Research Addendum for Peer Review

Project Manager: **Anthony D'Amato (damato@umn.edu)**

Evaluation of Biomass Harvesting Impacts on Minnesota's Forests

Project number: **146-F**

Submitted by:

Anthony D'Amato and Charlie Blinn
Department of Forest Resources, University of Minnesota

John Bradford, Shawn Fraver, Randy Kolka, and Brian Palik
USDA Forest Service, Northern Research Station

And

Rob Slesak
Minnesota Forest Resources Council

I. Abstract - Minnesota's forests are currently being viewed as potential feedstocks for the production of renewable energy. A primary concern about harvesting forest biomass to generate renewable energy is the long-term impacts these harvests will have on soil nutrients and long-term ecosystem productivity. In particular, repeated nutrient removals in harvested material may result in soil nutrient depletion with negative cascading effects on important forest benefits by decreasing future forest growth, carbon storage, and reducing wildlife habitat. Despite these concerns and current plans for widespread application of biomass harvests across Minnesota, little is known about the long-term ecological impacts of forest biomass harvesting, particularly on nutrient poor soils.

This project is designed to increase our understanding of the ecological impacts of biomass harvesting through the establishment of a network of research sites in aspen forests on nutrient poor soils in Minnesota. Treatments representing various levels of biomass removal and green-tree retention will be implemented at each site to evaluate the importance of site-level legacies (green trees and harvest residues) in maintaining the resilience and sustainability of these systems under different biomass harvesting regimes. In addition, empirically derived estimates of nutrient removals from these sites will be used to model the long-term effects of repeated biomass removals on ecosystem productivity using the PnET model. Most importantly, this project will establish treatment sites, collect and analyze baseline data, and implement harvest treatments to facilitate long-term monitoring of the ecological impacts of biomass harvesting at several spatial scales. Results from this project will (1) provide critical information for informing management recommendations aimed at mitigating the impacts of biomass harvesting on nutrient poor soils, and (2) will provide long-term predictions of the effects of this practice on the productivity of aspen systems growing on nutrient poor sites.

II. Background

There is considerable interest in expanding energy production from forest-derived biomass within Minnesota and across the nation. In particular, Minnesota has substantial forest resources that could be utilized for biofuel production, thereby lessening carbon dioxide emissions from fossil fuels while simultaneously providing much-needed economic vitality (Becker et al. 2009). Nonetheless, little is known about the long-term environmental impacts of increased harvesting of forest-derived feedstocks in the region. This lack of information greatly limits our ability to ensure the long-term sustainability of these practices and forecast sustainable biomass feedstock supply within the region.

A fundamental concern about using forest biomass to generate renewable energy is the potential for eventual soil nutrient depletion as a consequence of repeated nutrient removals in harvested material (Hendrickson et al. 1989, Walmsley et al. 2009). In particular, increasing removals of nutrient-rich branches and foliage for use as feedstocks may have negative effects on site nutrient availability (e.g., Hendrickson et al. 1989, Johnson and Todd 1998, Sverdrup and Rosen 1998). If harvesting operations remove soil nutrients faster than they are replenished via atmospheric deposition and chemical weathering, ecosystem nutrient stocks will decline, eventually reducing site productivity. These decreases in site productivity could lead to reductions in the biomass production, requiring longer time periods between subsequent harvests and ultimately threatening the environmental sustainability of feedstock harvests (Proe and Dutch 1994, Egnell and Leijon 1999, Gough et al. 2007). Of particular concern are the impacts of these practices on nutrient poor sites where the risk of long-term nutrient depletion is greatest (Grigal 2004).

Beyond soil nutrients, understory plant communities can be directly impacted by the disturbance of forest harvesting operations, although the impacts of intensive biomass harvests are uncertain. These communities play a central role in the dynamics and functioning of forest ecosystems by influencing long-term patterns of productivity and succession (George and Bazzaz 1999, Royo and Carson 2006, Gilliam 2007) and contributing to forest nutrient and carbon cycles(Zak et al. 1990, Anderson and Eickmeier 2000, Chastain et al. 2006). The abundance of several tree and understory plant species is positively related to the levels of woody debris on the forest floor(Mladenoff and Stearns 1993, McGee 2001, Marx and Walters 2008), making these species particularly sensitive to increased levels of feedstock removal. In addition, the increased levels of physical disturbance associated with feedstock harvests may physically displace certain species or create opportunities for invasion by exotic, invasive plant species (Hobbs and Huenneke 1992, Parendes and Jones 2000, Sumners and Archibold 2007, Wolf et al. 2008). Once established, invasive species can cause dramatic changes to ecosystem structure (Asner et al. 2008) and site productivity (Allison and Vitousek 2004, Ashton et al. 2005), as well as placing native vegetation at risk. Together, the potential shifts in native plant species composition and the risk of invasive species have important consequences for long-term forest sustainability and resilience, thus making these critical response variables to measure in assessments of the sustainability of biomass harvesting.

