 1983, Crown Zellerbach Corporation began planting hybrid poplar in the lower Columbia River valley near Clatskanie, Oregon and in the mid-Columbia River basin near Boardman, Oregon (Huddy et al.1983). Ultimately, James River Corporation acquired Crown Zellerbach's paper division and expanded the Clatskanie plantation to 11,000 acres. Shortly thereafter, Boise Cascade and Potlatch Corporations took the lead from James River in the mid-Columbia River basin, independently establishing a combined total of 36,000 irrigated plantation acres in the areas around Boardman, Oregon and Wallula, Washington. By the mid-1990s, MacMillan Bloedel had added 7,900 plantation acres in the Nooksack, Skagit, Snohomish, and Snoqualmie River valleys of northwest Washington and in British Columbia's Fraser River Valley and Vancouver Island.

Under James River's ownership from 1991 through 2000, the Clatskanie plantation produced approximately 30,000 dry tons annually for the refiner-ground wood operation at its Wauna, Oregon mill for the manufacture of highbright specialty newsprint. Boise Cascade's goal for its poplar program was to provide the entirety of the hardwood fiber required for the production of uncoated free sheet at the company's Wallula, Washington mill. Planting began in 1991 and the program harvested up to 100,000 dry tons annually beginning in 1997. Today, Boise Cascade manages approximately 9,000 acres strategically located within 20 miles of its Wallula mill. The Potlatch program started in 1994 as a response to declining wood flow from national forests and the need to increase fiber self-sufficiency at the Lewiston, Idaho mill. A 17,000 acre plantation at Boardman, Oregon was sized to annually produce 170,000 dry wood tons to meet 25-30% of the fiber requirements of the Kraft pulp operation for paperboard manufacturing. However in 1999, the company shifted its focus to the higher value saw log market with residual chips being sold to area pulp and paper mills. Finally, the Macmillan Bloedel poplar program spun off its poplar operations along with mills at Powell River and Port Alberni, British Columbia in 1998 in the formation of Pacifica Papers Inc. and later NorskeCanada. Ultimately the majority of the poplar estate was acquired by Catalyst Paper Corporation that harvested the stands as they matured, but did not replant in view of continuing low market prices for pulpwood.

The second period encompassing 2001 through 2007 was a time of active acquisition and consolidation in the poplar plantation industry orchestrated by GreenWood Resources. In 2001, the Clatskanie plantation was acquired by a timber investment organization under GreenWood's management, and production shifted to saw logs to increase the holding's profitability. Then in 2004, Boise Cascade sold approximately 8,800 acres of its poplar plantation to a second GreenWood investment fund as part of a larger sale of its paper and wood-products businesses to Madison Dearborn Partners. Lastly in 2007, GreenWood Resources acquired the entirety of the Potlatch's poplar operation and quickly consolidated it with the two aforementioned poplar funds into a single entity, the GreenWood Tree Farm Fund (GTFF). Today the fund owns approximately 30,000 plantation acres, a saw mill, planer mill, and dry kilns with the capacity of milling and drying 80 million board feet per year. A veneer mill was added in 2013 by Columbia Forest Products as an integrated manufacturing line though independent of GTFF. None of the former Macmillan Bloedel poplar lands were incorporated into GTFF.

5.3.2.2 Pulping Aspects of Poplar

Poplar has been frequently pulped using the thermo-mechanical process in making a wide range of lightweight, coated and uncoated grades of specialty newsprint. The species is well suited to the mechanical pulping process where its comparatively low wood density conserves energy during chip refining. Additionally, poplar's characteristic bright wood is preserved in mechanical pulps with minimal hydrogen peroxide bleaching (Johal and Hatton 1997). The chemical process has also been used in pulping poplar where the short and relatively wide, thin-walled fibers have proven to be ideally suited for the manufacture of high quality bond paper grades. These chemical fibers are low in coarseness and collapse easily during sheet formation with longer softwood fibers resulting in a smooth, dense formation with few surface voids, superior opacity, and good print retention.

A frequently voiced concern in chemical pulping of poplar is that its low wood density reduces digesting efficiency, yielding less pulp per unit of digester volume. Yet, Rapid Impregnation, Short Time Kraft pulping studies (RIST) at the State University of New York have documented that the greater porosity of poplar wood can be taken advantage of in managing digester operations to produce a higher amount of pulp per unit time compared with hardwoods of higher wood density (Francis et al. 2006). It remains to be determined whether converting poplar biomass to liquid fuels will similarly benefit from the porosity relationship.

5.3.2.3 Poplar as an Energy Feedstock

The advantage of short rotation, intensive culture forestry, originally envisioned as a novel source of pulping fibers nearly 40 years ago, has been vital to the development of the Pacific Northwest's poplar plantation industry (Ribe 1974). These advantages included: (1) High volume fiber production on a comparatively small land area, (2) Early amortization of site preparation, planting, cultivation and cropping costs, (3) Increased uniformity in wood and fiber properties with resultant increases in processing efficiencies, (4) Mechanization of farming practices to reduce labor costs, and (5) Lowered establishment costs through coppice regeneration. Today, hybrid poplar is considered to be one of the most promising energy crops for the renewable energy industry because of many of these same benefits (De La Torre Ugarte et al. 2003, Huang et al. 2009). And the realization of a poplar bioenergy industry should prove impactful to rural communities as its economic contribution may exceed some traditional agriculture ventures (Lazarus et al. 2011). The magnitude of the impact is expected to be dependent upon the capacity of power generating facilities and likely bio-refineries too (Gasol et al. 2009).

The specific case for large scale hybrid poplar energy farms is therefore often made in terms of: (1) Feedstock production, (2) Energy conversion, and (3) Environmental impacts. It is notable that within each of these three considerations, important varietal effects have been documented that can be exploited to further the prominence of the poplar bioenergy model.

Production - Hybrid poplar is the fastest growing tree species within the temperate zone with growth rates approximating five to eight dry tons per acre per year achieved on four-to-eight year pulpwood rotations (Stanton et al. 2002).

Moreover, when regenerated by coppice, productivity increases between the planted stage and subsequent coppice stages, with increases of up to 33% reported on good quality sites (Paris et al. 2011). The length of the coppice stage is equally important with growth rates observed over a four year coppice cycle exceeding those during a two year one (Guidi et al. 2009). Biomass quality is correspondingly affected by the length of the coppice cycle with higher proportions of cellulose and lowered lignin proportions characterizing longer cycles. To improve biomass production by varietal selection, poplar breeding efforts target genotypes that can withstand repeated coppicing with high stool survival and a favorable distribution of stump sprouts to maximize harvesting efficiency (Al Afas et al. 2008).

Conversion - Poplar wood has been successfully converted to liquid fuels using both biochemical and thermo-chemical methods (Lu et al. 2009, Jones et al. 2009) In the biochemical process, steam explosion, hot water extraction and exposure to low-concentrated acids are often used in pretreating poplar wood to make the cellulose more accessible to hydrolytic enzymes (Lu et al. 2009).

Poplar genotypes composed of proportionately higher sugar and lower lignin contents are desired for biochemical conversion (Luo et al. 2002). Varietal selection also targets genotypes characterized by amorphous cellulose crystallinity and high acetyl contents to effect high rates of sugar release upon hydrolysis (Laureano-Perez et al. 2006). The cellulose component of biomass is critical though and varies among poplar varieties by seven to 15 percentage points (Dinus 2001). The other two major biomass constituents, hemicellulose and lignin, do not seem to display as much variance and selection opportunities may not be as good. For example, the range in glucose and xylose content among 51 hybrid poplar clones was 48 to 53% and 17 to 20% of sample dry weight, respectively (GreenWood Resources, unpublished data). Sannigrahi et al. (2010) reported that a fixed sample of clonal varieties varied in cellulose content from 42 to 49% of dry weight, 17 to 22% in hemicellulose, but 21 to 29% in lignin. Francis et al. (2006) reported a similar range for a fixed varietal sample with the respective variations in cellulose, hemicellulose, and lignin as 44 to 50%, 17 to 21%, and 18 to 23%. Though selection opportunities for lignin content may or may not be limiting, the opportunity to base selection on the syringyl-toguaiacyl monolignol ratio should be better, and likely more consequential (Studer et al. 2011). To illustrate, data from GreenWood Resources indicates substantial variation in the monolignol ratio combined with high clonal repeatabilities: The range in the syringyl-to-guaiacyl ratio was 1.26 – 2.06, 1.31 – 2.06, 1.30 – 2.18, and 1.53 – 2.32 for its 1994, 1996, 1999, and 2003 breeding populations, respectively. Clonal repeatabilities are also substantial at 0.79, 0.77, 0.70, and 0.79 for the respective populations. Higher proportions of the syringyl monolignol form are generally indicative of heightened rates of sugar release.

The thermo-chemical method has also been used to convert hybrid poplar to pyrolysis oils by combustion of the wood at high temperatures in the absence of oxygen (Jones et al. 2009). The resultant gases are condensed to pyrolysis oils that are hydrotreated for cracking and distillation to gasoline and diesel fuels. Genotypes high in lignin may be well suited for combustion or fast pyrolysis due to elevated calorific content. Those with reduced wood concentrations of alkaline cations may also be preferred for the efficiency of the pretreatment step using dilute acids (Scott et al. 2000). But most of all, poplar varietal selection emphasizes specific gravity to increase biomass. The upper bound of poplar wood specific gravity approximates .400 (Robison et al. 2006).

Environmental - The net effect of poplar cropping systems on greenhouse gas emissions compares favorably to those of other cellulosic crops owing to their less frequent tillage and cutting cycles, with greenhouse gas sinks in excess of 200 g CO2e-C per square meter per year (Adler et al. 2007). Relative to petroleum derived fuels, liquid fuels production from European hybrid poplar plantations has been modeled to reduce contributions to global warming by 62%, although the location of the plantations and the intensity of the production practices strongly affect the outcome of the life cycle analyses (Gonzalez-Garcia et al. 2009). Rafaschieri et al. (1999) similarly report that, of all agricultural production factors that bear upon life cycle analyses for electrical power generation from poplar feedstock, pesticide and fertilizer usage are the weightiest ones. Soil carbon sequestration by poplar bioenergy cropping systems is a second environmental factor of note, although the dynamics are not well understood (Garten et al. 2011). The net amount of sequestered carbon reported for one poplar study in the southeastern United States ranged from five to 11 dry tons per acre after five years (Dowell et al. 2009). Increases of 68% in soil carbon over continuous rotations have been projected for low organic matter soils. Conceivably, clonal variation in biomass partitioning and the rate of root decomposition can be exploited to improve sequestration rates (Garten et al. 2011).

It has been known for some time that poplars emit significant quantities of isoprene, a volatile organic compound that potentially affects ozone concentrations (Isebrands et al.1999). Accordingly, as plantations of hybrid poplar become more commonplace as sources of cellulose for transportation biofuels they could influence regional air quality. Here again, varietal selection maybe important in mitigating emissions: Eller et al. (2012) have quantified the selection opportunity, reporting a threefold range in isoprene emissions among 30 poplar varieties. The variation allows for the selection of poplar varieties with reduced rates of isoprene emissions.

5.3.3 THE WESTERN MONTANA CORRIDOR PROJECT

The NARA team leadership identified the region between Columbia Falls and Missoula, Montana as the initial community development zone for a bioenergy and bio-products industry complex having many facets of the supply chain spectrum. This initial region was named the western Montana corridor. GreenWood Resources attended a NARA community meeting in Missoula in June 2012. During the meeting GreenWood participated in several conversations with entities that were potentially interested in a sustainable biomass supply from purpose-grown tree energy farms. One of the parties, Rivertop Renewables, is a Missoula chemical company that manufactures bio-products from sugar derivatives (e.g. glucaric, xylaric, arabinaric, and mannaric acids) with which the company's produces polymers for the manufacture of absorbents, adhesives, films, fibers, and various composites. GreenWood perceived sufficient interest in poplar biomass to initiate a strategic plantation business evaluation plan for the corridor.

The objective of the plan was to:

1. Complete a land study of the western Montana corridor to quantify the amount of suitable sites for poplar production.
2. Develop a silvicultural plan specific for the major plantation sites that would be needed to produce a sustainable supply of biomass.
3. Estimate the yield potential for major plantation site categories for the region and identify limiting factors to cost-effective biomass production.
4. Conduct an economic analysis for the major plantation site categories. This is the major deliverable for this preliminary project report.