This proposal seeks to increase our understanding of the ecological impacts of biomass harvesting on nutrient poor sites through the establishment of a network of research sites on nutrient poor soils in Minnesota. Treatments representing various levels of biomass removal and green-tree retention will be implemented at each site to evaluate the importance of site-level legacies (green trees and harvest residues) in maintaining the resilience and sustainability of these systems under different biomass harvesting regimes. In addition, empirically derived estimates of nutrient removals from these research sites will be used to model the long-term effects of repeated biomass removals on ecosystem productivity using the PnET model. Importantly, this project will establish treatment sites, collect and analyze baseline data, and implement harvest treatments to facilitate long-term monitoring of the ecological impacts of biomass harvesting at several spatial scales. In addition, this proposed project complements a companion study established on nutrient rich soils within northern Minnesota and established through funding by the Minnesota Forest Resources Council (MFRC) and United States Department of Agriculture (USDA). Collectively, results from these areas will be critical for assessing the sustainability of biomass harvesting across the full range of forest conditions in the state and will be central to informing future revisions of harvesting guidelines.

III. Hypotheses

We put forth the following hypotheses regarding the impacts of biomass harvesting on aspen-dominated forest systems growing on nutrient poor soils in northern Minnesota:

a. The size and abundance of tree regeneration established following biomass harvesting will be greatest within the whole-tree harvesting (no slash) treatments, compared to the 20% and 100% slash retained treatments. This difference will be due to the influence of logging slash on sprouting of aspen, as well as the lower levels of exposed soil for the establishment of other tree species within the 20% and 100% slash retained treatments.

b. The response of tree regeneration will be affected by leave trees, with dispersed leave tree treatments resulting in the lowest regeneration densities and heights compared to no retention and clumped retention treatments.

c. Retained clumps of trees within harvest areas are able to maintain understory vegetation communities similar to unharvested intact stands.

d. The presence of exotic, invasive plant species will be greatest within the treatments receiving the highest levels of biomass removal.

e. There will be no detectable short-term differences in soil nutrient levels between biomass harvesting treatments**.**

f. Repeated removals of nutrients in logging slash over multiple rotations will result in declines in ecosystem productivity.

IV. Methodology

Activity 1: Develop a network of research sites on nutrient poor soils to assess impacts of biomass harvesting on biodiversity and productivity

Currently, little information exists on the potential impacts of biomass harvesting on aspen-dominated systems growing on nutrient poor soils. To address this need, we will establish large-scale manipulations of aspen-dominated forests on nutrient poor sites allowing us to assess the ecological impacts of biomass harvesting on these systems, and to evaluate potential management recommendations for sustaining the ecological functions of these site types within the context of this management regime. In particular, research will be conducted at 4 aspen forest sites on nutrient poor outwash sands within northern Minnesota. Each site will be a minimum of 120 acres to accommodate each treatment, as well as buffers between treatment units. Study sites will be located on lands owned by the St. Louis County Land Department and Minnesota Department of Natural Resources. At each site, the following treatments will be replicated using a randomized complete block design:

a) ***Woody biomass removal*:** Four levels of woody biomass removal will be implemented: no harvest (control), bole-only harvest, whole-tree harvest, and biomass removal following MFRC guidelines (Figure 1). For biomass removal treatments following MFRC guidelines, trees will be whole-tree harvested, and 20% of limbs and tops will be either left in the woods or transported from the landing and scattered in the harvest area (MFRC 2007). Comparisons between these treatments will allow long-term studies to assess whether different levels of woody biomass harvesting have lasting effects on forest regeneration, nutrient availability, and stand productivity. In addition, comparisons of woody biomass treatments following MFRC guidelines with whole-tree harvests will allow for an evaluation of the importance of deadwood legacies in mitigating the ecological impacts of biomass harvesting operations.

b) ***Retention of green trees*:** Three levels of green-tree retention will be evaluated: no retention, dispersed retention, and aggregated retention. For the green tree retention treatments, we will follow MFRC guidelines, which recommend either 6-12 scattered leave trees per acre or one or more clumps (1/4-acre or larger) comprising in total at least 5 percent of the treated area in clearcut aspen stands (MFRC 2005). Comparisons between stands with and without green trees will allow long-term studies to assess the importance of green trees in maintaining community resilience and sustainability following roundwood (bole-only) and biomass (whole-tree) harvests. Moreover, comparisons of treatments with differing retention patterns will test the differential ability of these spatial patterns to influence productivity and ameliorate the ecological impacts of roundwood and biomass harvesting treatments. Finally, examination of the interactive effects of green tree and harvest residue retention treatments will evaluate the relative importance of each of these factors in mitigating the ecological impacts of harvesting operations. Collectively, these long-term analyses will represent the first formal evaluation of the MFRC's recommended green tree retention levels and will serve to inform future refinement of those guidelines.