Key to the strategic assessment is a poplar testing program that GreenWood has conducted since 2009 with Flathead Valley Community College in Kalispell. Growth and yield and clonal varietal performance data from the plot is indispensable to the strategic plan.

Two foundational points define the strategic planning process. First, GreenWood recognizes that the NARA feedstock strategy relies upon logging residuals that follow saw log harvests as well as biomass from thinning operations as the sole source of renewable biomass. Thus the poplar plantations are envisioned as a supplementary supply. GreenWood's expectation is that hybrid poplar biomass plantations may not be cost competitive with logging residuals. Yet in order for NARA bio-refineries to secure requisite financing, their feedstock supply portfolios should require purpose-grown energy plantations as a mandatory addition to forest residuals. A portfolio that includes a component of purpose-grown trees will reduce supply and pricing uncertainties and improve refinery operations. Secondly, the western Montana corridor does not meet all of the requirements of a poplar bioenergy production program. The amount and distribution of precipitation within this region is the main limiting factor. Thus, the silvicultural plan by necessity includes irrigation in many cases. The region's mean winter minimum temperature is also a critical limiting factor. Here clonal selection based on the Kalispell plot plays a critical role in the identification of adapted plant material.

5.3.4 THE WESTERN MONTANA CORRIDOR LAND STUDY

5.3.4.1 Objective

GreenWood's land study was designed to delineate areas potentially suitable for sustainable poplar plantations in the western Montana corridor between Columbia Falls in the north and Missoula in the south. Public spatial datasets were relied upon to determine land and current use categories that fit descriptions for prospective poplar plantation developmental sites. The classifications developed from each of the spatial dataset were: (1) Gap Analysis of land use in agriculture, pasture, or haying, (2) Annual precipitation rates ranging from 15 to 40 inches within five inch increments, (3) Soil depth greater than 45 inches, and (4) Topography described as level or gently rolling with maximum slope of eight percent. The principal dataset employed was the U. S. Geological Survey's Gap system based on 2001Landsat imagery. The dataset contains 590 ecosystem classifications. Three other datasets were also used corresponding to average annual precipitation, soil depth, and topographic flatness.

5.3.4.2 Methodology

Columbia Falls and Missoula were treated in the land study as probable locations for refineries that would receive poplar plantation-grown biomass along with a larger supply of logging residuals (Figure 5.3.1). Concentric rings of 25, 50, and 75 mile radii centered on each of the two refinery locations were used to define likely plantation development areas in parcels of minimum size of 20 acres. This minimum provides sufficient area for headlands for machinery operation without too great a loss of actual plantation area.

5.3.4.3 Results

The evaluation of the U. S. Geological Survey's Gap dataset showed that there is a total of 681,079 acres meeting the identification criteria currently being managed for agriculture or for pasture and hay. When this subset was intersected with the other datasets classifying the amount of annual precipitation, topography, and soil depth, a total of 40,622 acres were noted that could be found within the concentric distance rings and receiving between 25 and 40 inches of annual precipitation (Table 5.3.1). Inspection of seasonal rain distribution showed that the precipitation mainly falls outside the growing season. Thus irrigation is essential throughout much of the corridor; this will have a decidedly negative impact on the economics of production. The follow-up inspection also showed that nearly all agricultural areas have developed pivot irrigation systems. The pastoral lands are generally situated at higher elevations with rolling terrain and are not set up for irrigation.

Assuming that 20 to 25% of the 40,622 acres receiving the higher rainfall amounts can be converted to biomass production, a total of 8,124 to 10,155 acres are available within the corridor for developing purpose-grown biomass to supplement the supply of logging residuals from local softwood forests. A base case scenario was developed around a 10,000 acre development on sites of reasonable agricultural quality managed with intensive cultivation without irrigation. This became the basis of comparison of incremental addition of irrigation and other management inputs.

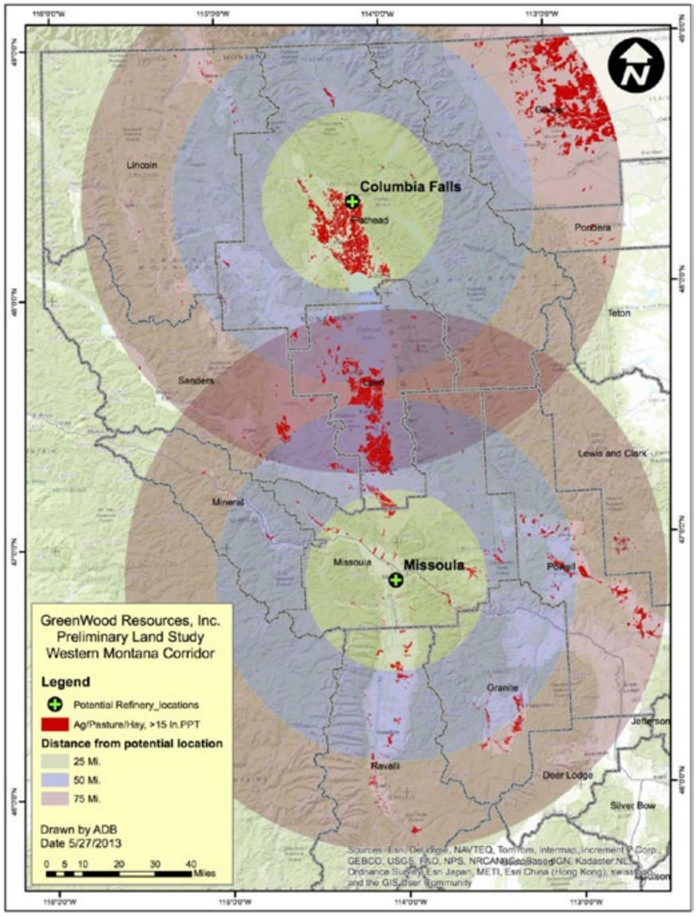

Figure 5.3.1. Preliminary land study of the Western Montana Corridor

Table 5.3.1. Results of WMC land study

Sum of Acres			Precipitation						
Location	Ring Miles	Grid Code	15	20	25	30	35	40	Grand Total
Columbia Falls	25	Agriculture		38275	4546	314			43135
		Pasture/Hay		33920	8738	1318	266		44242
	25 Total			**72195**	**13284**	**1632**	**266**		**87377**
	50	Agriculture	919	5642	247				6807
		Pasture/Hay	6241	10195	2440	728	25	34	19663
	50 Total		**7160**	**15837**	**2686**	**728**	**25**	**34**	**26470**
	75	Agriculture	33397	27295	4425				65118
		Pasture/Hay	46420	48500	4977	460	56		100413
	75 Total		**79818**	**75795**	**9402**	**460**	**56**		**165531**
Columbia Falls Total			86978	163827	25373	2819	348	34	279378
Missoula	25	Agriculture	4647	7620					12267
		Pasture/Hay	18275	15608	457				34340
	25 Total		**22922**	**23228**	**457**				**46607**
	50	Agriculture	38149	25861	937				64947
		Pasture/Hay	70765	55053	1220	156			127194
	50 Total		**108915**	**80914**	**2157**	**156**			**192141**
	75	Agriculture	28022	18674	455				47151
		Pasture/Hay	59553	47425	8319	481	25		115803
	75 Total		**87575**	**66099**	**8774**	**481**	**25**		**162954**
Missoula Total			219412	170240	11388	636	25		401701
Grand Total			**306389**	**334067**	**36760**	**3455**	**373**	**34**	**681079**

5.3.5 FEEDSTOCK PRODUCTION SYSTEM

A successful poplar program in the western Montana corridor will rely upon a tailored silvicultural program and the selection of adapted plant varieties. Appendix II, details the site preparation, crop care, and harvest activities for a 22-year coppice biomass production rotation. The structure of the 22-year rotation includes an initial planted stage that is harvested following two full growing seasons to initiate the first of five successive four-year coppice cycles. The set of silvicultural activities assumes the sites to be planted are either currently, or have recently been managed for pasture, haying, or crop production. The table also shows per-acre activity costs including those for operating and maintaining drip irrigation systems where applicable. Land and capital costs as well as management fees are not included in Appendix II, although they are included in the following section's economic analyses.

5.3.5.1 Soils

The major soil types that would be targeted for project development in the northern portion of the corridor in Flathead County are Swim silt loam, Kiwanis fine sandy loam, and Walters very fine sandy loam. Likewise in the southern portion of the corridor in the vicinity of Lake County, there are three soil types that would be most suitable for poplar plantation development. These are more consistent in textural classification and include Polson, Gird, and Lonepine silt loams. All of these soil types have good structure for poplar management with a depth-to-water table of 48 to 80 inches (Appendix I). Supplemental irrigation is a likely requirement of poplar production in nearly all situations in view of the limited growing season precipitation.

5.3.5.2 Site Preparation

Crop survival and optimum growth over the rotation are linked to the quality of site preparation. Site prep begins the year prior to planting with measures to control existing vegetation taking place in June through the application of a contact herbicide (glyphosate and/or 2,4-D). The site is not disturbed for at least seven days following the chemical application. Chemical weed control is followed by one or two passes with a heavy breaking-disk in July or August, then one pass with a finish disk and a cultipacker to smooth the surface. At this point, the site should be free of weeds with a maximum clod size of two inches. Subsoiling or chisel plowing is scheduled in the late summer or early fall to loosen any dry or compacted profiles while also marking the planting rows. Rows should be ripped to a depth of 16 inches to accommodate the planting of 18 inch cuttings. Dry fertilizer (nitrogen, phosphorus, potassium) is added at this time in quantities based on soil tests. Irrigation tube layout is scheduled after ripping in the late summer or fall, or in the spring of the planting year. Rows are oriented parallel to the long axis of the field to maximize harvesting efficiency. Row lengths must provide adequate space for turning the harvesters and the accompanying transport equipment used to convey material to the field edge for loading.

A second herbicide application is made in the fall in the form of a contact chemical to control re-sprouted weeds with the optional addition of a pre-emergent herbicide to control the germination of weed seeds over the remainder of the fall and through the following spring. A third application of a contact and pre-emergent chemical mix is made in the spring just prior to planting to ensure a weed-free condition into the early and middle part of the first growing season.

5.3.5.3 Poplar Varietal Selection

The use of superior clonal varieties and quality planting stock is essential for successful plantation performance. Five selected varieties from three taxa have proven well in GreenWood's collaborative clonal trials in Kalispell and Caldwell, Idaho, and are the ones likely best suited for the Western Montana corridor project. These five varieties originate in the following taxa: (1) Two from the P. ×canadensis (P. deltoides × P. nigra) taxon, (2) one from the P. deltoides × P. maximowiczii taxon, and (3) two from the P. ×generosa (P. trichocarpa × P. deltoides) taxon (Appendix III). The mean age-four height of the five topmost varieties in the Kalispell trial is 30 feet. The projected mean annual biomass increment (MAI) of these selections varies from 3.7 to 4.6 bone dry tons per acre (Appendix III). It is noteworthy that nearly all five selections are bred using P. deltoides selections from provenances from the North Central region, a reflection of greater adaptation to western Montana winters.

5.3.5.4 Crop Establishment

Poplar bio-energy plantations are established at density of 1,450 stems per acre. Rows are spaced 10 feet apart; three feet separate each tree within the row. Silvicultural activities in Appendix II are based on plantations established from unrooted cuttings 18 inches in length. This cutting length provides for good establishment under the typically dry conditions of western Montana and irrespective of whether irrigation is applied. Cuttings are collected in December through February from stoolbed nurseries and held in frozen storage until field planting.

Proper planting technique is among the most critical steps in successful plantation establishment. The cuttings should be planted in the soil to a depth of no less than 80% of their length to produce a favorable root-to-shoot ratio during the establishment phase when adventitious rooting is taking place. Cuttings must be planted with a vertical orientation. At least one axillary bud should be at, or above soil level. If irrigation is applied, the system should be functional and water running at the time of planting so that the cuttings are inserted into moist soil. Soil must be firmly packed around each cutting, eliminating air pockets, and allowing the soil to be fully in contact with the cutting to encourage vigorous rooting. Cuttings are normally planted by hand using labor crews to stick the cuttings into the ripper lines and firm up the soil. Varieties are deployed as monoclonal blocks.