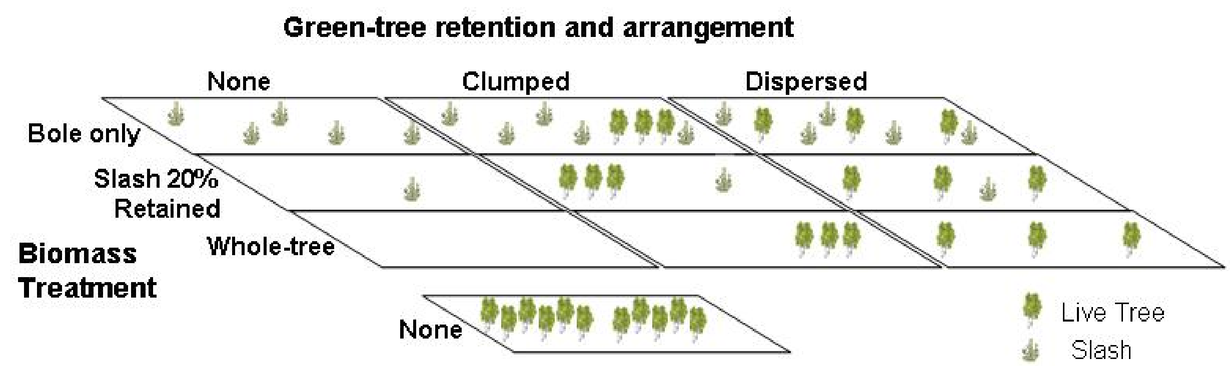

Figure 1: Conceptual diagram of treatments to assess the impact of biomass harvesting on saproxylic communities, nutrient cycling, and productivity in aspen ecosystems. Treatments include 3 levels of biomass harvesting, three levels of green tree retention, and an untreated control. All 10 treatment combinations will be included at each site, and will cover at least 10 acres.

Importantly, the design for these research sites is the same as an ongoing large-scale study in aspen systems on nutrient rich soils in the state, allowing us to integrate the findings of this work into a broad context that represent a significant portion of the forested conditions in Minnesota.

Activity 2: Determine the impacts of biomass harvesting on regeneration and growth of ecologically important tree species and spread of invasive species

Vegetation measurements
Within each treatment, six 400 m^2 sampling plots will be established for collecting vegetation data, with each of the larger sampling plots split into 200 m^2 subplots for implementing planting treatments. Plots will be at least 25 m from the treatment border and green-tree aggregates and will be randomly located. For treatments containing green-tree aggregates, two of the six sampling plots will be placed within the center of aggregate-retention groups. All vegetation will be measured annually within a series of nested plots. The largest plot (400 m^2) will be used for sampling living and standing dead overstory trees (DBH $\geq$ 10 cm), recording species and

DBH for all trees. Species and DBH will be recorded for all saplings (DBH $\geq$ 2.54 cm and < 10 cm) occurring within three nested 25 m^2 plots. Advance tree regeneration and shrubs (< 2.54 cm DBH and $\geq$ 0.15 cm tall) will be tallied by species and measured (diameter at 15 cm) in three, 10 m^2 subplots nested within the sapling plots. Tree seedlings (<15 cm tall) within these plots will be tallied by species. Dead stems will be included in advance regeneration and shrub measurements on one of the 10 m^2 subplots per sampling plot. One litterfall trap will be randomly placed in each 400 m^2 plot for deriving estimates of litterfall rates. Published biomass equations will be used for estimating aboveground biomass within each plot (Jenkins et al. 2003), as well as for determining aboveground carbon stores. Finally, percent cover of understory vegetation will be measured in 8 randomly located 1m^2 plots. All plot locations will be marked and photographed to allow for repeated measurements and interpretation of results over the duration of the study.