5.3.5.5 Crop Care, Initial 2 Year Cycle

Clean cultivation promotes rapid site capture by the stand precluding weed competition for soil moisture, light, and nutrients. Two between-row mechanical cultivations are scheduled in early and late summer during each of the first two growing years. Tractors and implements are sized to fit between the 10-foot tree rows allowing for a minimum one foot clearance on either side. Within-row weed control is manually effected through hoeing or spot spraying using a shielded herbicide spray wand. Each entry into the field for within-row weed control is anticipated to cover 50% of the acres during the initial two-year stage (Appendix II). Irrigation application during the first year approximates 12 acre inches. This increases to 14 acre inches in year two. Insect pests are intermittent or localized in their occurrence; the schedule of pest control treatments in Appendix II assumes that 25% of the acres require control in any given year. Disease prevention is assumed to be provided through the deployment of resistant varieties.

5.3.5.6 Crop Care, 5 Repeated 4 Year Cycles

In preparation for the coppice phase of the 22-year rotation, weed control resumes during the first season after the initial harvest at a less intensive level with pre-emergent chemicals applied before sprouting of the stand. The pre-emergent application is followed by one or two entries into the field for within-row spot spraying or manual mechanical weed control. Mechanical tractor cultivation is also scheduled for one or two entries into the field for between-row control. The intensity of weed control declines in the second year of the coppice cycle as the crop recaptures the site; weed control is discontinued in years three or four of each coppice cycle.

Pest control continues at the same level as in previous years; the schedule of activities in Appendix II anticipates an annual treatment rate of 25% of the plantation acres. Annual application of liquid fertilizer may be recommended based on the results of soil nutrient analysis. Otherwise dry fertilizer is banded along the tree rows the spring following harvest. Irrigation application increases steadily as the crop matures through the fourth growing season from coppice, moving from 12 acre inches to 18 acre inches, in steady uniform annual increments. These irrigation rates are suggested applications, as crop demand will vary by site, available rainfall, soil type, and climate conditions. Costs shown in Appendix II are based on delivered water cost at $ 5.00 per acre inch.

5.3.5.7 Harvesting and Yield Projections

Harvest is initiated at the end of the second growing season of the initial planted cycle. This first harvest is not anticipated to fully reflect the growth and yield potential of the plantation, but serves to initiate the ensuing coppice cycles where full yield potential is realized (Appendix IV). Current harvesting technology utilizes a specialized harvesting head to sever the stems from the stumps which are then fed into a conventional agricultural forage chopper that chips the trees and blows the mass into a trailing truck or dump wagon. (Irrigation components are removed from the field prior to entry by harvest equipment.) Biomass is unloaded into road-ready trucks for transportation to the refinery. Temporary chip piles may be created either at the refinery or at the plantation to build an inventory as a hedge against supply constraints during the harvest period. Although a “just-in-time” delivery system is ideal for biomass harvesting, temporary piles up to 1,000 green tons can be produced and held for up to three months with moisture loss only in the outer portion of the pile and minimal deterioration within the pile. At the conclusion of the fifth and final coppice harvest, the field will be restored to a pre-poplar stand condition and prepared for another rotation of hybrid poplar biomass production.

The estimation of biomass mean annual increments (MAI) for the project was projected from data from the top clones from the Kalispell clone trial that were extrapolated to a per-acre basis (Appendix III). GreenWood biomass equations were used in the expanding individual stem weights to a stand distribution of 1,450 trees per acre. MAIs range from a low of 3.7 bone dry tons (BDT’s) (P. ×canadensis) per acre per year up to 4.6 BDT’s per acre per year (P. ×generosa). The MAIs used in the economic model to bracket these ranges were 2.8 BDTs for lower quality sites to 4.9 BDTs for higher quality sites to account for the effect of varying soil quality and irrigation. Harvest costs in Appendix II are based on an optimum projection of 19.6 BDTs per acre. Moisture content of 57% water is incorporated into the production cost calculations, as harvest costs are based on a green ton basis.

5.3.6 ECONOMIC ANALYSIS

5.3.6.1 Modeling Objectives

The primary objective of the economic analysis was to evaluate the commercial viability and performance of developing and managing a 10,000 acre hybrid poplar energy plantation located within 75 miles of potential refinery locations in Missoula and Columbia Falls. The coppice management scheme was modeled as the most suitable silvicultural system to achieve the investment objectives. Break-even pricing was derived and the sensitivity of key profitability drivers was evaluated to assess the impact on the IRR of the project. The analysis looked at biomass production as a function of site quality categorized as agricultural (level terrain, higher productivity) with and without irrigation and pasture (rolling, lower productivity) without irrigation. The project-level analysis focused on achieving sustained production levels and biomass delivery at or below threshold prices, factoring the amount and cost of suitable land and transportation distances to refineries. The key elements addressed in studying and modeling the plantation development project were:

1. Land quality.
2. Mode of land acquisition; impact of land pricing and distance from facility.
3. Irrigation requirement and profitability.
4. Total area of land needed for required production.
5. Minimum scale of plantation required for economies of scale.
6. Timing of land acquisition and decision to lease as opposed to a purchase option.
7. Modifications in coppice rotations during the transition phase of land development to achieve the level of sustainable fiber production.

A forest-level modeling system (Woodstock) was used to simulate dedicated bioenergy plantation development and management to produce a sustainable fiber supply over a range of land parcels varying in current land-usage, biomass productivity, lease rate, and distance from potential processing facilities. Woodstock optimization capability determines the most productive, cost effective and profitable way to develop and manage plantation resources to deliver required biomass supplies. Woodstock was used to provide long term wood supply and cash flow forecasts which were exported to financial models to evaluate financial performance (breakeven analysis, IRR, NPV) and perform sensitivity analyses. The cash flow profile, level of required capital investment, and timberland asset valuations for investment entry and exit decisions are optional outputs for such ventures.

5.3.6.2 Model Inputs

Plantation Development Strategy - The analysis was structured on the development of a fixed 10,000 acre plantation that would produce a sustainable volume varying between 28,000 and 46,000 BDT per year dependent on land quality. Two zones of 5,000 acres of plantations concentrated around Missoula and Columbia Falls were assumed. An initial two-year planted cycle followed by a succession of four-year coppice cycles was also assumed. Land development rate was set at 2,500 acres per year for the first four years. If scaling up at this rate is not possible due to land availability, then deviation in the cutting cycle lengths and associated yields will be necessary to provide sustained biomass production. This issue is not addressed in the modeling exercise under the assumption that any deficits in dedicated plantation wood supply could be offset by increasing the amount of biomass originating as logging and thinning residuals.

Land - Based on the GIS land study, it was determined that the land supply is not constrained when the project is scaled to 10,000 acres. The land base considered for this study includes: (1) Productive agricultural land of generally level terrain with irrigation infrastructure and access to deep wells and (2) Less productive pastoral lands of rolling terrain unsuitable for irrigation. Given the probability

Table 5.3.2. Historical land lease rates in the WMC. Sources: http://www.nass.usda.gov/Statistics_by_State/Montana/Publications/Annual_Statistical_Bulletin/2011/economic.pdf http://www.nass.usda.gov/Statistics_by_State/Montana/Publications/Annual_Statistical_Bulletin/2012/EcoCashRents.pdf

Processing Facility Location	Missoula					Missoula & Columbia Falls					Columbia Falls					NW Montana Average				
County	Missoula					Lake					Flathead									
Year	2008	2009	2010	2011	2012	2008	2009	2010	2011	2012	2008	2009	2010	2011	2012	2008	2009	2010	2011	2012
Irrigated agricultural land			25.50		31.50	56.50	78.00	73.00	64.00	62.50		64.00	64.00			50.50	63.00	63.00	53.00	80.00
Non irrigated agricultural land										29.50		30.50					24.50			23.00
Pasture	41.50	16.50	18.00			13.50	10.00	19.00	10.50	10.00		8.40	3.30		9 .00	12.00	9.30	9.80	9.20	8.10

that only a portion of this land base within the preferred 25 mile radius would be available and the block sizes may not be adequate, 5,000 acre land banks within 75 miles (weighted average of 50 miles) from Missoula and Columbia Falls were assumed to be potentially available.

The price for land in the surrounding counties was evaluated and an average annual lease rate of $65 per acre was assumed applicable for the base case economic analysis of agricultural land. The lease rate for pastoral ground was $10.00 per acre per year (Table 5.3.2).

Silviculture and Yields - The plantation models are based on the feedstock production system described in Appendix II. The salient elements are establishment by cuttings at a stocking rate of 1,450 stems per acre. The plant material base would be made up of tested varieties of three adapted hybrid taxa. Stands are managed on a 22-year rotation distributed as an initial two-year coppice set-up, plus five cutting cycles of four years each. Harvesting on repeated four-year coppice cycles is gauged to be optimum in terms of maximizing recovered yield. Irrigation is assumed on the agricultural sites but not the pastoral land. The per-acre MAI for the agricultural sites is assumed at 4.9 BDTs per acre and 2.8 BDTs per acre for the lower quality, pastoral sites.

Operating Costs - The cost structure associated with site preparation, crop care, and harvest operations described under feedstock production are based on preliminary estimates from comparable coppice bio-energy plantations and adjusted for local farming contractor rates (Appendix II). However, the cost structure reflects the higher end of the spectrum for intensive levels of site preparation and ongoing crop care. In practice, some variable operational costs will likely be lower (e.g. weed and pest control costs). It is probable too, that fertilizer requirements can be reduced depending on soil type. All costs are modeled in real terms.

Irrigation Options - The productivity of bioenergy coppice plantations can be enhanced through irrigation on dryland sites targeted for this economic analysis. The agricultural lands are high quality soils with good nutrition levels and water retention capacity. But where annual precipitation is less than 30 inches that is not evenly distributed, irrigation is a necessary option to enhance survival, growth, and biomass yields. Modeled irrigation system costs are specific to a drip system with irrigation hoses placed along each planting line. This system requires the placement of pumps on wells. Modeling includes the cost of hose removal and roll out at the beginning and end of each harvesting operation, respectively. The cost of annual irrigation is comprised of water plus electricity for pumps.

Fertilizer Options - The western Montana production system is modeled assuming fertilizers would be applied. GreenWood's opinion is that as the project develops fertilization may not be required on agricultural sites at the frequency or concentrations prescribed. When applied, however, nitrogen would be as a liquid amendment delivered through the drip irrigation system. On non-irrigated, pastoral sites the fertilizer would be applied during initial site preparation by incorporation into the rip lines and subsequent applications would be made after each harvest cycle by banding alongside the stool rows.

Capital Costs - Modeled capital costs are limited to irrigation development. Most leased agricultural properties include wells and a network of roads of adequate density and grade for coppice plantation management. The capital cost of a "greenfield" development of a drip irrigation system is approximately $1,000 per acre for land blocks ranging from 200 to 500 acres. This scale is required for an efficient design of pump systems, filters, and controls. Capital costs increase significantly for smaller parcels of land. All mechanized operational capital cost are embedded in contract rates for operation; no machinery or equipment cost are directly modeled. Similarly, no buildings or vehicle fleets are included, as these are contained in the structure of the management fee.

Harvesting and Biomass Transport Costs - Harvesting costs are estimated on a per acre basis. The initial age-two harvest operations of small dimension coppice shoots is $249.53 per acre, while subsequent cutting cycle harvests of large coppice is $569.77 per acre. Costs include in-field harvest and chipping, and transport to field edge. The cost of biomass transportation to refineries is based on chip vans with a 30 green ton capacity and a 57% biomass moisture content. These are estimated at $1.94, $3.88, and $5.81 per BDT for haul distances of 25, 50, and 75 miles, respectively.

Management Fees and Other Indirect Costs - Many of the indirect costs associated with farm operations and management are fixed and therefore scalable, while others are proportional to acreage. In the economic model, these costs were scaled to a 10,000 acre operation. The cost allocations and applied rates could be significantly different depending on the services required, scale of the venture, and the aggregation level of plantation blocks. Annual management fees include the following:

1. Investment Management Fees ($10 per acre): Investor reporting and liaison, research and development, subscriptions/memberships, software licensing, other business G&A.

2. Property Management ($30 per acre): Contract management, legal services, strategic/operation planning, resource analysis, valuations, accounting, budgets, financial forecasting.

3. Operation Management ($30 per acre): Personnel management, industry/local government and landowner/community interaction, plant material sourcing, crop monitoring, operational planning and logistics, contract negotiation, supervision and quality control, plantation protection, health and field data collection, vehicles and buildings.

4. Plantation Protection, Maintenance, and other Indirect Project Expenditure
    a) fire suppression: $ 0.50 /acre/year
    b) firebreak maintenance: $ 0.50 /acre/year
    c) road maintenance, internal and external access: $ 1.00 /acre/year
    d) mapping and GIS: $ 0.50 /acre/year
    e) stand inventory: $ 1.00 /acre/year
    f) foliar and soil analyses: $ 0.50 /acre/year
    g) land lease: $ 65.00 /acre/year (agricultural sites) and $10.00 /acre/year (pastoral)
    h) financial audit: $ 2.00 /acre/year
    i) third party appraisal: $ 2.00 /acre/year
    j) insurance: $ 2.00 /acre/year

Key Drivers and Sensitivity Factors - The break-even price required for a bioenergy plantation was modeled along with a sensitivity analysis for a wide range of potential prices including market pricing at the bio-refinery gate (unloaded). All prices and costs are expressed on a per acre or bone dry ton basis. The main variables evaluated included:

1. Market price of biomass
2. Land productivity
3. Transportation distance between plantation and biorefinery
4. Land lease rates
5. Application of fertilizer and irrigation

5.3.6.3 Major Findings

Relative profitability of different land classes – Agricultural land is more suitable than pastoral land despite land cost differences as the growth rates and yields are higher. Coppice systems developed and managed on agricultural land with irrigation are more profitable than those of pastoral operations despite higher lease costs. Mechanized harvesting systems are likely to be more productive and operate at a lower unit cost on agricultural sites of level terrain than rolling pastoral lands. Also the road infrastructure is more extensive providing easier access and shorter haul distances to field edge.

Relative profitability of varying haul distances – The profitability of coppice systems obviously diminishes with increased distance from delivery points, but the sensitivity of irrigated lands on agricultural sites is low due to the comparatively higher productivity rates. The profitability of the non-irrigated pasture lands is more sensitive to haul distance despite lower costs structures due to their lower productivity status.

Relative profitability of irrigated and non-irrigated sites – The rainfall received on the majority of the land in the study zone ranges from 15 - 20 inches (Table 1). This is largely seasonal and falls outside the growing season so dependency on irrigation is necessary on both agricultural and pastoral. However, the use of irrigation is precluded on pastoral lands due to the absence of irrigation infrastructure. Furthermore the terrain of the pastoral sites is a limitation to effective irrigation. Thus, pastoral lands cannot be effectively utilized without exposure to higher levels of crop failure or lower growth rates. The productivity and financial returns of irrigated sites exceed those of non-irrigated sites. Irrigation costs are associated with higher annual lease costs.

Plantation development strategy – Plantation blocks of at least 200 – 500 acres are needed for cost-effective drip irrigation management. These can be aggregated in clusters of 20 acre blocks that exceed the threshold for cultivation and harvesting efficiencies. Under the base scenario, a 15 million dollar capital investment is required to build up the 10,000 acres to generate the annual production of 46,000 BDTs. A five to 10% acreage buffer is factored in to accommodate potential plantation under-performance due to slower-than-anticipated growth. Capital inflow is expected for the initial six years until production revenue is generated from the project.

Finding – Dedicated bioenergy plantation development in the western Montana corridor is considered financially feasible and can generate real returns in excess of 10% at market prices of $150/BDT. The break-even market prices (Project IRR = 0%) are sensitive to distance, land costs and land productivity, and for the base case scenario - sites of reasonable agricultural quality managed with intensive cultivation without irrigation is $115/BDT (Table 5.3.3). Comparable information is not presented from the analyses of the pastoral sites modeled at a base MAI of 2.8 BDT production and a $10.00 an acre annual lease. The investigation of the pastoral land development of rolling terrain led to the conclusion that coppice biomass farming is not practical due a variety of risk and operating factors (e.g. mechanization, infrastructure, logistics).

The success of the bioenergy plantations is very sensitive to, and contingent on, the availability of 10,000 acres of mostly agricultural land that needs to be concentrated within a weighted average hauling distance of 50 miles of a bio-refinery to maintain required level of plantation profitability. The development should ideally be conducted by phasing in the leasing of land in equal portions over the target harvesting cycle lengths. This will lead to an even distribution of plantation age classes that will expeditiously achieve the maximum sustainable production while creating an even flow of work for farm operations.

Table 5.3.3. Break-even price analysis and internal rate of return for management options for ag sites with irrigation capacity

Model Var.	Scenario	Market Dist. (mi)	Yield (High/Low%)	Irrigation Status	Fertilizer	Lease ($/acre)	Refinery Price ($/BDT)	Pre-Tax IRR	Note
	Base case	50	100:0	No irrigation	periodic	65	150	10.4%	1
Market Price Changes	market -$10/BDT	50	100:0	No irrigation	periodic	65	140	8.2%	
	market -$20/BDT	50	100:0	No irrigation	periodic	65	130	5.7%	
	market -$30/BDT	50	100:0	No irrigation	periodic	65	120	2.5%	
	market -$35/BDT	50	100:0	No irrigation	periodic	65	115	0.2%	
Land Productivity	High Land Productivity	50	75:25	No irrigation	periodic	65	150	8.2%	
	Average Land Productivity	50	50:50	No irrigation	periodic	65	150	5.6%	
	Low Land Productivity	50	25:75	No irrigation	periodic	65	150	2.2%	
	Low Land Productivity	50	0:100	No irrigation	periodic	65	150	0.0%	
Transport Distance	Transport - 25 miles	25	100:0	No irrigation	periodic	65	150	11.2%	2
	Transport + 25 miles	75	100:0	No irrigation	periodic	65	150	9.7%	
Land Lease Rates	Lease - $20/acre	50	100:0	No irrigation	periodic	45	150	11.9%	
	Lease - $10/acre	50	100:0	No irrigation	periodic	55	150	11.2%	
	Lease + $10/acre	50	100:0	No irrigation	periodic	75	150	9.7%	
	Lease + $20/acre	50	100:0	No irrigation	periodic	85	150	9.0%	
Irrigation & Fertilizer	No irrigation, no fertilizer	50	100:0	No irrigation	none	65	150	11.1%	3
	Irrigation - annual fertilizer	50	100:0	Irrigated (drip)	drip	65	150	3.1%	4
	Irrigation - fertilizer periodic	50	100:0	Irrigated (drip)	periodic	65	150	3.9%	

Note 1: Break-even delivered price = $114.68/BDT
Note 2: Land lease rate positively correlated to productivity, but keep lease cost constant to model impacts of productivity. Fertilizer cost deducted but no change in yield projections.
Note 3: Fertilizer impacts on productivity not known.
Note 4: Break-even delivered price = $137.91/BDT

Table 5.3.4. Cash flow of base case scenario of bioenergy plantation development in Western Montana Corridor

Cash Flow and Return on Investment Analysis (Before taxes)

Investment Model for:	NARA Bioenergy Plantation Development & Management
Model Scenario:	Scenario 1 - Base Case
Date:	6-Jun-2013

CURRENCY: USD		2013 Year 0 1/1/2013	2014 Year 1 1/1/2014	2015 Year 2 1/1/2015	2016 Year 3 1/1/2016	2017 Year 4 1/1/2017	2018 Year 5 1/1/2018	2019 Year 6 1/1/2019	2020 Year 7 1/1/2020	2021 Year 8 1/1/2021	2022 Year 9 1/1/2022	2023 Year 10 1/1/2023	2024 Year 11 1/1/2024	2025 Year 12 1/1/2025	2026 Year 13 1/1/2026	2027 Year 14 1/1/2027	2028 Year 15 1/1/2028	2029 Year 16 1/1/2029	2030 Year 17 1/1/2030	2031 Year 18 1/1/2031	2032 Year 19 1/1/2032	2033 Year 20 1/1/2033
REVENUE																						
Biomass sales																						
Delivered bioenergy facility		0	0	0	2,250,000	2,250,000	2,250,000	2,250,000	6,900,000	6,900,000	6,900,000	6,900,000	6,900,000	6,900,000	6,900,000	6,900,000	6,900,000	6,900,000	6,900,000	6,900,000	6,900,000	6,900,000
Field edge		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Propagation materials																						
Cuttings		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rods		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL INCOME		**0**	**0**	**0**	**2,250,000**	**2,250,000**	**2,250,000**	**2,250,000**	**6,900,000**	**6,900,000**	**6,900,000**	**6,900,000**	**6,900,000**	**6,900,000**	**6,900,000**	**6,900,000**	**6,900,000**	**6,900,000**	**6,900,000**	**6,900,000**	**6,900,000**	**6,900,000**
COGS																						
Timber Depletion		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temporary harvest roading		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harvesting & transport to field edge		0	0	0	623,825	623,825	623,825	623,825	1,424,425	1,424,425	1,424,425	1,424,425	1,424,425	1,424,425	1,424,425	1,424,425	1,424,425	1,424,425	1,424,425	1,424,425	1,424,425	1,424,425
Loading		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harvest management		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Road usage & other taxes		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transport cost to processing facility		0	0	0	134,850	134,850	134,850	134,850	413,540	413,540	413,540	413,540	413,540	413,540	413,540	413,540	413,540	413,540	413,540	413,540	413,540	413,540
Contingency		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Collection & storage of propagation materials		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transport of propagation materials		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total COGS		0	0	0	758,675	758,675	758,675	758,675	1,837,965	1,837,965	1,837,965	1,837,965	1,837,965	1,837,965	1,837,965	1,837,965	1,837,965	1,837,965	1,837,965	1,837,965	1,837,965	1,837,965
GROSS PROFIT		**0**	**0**	**0**	**1,491,325**	**1,491,325**	**1,491,325**	**1,491,325**	**5,062,035**	**5,062,035**	**5,062,035**	**5,062,035**	**5,062,035**	**5,062,035**	**5,062,035**	**5,062,035**	**5,062,035**	**5,062,035**	**5,062,035**	**5,062,035**	**5,062,035**	**5,062,035**
EXPENSES																						
Tree Farm Expenses																						
Silvicultural treatments																						
Weed Control		0	100,000	200,000	300,000	383,000	333,000	233,000	233,000	233,000	233,000	233,000	233,000	233,000	233,000	233,000	233,000	233,000	233,000	233,000	233,000	233,000
Cultivation		0	150,000	300,000	450,000	600,000	450,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000
Fertilizer		0	0	0	112,500	112,500	112,500	112,500	112,500	112,500	112,500	112,500	112,500	112,500	112,500	112,500	112,500	112,500	112,500	112,500	112,500	112,500
Other		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Irrigation																						
Irrigation tube layout / start-up / removal		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Irrigation water / electricity		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest Protection & Maintenance																						
Pest & Disease Control		0	0	34,375	68,750	103,125	137,500	137,500	137,500	137,500	137,500	137,500	137,500	137,500	137,500	137,500	137,500	137,500	137,500	137,500	137,500	137,500
Forest Health (Pest & Disease) Monitoring		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest Security		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fire control		1,250	2,500	3,750	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Firebreak & boundary maintenance		1,250	2,500	3,750	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Road Maintenance& Storm Damage Cleanup		2,500	5,000	7,500	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Other		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Tree Farm Expenses		5,000	260,000	549,375	951,250	1,218,625	1,053,000	803,000	803,000	803,000	803,000	803,000	803,000	803,000	803,000	803,000	803,000	803,000	803,000	803,000	803,000	803,000
Company Expenses																						
Property Leases		162,500	325,000	487,500	650,000	650,000	650,000	650,000	650,000	650,000	650,000	650,000	650,000	650,000	650,000	650,000	650,000	650,000	650,000	650,000	650,000	650,000
Fire Insurance		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mapping & GIS		1,250	2,500	3,750	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Forest Inventory		2,500	5,000	7,500	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Soil & Foliar Analyses		1,250	2,500	3,750	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Government permits & fees		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Community development		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Environmental certification		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Legal Fees		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Financial audit / accounting fees		5,000	10,000	15,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Appraisal		5,000	10,000	15,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Other company expenses / G&A		5,000	10,000	15,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Total Company Expenses		182,500	365,000	547,500	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000
Management Fees																						
Operation Management Fee		75,000	150,000	225,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000
Property Management Fee		75,000	150,000	225,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000
Investment Management Fee		25,000	50,000	75,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
Total Management Expenses		175,000	350,000	525,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000
TOTAL EXPENSES		**362,500**	**975,000**	**1,621,875**	**2,381,250**	**2,648,625**	**2,483,000**	**2,233,000**	**2,233,000**	**2,233,000**	**2,233,000**	**2,233,000**	**2,233,000**	**2,233,000**	**2,233,000**	**2,233,000**	**2,233,000**	**2,233,000**	**2,233,000**	**2,233,000**	**2,233,000**	**2,233,000**
OPERATING CASHFLOW		**(362,500)**	**(975,000)**	**(1,621,875)**	**(889,925)**	**(1,157,300)**	**(991,675)**	**(741,675)**	**2,829,035**	**2,829,035**	**2,829,035**	**2,829,035**	**2,829,035**	**2,829,035**	**2,829,035**	**2,829,035**	**2,829,035**	**2,829,035**	**2,829,035**	**2,829,035**	**2,829,035**	**2,829,035**
CAPITAL COSTS																						
Timber and Timberland																						
Land purchase		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Existing biomass crops		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Establishment & Silviculture																						
Site Preparation - herbicide		237,500	375,000	512,500	650,000	550,000	412,500	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000
Site Preparation - disk		162,500	162,500	162,500	162,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Site Preparation - row mark & rip		62,500	62,500	62,500	62,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Planting		0	1,160,000	1,160,000	1,160,000	1,160,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Land Improvements / Infrastructure																						
Access Road Construction		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Firebreak Construction		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Irrigation Capital		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vehicles & equipmnet		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buildings		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Fixed Assets		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL CAPITAL		**462,500**	**1,760,000**	**1,897,500**	**2,035,000**	**1,710,000**	**412,500**	**275,000**	**275,000**	**275,000**	**275,000**	**275,000**	**275,000**	**275,000**	**275,000**	**275,000**	**275,000**	**275,000**	**275,000**	**275,000**	**275,000**	**275,000**
Add back non-cash expenses		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL NET CASH FLOW		**(825,000)**	**(2,735,000)**	**(3,519,375)**	**(2,924,925)**	**(2,867,300)**	**(1,404,175)**	**(1,016,675)**	**2,554,035**	**2,554,035**	**2,554,035**	**2,554,035**	**2,554,035**	**2,554,035**	**2,554,035**	**2,554,035**	**2,554,035**	**2,554,035**	**2,554,035**	**2,554,035**	**2,554,035**	**2,554,035**
CUMULATIVE NET CASH FLOW		(825,000)	(3,560,000)	(7,079,375)	(10,004,300)	(12,871,600)	(14,275,775)	(15,292,450)	(12,738,415)	(10,184,380)	(7,630,345)	(5,076,310)	(2,522,275)	31,760	2,585,795	5,139,830	7,693,865	10,247,900	12,801,935	15,355,970	17,910,005	20,464,040
Period - End Terminal Value at IRR		982,268	3,818,779	7,732,803	11,456,867	15,508,166	18,515,017	21,445,109	21,107,299	20,734,578	20,323,338	19,869,599	19,368,969	18,816,602	18,207,151	17,534,717	16,792,790	15,974,190	15,070,993	14,074,455	12,974,932	11,761,779
Internal Rate of Return	10.33%																					
ESTIMATED TIMBER VALUE (31 DEC)		1,435,725	4,314,298	8,265,103	12,016,538	16,065,492	19,098,216	22,024,712	21,673,149	21,286,428	20,861,036	20,393,105	19,878,380	19,312,183	18,689,367	18,004,268	17,250,660	16,421,691	15,509,825	14,506,773	13,403,415	12,189,722
Discount Rate	10.00%																					