Soil measurements

Soil sampling will be conducted in three circular 25 m^2 subplots radiating from plot center at azimuths of 90, 210 and 330° (Figure 1). An individual forest floor and mineral soil sample will be taken from each subplot and composited at the plot-level. The soil sampling location will be randomized within each subplot and marked with a pin flag to avoid resampling of the same areas in future measurements. Total C, N, Ca, Mg, Na, P, and K will be measured on soil samples collected from the surface of the O horizon to a depth of 20 cm. O horizon or forest floor material will be collected from 25 cm diameter PVC rings, where litter depth will be measured and the entire sample from within the ring collected. Following the removal of the litter, a soil core with a known volume will be collected to a depth of 20 cm. Forest floor material will be dried at 65°C and mineral soils dried at 105°C for preparation of the analysis of total C, N, Ca, Mg, Na, and K. Also, depth of forest floor measurements and core volume will be used for calculating bulk density of forest floor and mineral soil layers allowing us to determine the soil mass per unit area of C, N, Ca, Mg, Na, P, and K. Herbaceous biomass will be determined by clipping and collecting all herbaceous material within one soil sampling location per plot. This collection will occur within a 25 cm diameter PVC ring.

Coarse woody debris: Within each 400 m^2 plot, species, height, and DBH will be recorded for all snags (standing dead trees ≥ 7.5 cm DBH and $\geq$ 1.5 m tall). Downed coarse woody debris (CWD; $\geq$ 10 cm diameter at the large end and $\geq$ 1 m in length) will be measured within each plot using the line intercept method (Harmon and Sexton 1996). In each plot, three 20-m transects radiating from plot center at azimuths of 30, 150, and 270 degrees will be established and used for sampling CWD (Figure 1). Intercept diameter, species (when possible), and decay class will be recorded for all CWD pieces encountered along these transects. In order to convert CWD volumes to biomass estimates, we will use published density values from Harmon et al. (2008). In addition, nutrient and carbon content of these samples will be determined using the methods outlined in Sollins et al. (1987) and used for estimating deadwood carbon and nutrient pools.

Fine woody debris: Fine woody debris (FWD; < 10 cm diameter at large end) will be measured along a portion of the three CWD transects using the line-intercept method (Figure 1, Brown 1974). Transect lengths will be varied based on FWD size classes following the protocol outlined by Brown (1976). In particular, species and diameter for FWD $\geq$2.5-7.5 cm in diameter will be recorded along a 4 m transect, whereas all FWD 0.625-2.5 and < 0.625 cm in diameter will be recorded along 2 and 1 m subsections of this transect, respectively. Volumes of FWD will be determined for each species using equations in van Wagner (1968). FWD biomass and nutrient and carbon content will be determined following the same procedures as CWD. In cases in which species cannot be determined for FWD, we will classify wood as either "conifer" or "hardwood" and will use wood density values that represent the average density of conifer and hardwood species on the plot prior to harvest. Data from these samples will be integrated with aboveground biomass estimates derived using the equations in Jenkins et al. (2003) to determine the levels of nutrient and carbon removed in biomass harvesting operations.

Statistical analyses: The immediate and long-term impacts of biomass harvests on nutrient availability and cycling rates, tree regeneration density and size, and non-native invasive species abudance will be evaluated using mixed-model and repeated-measures mixed-model ANOVAs, respectively. Non-metric multidimensional scaling will be used to evaluate changes in community composition for understory vegetation over time and across biomass harvesting levels. In addition, multi-response permutation procedures will be used to compare the composition of each of these communities between different levels of harvestings.

Activity 3: Model long-term sustainability of biomass harvesting on nutrient poor soils

The ecological sustainability of biomass harvesting hinges on nutrient availability and potential nutrient limitations. We will integrate findings from Activity 2 into a well-validated ecological computer model (PnET) to simulate multiple levels of biomass harvesting on a range of soil qualities. This activity integrates soil nutrient and ecosystem productivity measurements collected under Activity 2 into an ecological simulation model to generate estimates of the long-term impact of biomass harvests on forest productivity. Building on our insights about environmental impacts and sustainability from field measurements, we will simulate long-term forest growth and feedstock production in aspen forests growing on nutrient poor sites.