5.3.7 RISK ASSESSMENT

Ventures in plantation development are naturally accompanied by a wide range of risk. Therefore, it is necessary to: (1) Isolate those that are material from those that are immaterial and (2) Determine appropriate courses of action for the material ones that will potentially add cost, reduce revenue, or increase earnings volatility.

Risks may be classified and addressed through a range of mechanisms:

1. Manageable risks – apply preventative or remedial silviculture measures.
2. Insurable risks – arrange for cost effective coverage.
3. Unforeseen business or market risks that decrease the expected revenue stream – reduce productive area for catastrophic losses; add contingencies to expenditures, reduce expected market prices; reduce expected net earnings and/or increase discount rate to a higher risk adjusted return level.
4. Acceptable and quantified potential risks – reduce expected net earnings and/or increase discount rate to a higher risk-adjusted return level.

The key risks for bioenergy plantation investment are outlined in table 5 along with the relative probability of occurrence and potential impact on the asset's profitability and growth in value. Operational and market risks vary with the project investment period and some will be reduced through management actions (e.g. adapting silviculture with experience and field trials to minimize crop losses; contracts to control operational costs, land lease contracts with terms to contain costs, wood supply contracts that maintain market security), while others will persist (e.g. markets), while others will increase with time (e.g. fire occurrence in advance coppice cycles).

The key risks that determine the financial performance of the venture are:

Availability and Price of Suitable Land – The bioenergy plantations are heavily dependent on the following:

1. Land base - Concentration of acreage within a reasonable radius of the refineries to minimize cartage costs.
2. Site quality - Productive soils to achieve target yields especially in areas with limited rainfall and where it is concentrated outside the growing season. Also important is land that has suitable terrain for mechanized operations.
3. Parcel size - Large, contiguous bocks of 200-500 acres are necessary to achieve economies of scale. Blocks of 20 acres are the minimum unit size for effective coppice plantation development; contiguous blocks or aggregates of blocks are recommended so as to attain operational efficiency and to reduce infrastructural and management overhead rates.
4. Support services - Access to agricultural and forestry expertise and capability for land preparation, crop care, and harvesting operations and transport. Access to service industries for maintaining vehicles and machinery.
5. Lease program - Ability to lease the minimum level of land (10,000 acres in this scenario) for progressive property development to achieve sustainable fiber production that meets contractual wood supply volumes. The dominant land use in the proposed investment zone is cropping and grazing. Although there are adequate lands within close proximity of potential refinery locations in the corridor, the performance of current land uses will determine land availability and lease rates.

Market prices for biomass – Bioenergy plantations are intensive operations that have a high cost structure. According to the base case scenario – quality agricultural sites, MAI of 4.6 BDT per acre, no irrigation, the feasibility and 27 financial profitability is contingent on a minimum breakeven prices of at least $115/BDT. The volatility in prices for biomass delivered to bio-refineries will be heavily impacted by the following:

1. Bioenergy final product market prices.
2. Fiber supply balances and prices for substitutes (e.g. non-cellulosic sources of sugar).
3. Government intervention (e.g. incentives, taxes)
4. Decisions by refineries as to whether to maintain the consumption of plantation fiber for the critical investment term of the poplar plantation (i.e. the payback period).

Achieving Target Growth Rates and Yields on Non-Irrigated Land – The large majority of the potential investment area receives less than 25 inches of rainfall per year. Moreover this is unevenly distributed seasonally. While the target mean annual increments are achievable, doing so is contingent on:

1. Regular rainfall. Prolonged drought will significantly impact growth rates, affect the length of cutting cycles or yields, and will increase production costs. The venture will be exposed to failure to meet contracted biomass supply volumes.
2. Attaining high survival rates. The quality of planting materials and effective weed control are critical during the formative stages of the tree stand.

3. Low levels of pests and diseases. The extent and the severity of disease infections and insect infestations can materially impact of tree survival, vigor and yield, though their impact can be mitigated by factoring in crop monitoring and protection activities.

Table 5.3.5. Key risks for bioenergy plantation investment

Source	Types of Risk Present	Potential Risk of Occurrence	Potential Value Impact
Market Risk	Risk - prices an/or implied volatility will change.		
	Commodity risk - market prices biomass or competitive substitutes; maintained demand level to absorb full production level.	High	High
	Land availability risks - limited supply of available land, high initial or renewal lease rates	High	High
	Financing - Equity Cost / Interest Rate Risk (D:E dependent)	Moderate	Low
Operational Risks	Risks associated with people, systems, processes and environment		
	Inability to achieve target growth rates & yields due to prolonged drought or inadequate silvicultural treatments	Moderate	Moderate-High
	Damage to Physical Assets - natural catastrophic events (drought, late frosts, snow damage, wind damage & fire)	Moderate	Moderate-High
	Pests & Diseases - spread more difficult to contain than hoped, incaresed incidence and impact in growth & yield	Moderate	Low-Moderate
	Legal Risk - Employment Practices and Workplace Safety - employee health and safety standards	Low	Low
	Business Disruption & Systems Failures - utility disruptions, computer failures	Low	Low
	Execution, Delivery, & Process Management - data entry errors, accounting errors	Low	Low
Credit Risk	Risk that a borrower will default. Lost principal and interest, disruption to cash flows, and increased collection costs.		
	Buyer of biomass defaults or goes into receivership	Low	Low
Country risk	Government Intervention		
	Government land-use policy & regulatory changes - incentives & taxation	Low	Moderate
	Price regulation (energy)	Low	Moderate
Liquidity risk	Asset cannot be traded quickly enough in the market		
	Limited market depth - specialized venture (limited market) and long term investment	Moderate	Low-Moderate

5.3.8 CONCLUSIONS

Strategic value of energy plantations – Hybrid poplar energy plantations offer a mechanism for rapidly producing substantive quantities of woody biomass for bioenergy facilities in areas of limited wood supply in western Montana. The NARA biomass supply strategy for this region is largely dependent on residual materials from logging and thinning operations in coniferous forests. Reliance on this source may be accompanied by a degree of uncertainty due to cyclicality in solid wood markets. Environmental concerns may also impact supply availability. Poplar plantations managed as a dedicated supplementary supply offer resource security that may be essential for refinery capital investments. The ability to consistently supply biomass at controllable prices can be maintained through large-scale plantation blocks within economic cartage distances.

Preliminary economic analyses isolate key drivers and constraints for profitable plantation development –

1. The most suitable biomass production system uses locally adapted poplar clonal varieties grown at high density under coppice management. The silvicultural regimes evaluated were modeled using a 22-year rotation composed of an initial two year cycle from planting followed by five successive coppice cycles of four years each.
2. A 10,000 acre operation represents approximately one-quarter of the agricultural and pastoral land base in the western Montana corridor that receives 25 to 40 inches of annual precipitation. Agricultural land offers the more favorable option for bioenergy plantation development to achieve satisfactory yields relative to the cost of the land. Pastoral lands of lower productivity and rolling terrain provide less favorable economics due to lower soil quality and biomass productivity combined with higher costs of mechanized cultivation and harvesting operations.
3. On higher quality agricultural sites receiving 25 to 40 inches of annual precipitation and assuming good seasonal distribution, a MAI of 4.6 BDT per acre may be achievable without irrigation. With irrigation, the attainment of comparable growth rates can be ensured across a greater area of the corridor's agricultural region where precipitation is limited, but the financial yields are lower. Thus irrigation is not recommended for coppice plantation development on financial grounds, but it is nonetheless very likely essential for the sustainability of yield.

Economic viability contingent on key variables – The ability to secure sufficient quantity of agricultural land in large contiguous blocks within an economic fiber cartage distance of the potential bioenergy processing facilities is essential. The cost of land leases represents a significant impact to program profitability, so it is necessary to: (1) Achieve full site utilization and maximize growth rates through effective plantation establishment, intensive silviculture and crop protection; (2) Long term leases at or below trend line rates need to be secured to contain land costs; and (3) Efforts need to be made to secure agricultural land with the minimum of necessary land improvements.

The project viability is sensitive to the level of indirect costs. The scale of operation (contiguous areas with a minimum of 200 – 500 acres) is critical to keep fixed costs low especially if the irrigation option is selected. Much of the agricultural land in the Missoula-Columba Falls corridor has irrigation infrastructure but designing and setting up pumps and distribution tubes requires scale to contain costs per unit area. Similarly, management fees are significant due to the high level of crop monitoring, high frequency of operations, and potentially large number of individual properties dispersed within the necessary transportation radius of the biorefinery. These costs are extremely scalable at the individual farm and project level.

Next Steps: The need to refine input data to validate and enhance potential investment returns – The economic returns of bioenergy plantation management are subject to a large amount of uncertainty and due diligence that would be required to evaluate the possible venture. Key areas of investigation include:

1. Comprehensive assessment of biomass fiber supply, demand, and pricing to determine future demand and price outlook.
2. Evaluation of availability of suitable land (soil quality, soil pH, precipitation rates and distribution patterns, lease price, productivity, terrain, contiguous blocks of minimum 200-500 acres, good road access, located within an economic radius of refineries).
3. Research trials to confirm growth rates and recoverable yields of coppice, susceptibility to pests and diseases, cost effective fertilizer application rates and techniques.
4. Evaluation of silvicultural system (different planting densities and cutting cycle lengths) to maximize financial yields.
5. Continued evaluation of harvesting systems (equipment, scale of operations, coppice density and size).
6. Evaluation of marginal land and its cost structure for suitability for coppice development without irrigation.
7. Determination of varying mechanisms for scaling up production within minimum time frame to provide a sustainable feedstock.
8. Investigate ways to modify coppice cycle lengths to maintain the supply as coppice crops transitions between cutting cycles. The initial 2-year harvest produces a much lower yield than subsequent 4-year cutting cycle harvests. The final cutting cycle harvest is slightly lower due to the declining vigor of the rootstock. Regulating a sustainable supply from a fixed land area will require alterations in the cutting cycles.

5.3.8.1 Future Prospects

Dedicated bioenergy plantations offer a mechanism for providing supplementary fiber supply for bio-refineries. The evaluation of bioenergy plantations has not incorporated the synergies achieved by blending with other fiber supplies, the cost savings from increased operation scale, or the prospects of increased growth rates and drought tolerance achievable through continued hybridization and varietal development.

As energy prices increase, biomass fiber demands increase, technology improves, and tree improvements advance, the viability will likely expand into progressively more marginal sites, and the financial performance of dedicated bioenergy plantations will progressively improve.

5.3.9 REFERENCES

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Natural Resource Conservation Service | Soil Descriptions for Lake County and Flathead Valley, MT

TOP THREE SOILS, BY AREA, IN THE LAKE COUNTY AREA, NEAR MISSOULA, MT (44% OF AVAILABLE LANDS)

Lake County Area, Montana
130—Polson silt loam
26% of available lands

Map Unit Setting

- Elevation: 2,400 to 3,500 feet
- Mean annual precipitation: 14 to 19 inches
- Mean annual air temperature: 39 to 45 degrees F
- Frost-free period: 105 to 135 days

Map Unit Composition

- Polson and similar soils: 85 percent
- Minor components: 15 percent

Description of Polson Setting

- Landform: Alluvial fans, stream terraces
- Down-slope shape: Linear
- Across-slope shape: Linear
- Parent material: Glaciofluvial deposits

Properties and qualities

- Slope: 0 to 2 percent
- Depth to restrictive feature: More than 80 inches
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 15 percent
- Maximum salinity: Very slightly saline to slightly saline (4.0 to 8.0 mmhos/cm)
- Sodium adsorption ratio, maximum: 30.0
- Available water capacity: Moderate (about 8.7 inches)

Interpretive groups

- Farmland classification: Farmland of local importance
- Land capability classification (irrigated): 3s
- Land capability (nonirrigated): 3s
- Hydrologic Soil Group: C

Typical profile

- 0 to 10 inches: Silt loam
- 10 to 18 inches: Silt loam
- 18 to 60 inches: Silt loam

Lake County Area, Montana
63—Gird silt loam
10% of available lands

Map Unit Setting

- Elevation: 2,300 to 4,300 feet
- Mean annual precipitation: 14 to 22 inches
- Mean annual air temperature: 39 to 45 degrees F
- Frost-free period: 105 to 135 days

Map Unit Composition

- Gird and similar soils: 85 percent
- Minor components: 15 percent

Description of Gird Setting

- Landform: Alluvial fans, stream terraces
- Down-slope shape: Linear
- Across-slope shape: Linear
- Parent material: Glaciofluvial deposits

Properties and qualities

- Slope: 0 to 2 percent
- Depth to restrictive feature: More than 80 inches
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 10 percent
- Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
- Available water capacity: High (about 10.3 inches)

Interpretive groups

- Farmland classification: Prime farmland if irrigated
- Land capability classification (irrigated): 2e
- Land capability (nonirrigated): 3e
- Hydrologic Soil Group: B

Typical profile

- 0 to 10 inches: Silt loam
- 10 to 17 inches: Silt loam
- 17 to 60 inches: Silt loam

Lake County Area, Montana
95—Lonepine silt loam
8% of available lands

Map Unit Setting
- Elevation: 2,000 to 3,500 feet
- Mean annual precipitation: 10 to 19 inches
- Mean annual air temperature: 39 to 45 degrees F
- Frost-free period: 105 to 135 days

Map Unit Composition
- Lonepine and similar soils: 85 percent
- Minor components: 15 percent

Description of Lonepine Setting
- Landform: Lake plains
- Down-slope shape: Linear
- Across-slope shape: Linear
- Parent material: Lacustrine deposits

Properties and qualities
- Slope: 2 to 4 percent
- Depth to restrictive feature: More than 80 inches
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 15 percent
- Maximum salinity: Nonsaline to very slightly saline (0.0 to 4.0 mmhos/cm)
- Available water capacity: High (about 10.9 inches)

Interpretive groups
- Farmland classification: Prime farmland if irrigated
- Land capability classification (irrigated): 2e
- Land capability (nonirrigated): 3e
- Hydrologic Soil Group: C
- Ecological site: Silty (Si) 10-14” p.z. (R044XW125MT)

Typical profile
- 0 to 6 inches: Silt loam
- 6 to 14 inches: Silt loam
- 14 to 60 inches: Silt loam

TOP THREE SOIL SERIES, BY AREA, IN THE FLATHEAD VALLEY AREA, COLUMBIA FALLS TO KALISPELL, MT (41% OF AVAILABLE LANDS)

Upper Flathead Valley Area, Montana
So—Swims silt loam
18% of available lands

Map Unit Setting
- Elevation: 2,600 to 3,400 feet
- Mean annual precipitation: 15 to 18 inches
- Mean annual air temperature: 39 to 45 degrees F
- Frost-free period: 100 to 120 days

Map Unit Composition
- Swims and similar soils: 90 percent
- Minor components: 10 percent

Description of Swims Setting
- Landform: Terraces
- Down-slope shape: Linear
- Across-slope shape: Linear
- Parent material: Alluvium

Properties and qualities
- Slope: 0 to 3 percent
- Depth to restrictive feature: More than 80 inches
- Drainage class: Moderately well drained
- Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 1.98 in/hr)
- Depth to water table: About 48 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 15 percent
- Maximum salinity: Nonsaline to very slightly saline (0.0 to 3.0 mmhos/cm)
- Available water capacity: High (about 10.2 inches)

Interpretive groups
- Farmland classification: Prime farmland if irrigated
- Land capability classification (irrigated): 3e
- Land capability (nonirrigated): 3e
- Hydrologic Soil Group: B

Typical profile
- 0 to 1 inches: Slightly decomposed plant material
- 1 to 5 inches: Silt loam
- 5 to 12 inches: Silty clay loam
- 12 to 26 inches: Silt loam
- 26 to 55 inches: Stratified very fine sandy loam to silty clay loam
- 55 to 60 inches: Loamy fine sand

Upper Flathead Valley Area, Montana
Kze—Kiwanis loam
13% of available lands

Map Unit Setting

- Elevation: 3,000 to 5,000 feet
- Mean annual precipitation: 12 to 17 inches
- Mean annual air temperature: 39 to 45 degrees F
- Frost-free period: 90 to 130 days

Map Unit Composition

- Kiwanis and similar soils: 90 percent
- Minor components: 10 percent

Description of Kiwanis Setting

- Landform: Stream terraces
- Down-slope shape: Linear
- Across-slope shape: Linear
- Parent material: Alluvium

Properties and qualities

- Slope: 0 to 3 percent
- Depth to restrictive feature: More than 80 inches
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 10 percent
- Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
- Available water capacity: Moderate (about 6.7 inches)

Interpretive groups

- Farmland classification: Prime farmland if irrigated
- Land capability classification (irrigated): 3e
- Land capability (nonirrigated): 3e
- Hydrologic Soil Group: B
- Ecological site: Silty (Si) 15-19” p.z. (R044XW184MT)

Typical profile

- 0 to 9 inches: Loam
- 9 to 39 inches: Fine sandy loam
- 39 to 70 inches: Very gravelly sand

Upper Flathead Valley Area, Montana
Wp—Walters very fine sandy loam
10% of available lands

Map Unit Setting

- Mean annual precipitation: 15 to 19 inches
- Mean annual air temperature: 37 to 43 degrees F
- Frost-free period: 90 to 130 days

Map Unit Composition

- Walters and similar soils: 90 percent
- Minor components: 10 percent

Description of Walters Setting

- Landform: Terraces
- Down-slope shape: Linear
- Across-slope shape: Linear
- Parent material: Alluvium

Properties and qualities

- Slope: 0 to 7 percent
- Depth to restrictive feature: More than 80 inches
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 5 percent
- Available water capacity: Moderate (about 6.2 inches)

Interpretive groups

- Farmland classification: Farmland of statewide importance
- Land capability classification (irrigated): 4e
- Land capability (nonirrigated): 4e
- Hydrologic Soil Group: B

Typical profile

- 0 to 2 inches: Slightly decomposed plant material
- 2 to 12 inches: Very fine sandy loam
- 12 to 15 inches: Silt loam
- 15 to 26 inches: Fine sandy loam
- 26 to 38 inches: Fine sandy loam
- 38 to 60 inches: Stratified sand to gravelly coarse sand

5.3.11 APPENDIX II

Activities for Western Montana Corridor Bioenergy Planting - Current or Former Ag Lands

Table 5.3.6. Year 0 - year before planting

Month	Activity	Percent of Area	Cost per Acre	Cost w/no irrigation	Cost w/ irrigation
June	Contact herbicide for vegetation control	100%	$40.00	$40.00	$40.00
July	Heavy disk	100%	$40.00	$40.00	$40.00
August	Finish disk and smooth	100%	$25.00	$25.00	$25.00
September	Row marking/riping	100%	$25.00	$25.00	$25.00
September	Fertilizer application (at time of ripping)	100%	$35.00	$35.00	$0.00
September	Irrigation tube layout (optional)	100%	$15.00	$0.00	$15.00
September	Herbicide - contact plus preemergent	100%	$55.00	$55.00	$55.00
			Subtotal	$220.00	$200.00

Table 5.3.7. Year 1 - the year of planting

Month	Activity	Percent of Area	Cost per Acre	Cost w/no irrigation	Cost w/ irrigation
January	Purchase plant material (unrooted cuttings)		$377.00	$377.00	$377.00
April	Herbicide - contact plus preemergent	100%	$55.00	$55.00	$55.00
April	Fertilizer application (drip-in, optional)	100%	$25.00	$0.00	$25.00
May	Irrigation start up (optional)	100%	$8.00	$0.00	$8.00
May	Plant cuttings	100%	$87.00	$87.00	$87.00
June	Between row cultivation	100%	$30.00	$30.00	$30.00
June	Along row spot spray or manual weeding	50%	$40.00	$20.00	$20.00
August	Along row spot spray or manual weeding	50%	$40.00	$20.00	$20.00
September	Irrigation cost (12 acre inches)	100%	$60.00	$0.00	$60.00
September	Between row cultivation	100%	$30.00	$30.00	$30.00
			Subtotal	$619.00	$712.00

Table 5.3.8. Year 2 - maintain the crop, initial harvest

Month	Activity	Percent of Area	Cost per Acre	Cost w/no irrigation	Cost w/ irrigation
April	Herbicide - along row preemergent	100%	$55.00	$55.00	$55.00
May	Irrigation start up (optional)	100%	$8.00	$0.00	$8.00
May	Fertilizer application (drip-in, optional)	100%	$25.00	$0.00	$25.00
May	Between row cultivation	100%	$30.00	$30.00	$30.00
July	Along row spot spray or manual weeding	50%	$40.00	$20.00	$20.00
August	Between row cultivation	25%	$55.00	$13.75	$13.75
August	Along row spot spray or manual weeding	50%	$40.00	$20.00	$20.00
September	Between row cultivation	100%	$30.00	$30.00	$30.00
September	Irrigation cost (14 acre inches)	100%	$70.00	$0.00	$70.00
September	Remove irrigation components (optional)	100%	$15.00	$0.00	$15.00
October	Harvest & transport to field edge	100%	$249.53	$249.53	$249.53
			Subtotal	$418.28	$536.28

Table 5.3.9. Years 3, 7, 11, 15, and 19 - first year of coppice

Month	Activity	Percent of Area	Cost per Acre	Cost w/no irrigation	Cost w/ irrigation
April	Herbicide - along row preemergent	100%	$55.00	$55.00	$55.00
April	Fertilizer application (banded, dry)	100%	$45.00	$45.00	$0.00
May	Irrigation tube layout and start up (optional)	100%	$23.00	$0.00	$23.00
May	Fertilizer application (drip-in, optional)	100%	$25.00	$0.00	$25.00
May	Between row cultivation	100%	$30.00	$30.00	$30.00
July	Along row spot spray or manual weeding	50%	$40.00	$20.00	$20.00
August	Pest control (only as needed)	25%	$55.00	$13.75	$13.75
August	Along row spot spray or manual weeding	50%	$40.00	$20.00	$20.00
September	Irrigation cost (14 acre inches)	100%	$70.00	$0.00	$70.00
September	Between row cultivation	100%	$30.00	$30.00	$30.00
			Subtotal	$213.75	$286.75

Table 5.3.10. Years 4, 8, 12, 16, and 20 - second year of coppice

Month	Activity	Percent of Area	Cost per Acre	Cost w/no irrigation	Cost w/ irrigation
April	Herbicide - along row preemergent	100%	$55.00	$55.00	$55.00
May	Irrigation start up (optional)	100%	$8.00	$0.00	$8.00
May	Fertilizer application (drip-in, optional)	100%	$25.00	$0.00	$25.00
May	Between row cultivation	100%	$30.00	$30.00	$30.00
July	Along row spot spray or manual weeding	33%	$40.00	$13.20	$13.20
August	Pest control (only as needed)	25%	$55.00	$13.75	$13.75
August	Along row spot spray or manual weeding	50%	$40.00	$20.00	$20.00
September	Irrigation cost (16 acre inches)	100%	$80.00	$0.00	$80.00
September	Between row cultivation	100%	$30.00	$30.00	$30.00
			Subtotal	$161.95	$274.95

Table 5.3.11. Years 5, 9, 13, 17, and 21 - third year of coppice

Month	Activity	Percent of Area	Cost per Acre	Cost w/no irrigation	Cost w/ irrigation
May	Irrigation start up (optional)	100%	$8.00	$0.00	$8.00
May	Fertilizer application (drip-in, optional)	100%	$30.00	$0.00	$30.00
July	Along row spot spray or manual weeding	50%	$40.00	$20.00	$20.00
August	Pest control (only as needed)	25%	$55.00	$13.75	$13.75
September	Irrigation cost (18 acre inches)	100%	$90.00	$0.00	$90.00
			Subtotal	$33.75	$161.75

Table 5.3.12. Years 6, 10, 14, 18, and 22 - fourth year of coppice

Month	Activity	Percent of Area	Cost per Acre	Cost w/no irrigation	Cost w/ irrigation
May	Irrigation start up (optional)	100%	$8.00	$0.00	$8.00
May	Fertilizer application (drip-in, optional)	100%	$30.00	$0.00	$30.00
August	Pest control (only as needed)	25%	$55.00	$13.75	$13.75
September	Irrigation cost (18 acre inches)	100%	$90.00	$0.00	$90.00
September	Remove irrigation components (optional)	100%	$15.00	$0.00	$15.00
October	Harvest & transport to field edge	100%	$569.77	$569.77	$569.77
			Subtotal	$583.52	$726.52

Table 5.3.13. Year 23 - year before planting, post-harvest site preparation

Month	Activity	Percent of Area	Cost per Acre	Cost w/no irrigation	Cost w/ irrigation
June	Contact herbicide for vegetation control	100%	$40.00	$40.00	$40.00
July	Heavy Disk	100%	$55.00	$55.00	$55.00
August	Finish disk and smooth	100%	$45.00	$45.00	$45.00
September	Row marking	100%	$30.00	$30.00	$30.00
September	Irrigation tube layout (optional)	100%	$15.00	$0.00	$15.00
September	Herbicide - contact plus preemergent	100%	$50.00	$50.00	$50.00
			Subtotal	$220.00	$235.00

5.3.12 APPENDIX III

Results of Hybrid Poplar Clonal Test at Kalispell, Montana

Table 5.3.14. Results of hybrid poplar clonal test at Kalispell, MT

Region	Taxon	Mean Height (ft)	Mean Survival (%)	Number of Clones	Top Height (ft)	Top Survival (%)	MAI of Top Clones (BDT)
PNW	DxM	13.8	85	4	15.2	100	
PNW	DxN	19.2	80	34	26.7	100	3.7
PNW	DxT	16.7	67	4	22.3	100	
PNW	TxN	13.8	83	1	13.8	83	
NC	NxM	17.9	92	1	17.9	92	
NC	NxT	19.8	100	2	21.3	100	
NC	TxD	27.1	88	2	28.5	100	4.0
NC	Dx(TD)	19.6	44	3	22.9	58	
NC	DxM	21.1	78	8	26.3	100	3.7
NC	DxN	26.8	96	32	34.7	100	4.6
NC	TDx(D)	21.8	0.67	5	25.8	1.00	

5.3.13 APPENDIX IV

Predicted Harvest Yields for Hybrid Poplar Bioenergy Plantings in the WMC

Table 5.3.15.

High site, irrigated				
Harvest Age	Description	Total Green Tons Per Acre	Total Bone Dry Tons (BDT's) Per Acre	Mean Annual Increment (BDT's Per Acre)
2	Initial planting harvest	16.3	7.0	3.5
6	1st Coppice Harvest	45.6	19.6	4.9
10	2nd Coppice Harvest	45.6	19.6	4.9
14	3rd Coppice Harvest	45.6	19.6	4.9
18	4th Coppice Harvest	45.6	19.6	4.9
22	5th Coppice Harvest	41.0	17.6	4.4

Table 5.3.16.

High site, non-irrigated				
Harvest Age	Description	Total Green Tons Per Acre	Total Bone Dry Tons (BDT's) Per Acre	Mean Annual Increment (BDT's Per Acre)
2	Initial planting harvest	14.0	6.0	3.0
6	1st Coppice Harvest	42.8	18.4	4.6
10	2nd Coppice Harvest	42.8	18.4	4.6
14	3rd Coppice Harvest	42.8	18.4	4.6
18	4th Coppice Harvest	42.8	18.4	4.6
22	5th Coppice Harvest	38.2	16.4	4.1

Table 5.3.17.

Low site, irrigated				
Harvest Age	Description	Total Green Tons Per Acre	Total Bone Dry Tons (BDT's) Per Acre	Mean Annual Increment (BDT's Per Acre)
2	Initial planting harvest	11.2	4.8	2.4
6	1st Coppice Harvest	36.3	15.6	3.9
10	2nd Coppice Harvest	36.3	15.6	3.9
14	3rd Coppice Harvest	36.3	15.6	3.9
18	4th Coppice Harvest	36.3	15.6	3.9
22	5th Coppice Harvest	31.7	13.6	3.4

Table 5.3.18.

Low site, non-irrigated				
Harvest Age	Description	Total Green Tons Per Acre	Total Bone Dry Tons (BDT's) Per Acre	Mean Annual Increment (BDT's Per Acre)
2	Initial planting harvest	9.8	4.2	2.1
6	1st Coppice Harvest	30.2	13.0	3.3
10	2nd Coppice Harvest	30.2	13.0	3.3
14	3rd Coppice Harvest	30.2	13.0	3.3
18	4th Coppice Harvest	30.2	13.0	3.3
22	5th Coppice Harvest	25.7	11.0	2.8

5.3.14 APPENDIX V

Plantation Development Management & Operation Areas - Base Case Scenario

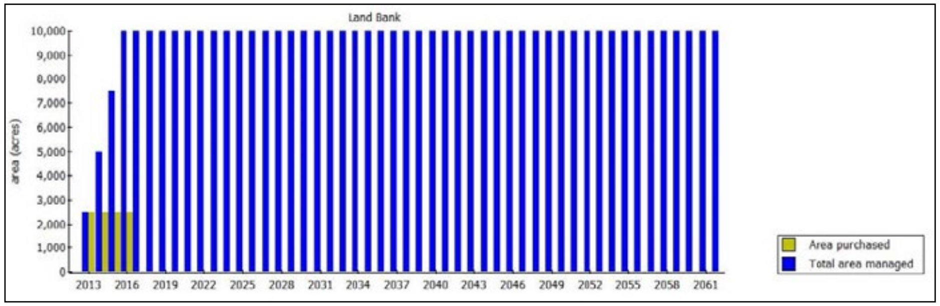

Figure 5.3.2 Land Bank

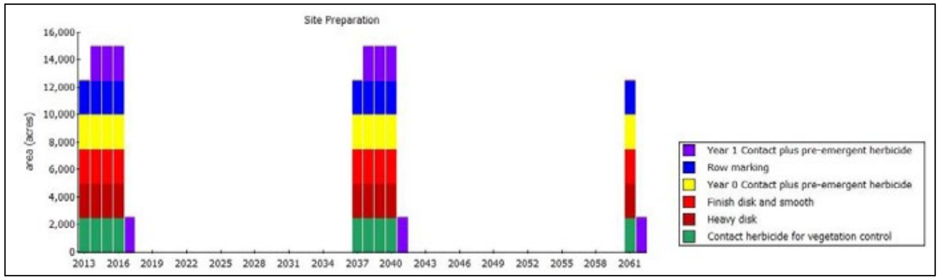

Figure 5.3.3. Site Preparation

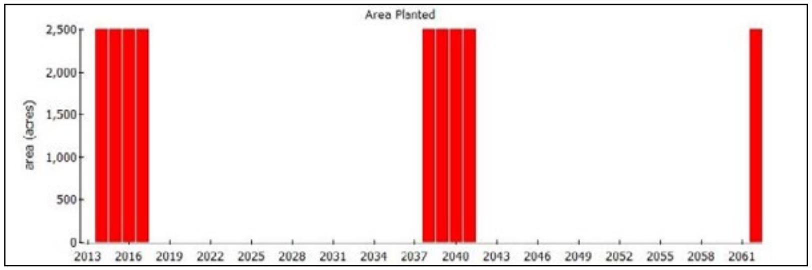

Figure 5.3.4. Area Planted

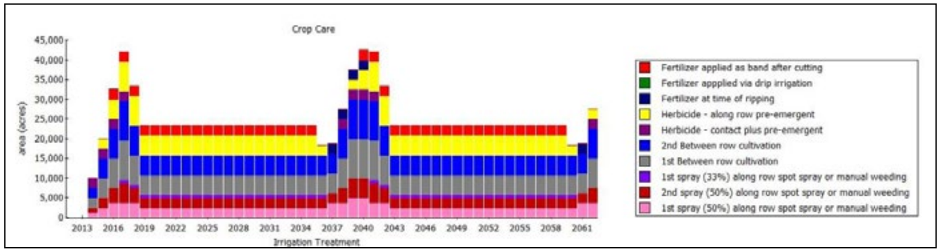

Figure 5.3.5. Crop Care

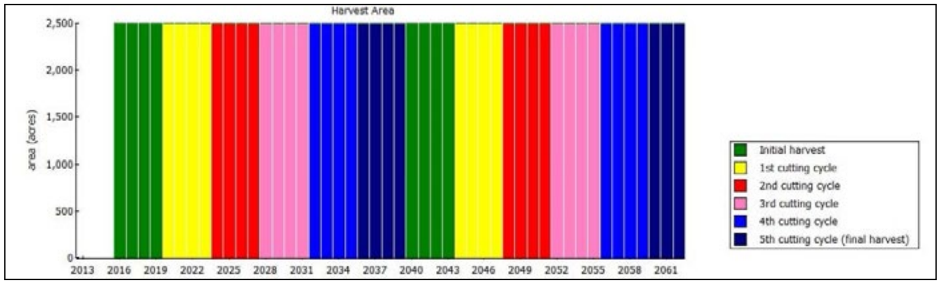

Figure 5.3.6. Harvest Area

Plantation Production Levels - Base Case Scenario

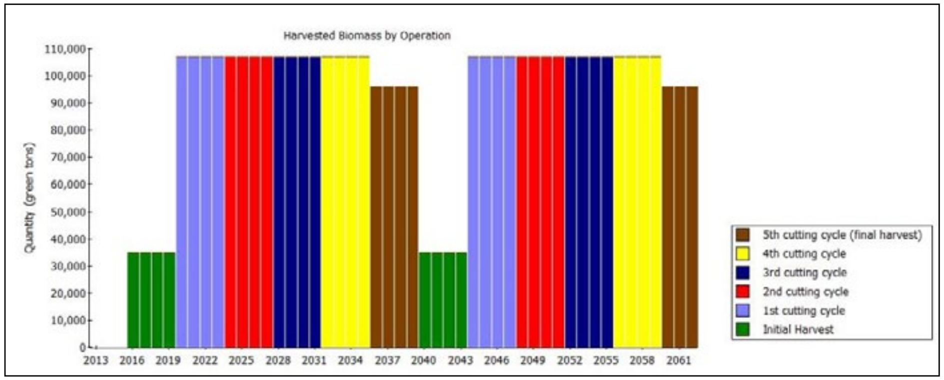

Figure 5.3.7. Harvested biomass by operation

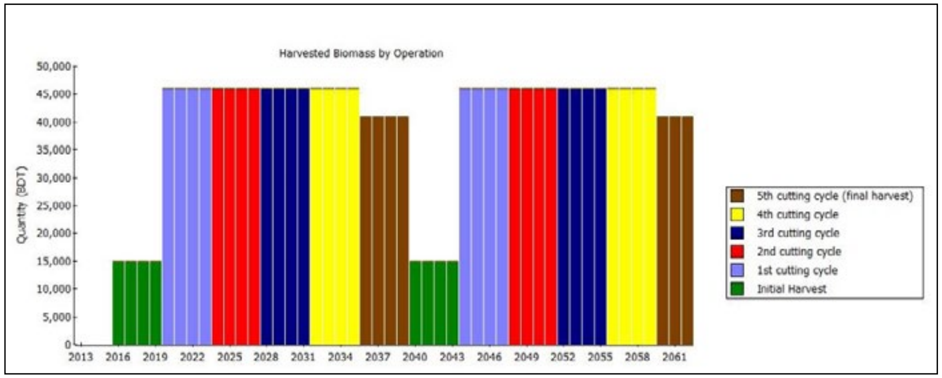

Figure 5.3.8. Harvested Biomass by operation

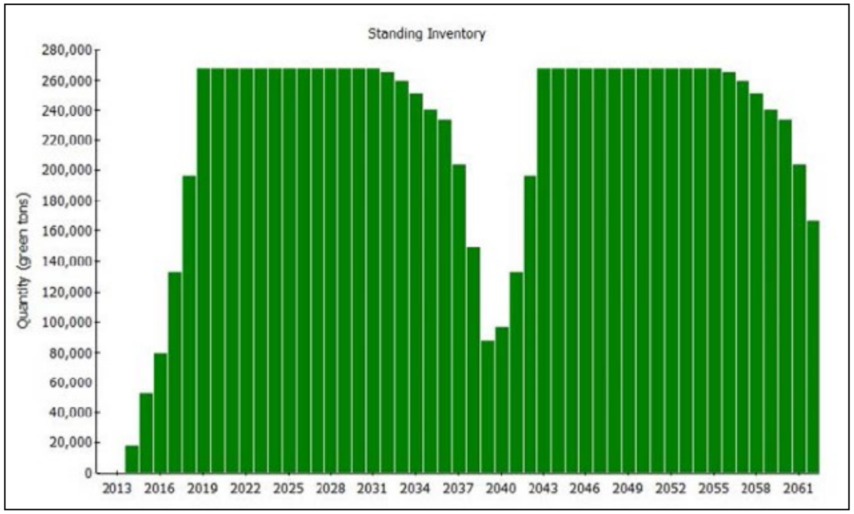

Figure 5.3.9. Standing inventory

Plantation Development and Management Direct Expenditure Profiles - Base Case Scenario

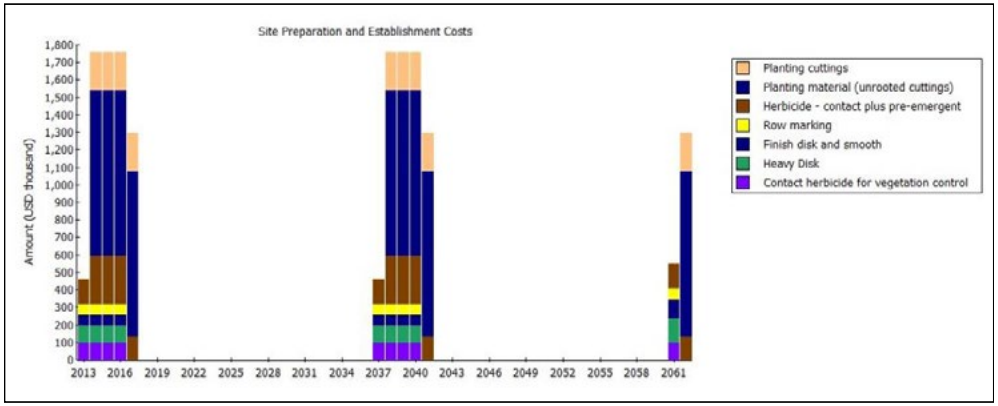

Figure 5.3.10. Site preparation and establishment costs

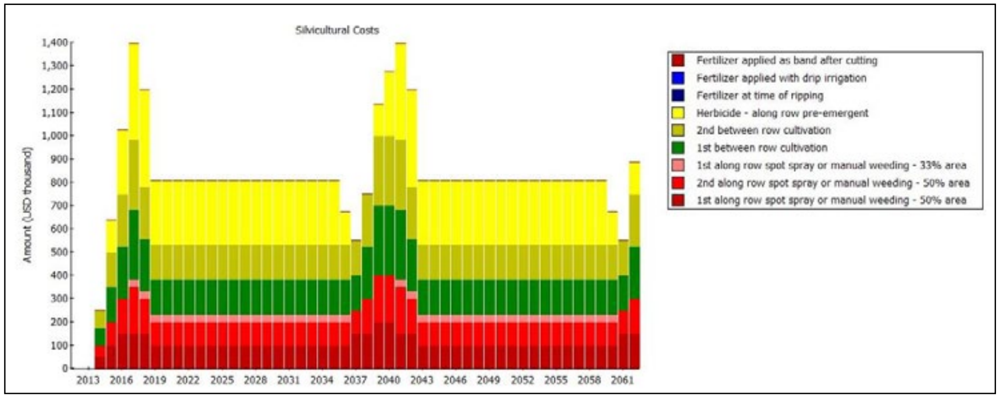

Figure 5.3.11. Silvicultural Costs

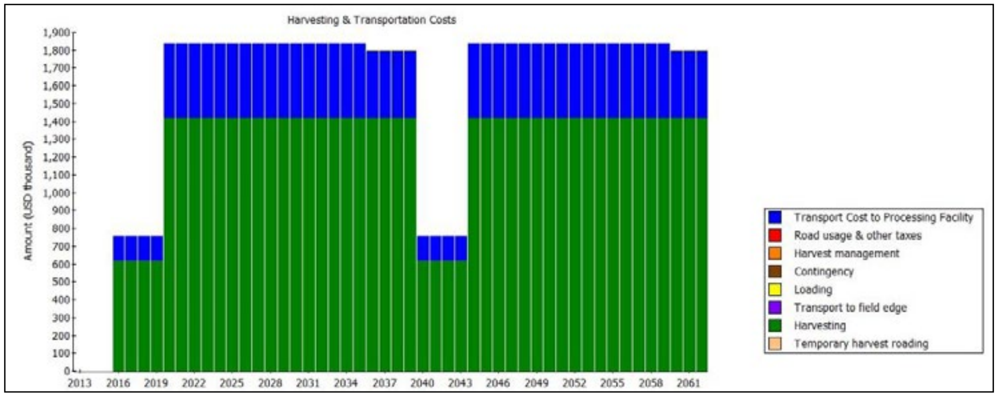

Figure 5.3.12. Harvesting and transportation costs

Plantation Development and Management Indirect Expenditure Profiles - Base Case Scenario

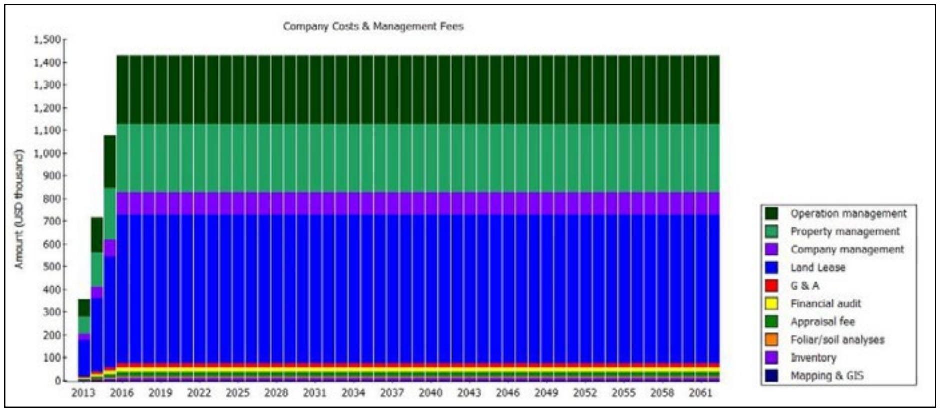

Figure 5.3.13. Company costs and management fees

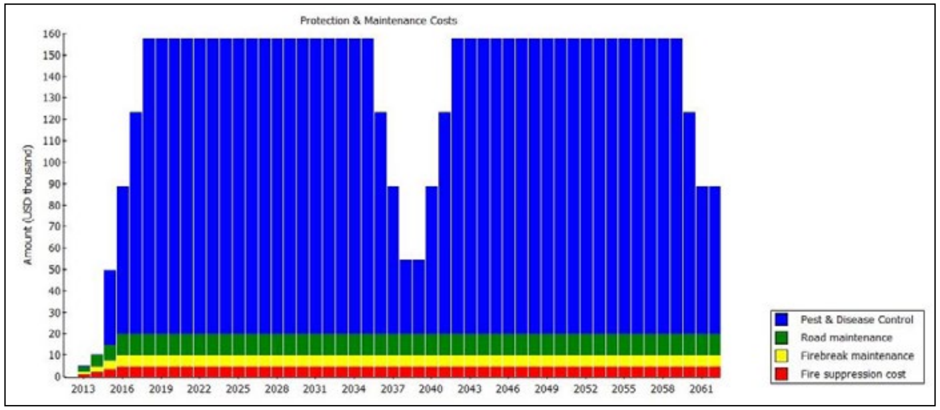

Figure 5.3.14. Protection and maintenance costs

Plantation Net Cashflow Profile (Break-even market price $115/BDT) - Base Case Scenario

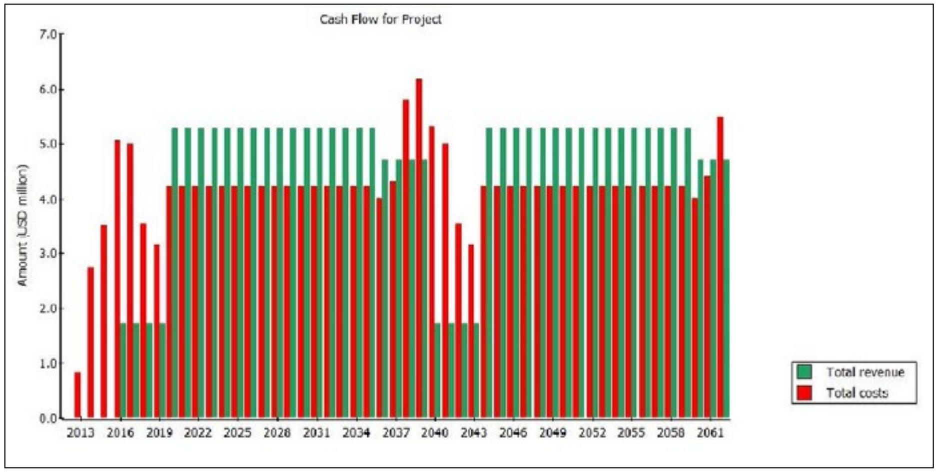

Figure 5.3.15. Cash flow for project