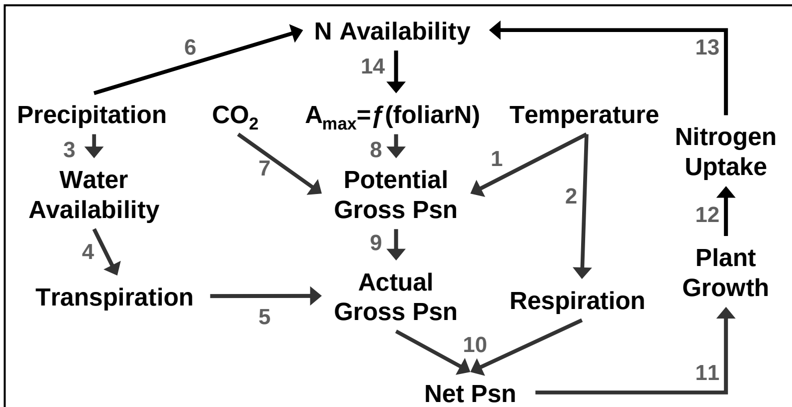

Figure 2: Conceptual diagram illustrating physiological processes included in PnET-CN. Temperature downregulates gross photosynthesis (1) based on deviations from optimal temperatures limiting maximum photosynthesis rates and high vapor pressure deficit limiting stomatal conductance. In addition, temperature impacts foliar respiration rates through a Q_{10} relationship (2) (Aber and Federer 1992). Precipitation alters soil water availability (3), which, combined with estimates of water use efficiency and vapor pressure deficit, limit transpiration (4) and downregulate actual gross photosynthesis (5). Precipitation influences the rate of nitrogen leaching and thus overall nitrogen availability (6). CO_2 concentration impacts production primarily by altering the maximum rate of photosynthesis (7). Internal CO_2 concentrations (Ci) are calculated from ambient CO_2 levels (Ca) and Ci/Ca ratios, which are linearly related to foliar nitrogen concentration. For a given Ca, Ci is used to estimate relative photosynthesis rates, which are translated into a proportional change in maximum photosynthesis rates (Ollinger et al. 2002). Foliar nitrogen plays a central role in PnET-CN by dictating maximum photosynthetic rate (A_{MAX}), A_{MAX} is combined with temperature and CO_2 to estimate potential gross photosynthesis (8), which, along with transpiration, dictates actual gross photosynthesis (9). Net photosynthesis is the difference between gross photosynthesis and respiration (10) and is used to generate monthly estimates of plant growth (11). Plant growth influences nitrogen update (12), nitrogen availability (13) and foliar nitrogen concentration (14).

Simulations of long-term impacts of feedstock harvests: We will utilize the PnET-CN ecological simulation model to assess the long-term impact of biomass harvesting on forest productivity. PnET-CN is an ecological simulation model that uses physiological algorithms to simulate productivity and biomass accumulation in response to variability in temperature, precipitation, and CO_2 concentration as well as natural disturbances and human landuse practices (Figure 2). PnET-CN was designed around observed relationships between nitrogen concentration in leaves and photosynthesis rate (Aber and Federer 1992, Aber et al. 1995, Aber et al. 1997) and simulates forest growth, carbon and nitrogen allocation and cycling as well as soil water balance and water limitation. As a part of an ongoing research effort, members of our group are currently working to parameterize PnET-CN for aspen forests of the northern Lake States and validate the model with an independent dataset of forest growth for over 150 sites (Reich et al. 1997, Reich et al. 2001 and Reich et al. unpublished). Preliminary analyses suggest that PnET-CN output agrees within 10% with measured stand level carbon gain and provides a near 1:1 prediction across a range of stands varying in productivity rates.

PnET-CN is ideally suited for simulating the long-term sustainability of biomass harvesting because it simulates ecosystem nitrogen cycling and the effect of nitrogen limitation on productivity. Results about the short-term consequences of biomass harvesting for nitrogen abundance and availability from Activity 2 will be integrated into PnET-CN by modifying parameters specifying the amount of nitrogen removed in harvesting events. To assess the long-term sustainability of biomass harvesting, we will use the parameterized PnET-CN to simulate harvesting regimes with varying intensity (i.e. amount of biomass removed) and rotation lengths for 100 years in the future. This will identify the intensity of biomass harvesting (in terms of both amount removed and frequency of harvest) that can be sustained without adversely affecting nitrogen availability and forest productivity.

V. Description of the results and deliverables to produced from the proposed research

The deliverables of the project will be (1) operational-scale field experiments that will serve to inform scientists and land managers on the impacts of biomass harvesting on the structure and function of aspen forests on nutrient poor soils; (2) datasets that enable an evaluation of the plant community, tree seedling, and soil nutrient responses of aspen systems under different levels of biomass removal; (3) predictions regarding the long-term impacts of repeated biomass removals on the productivity of aspen systems growing on nutrient poor soils; and (4) policy-maker, land manager, and public education accomplished via a combination of conferencing, reports, seminars, and web-based information.

VI. Timetable for the proposed research (organized by project results)

Activity 1: Develop a network of research sites on nutrient poor soils to assess impacts of biomass harvesting on biodiversity and productivity

Date	Milestone
July 2011	Project begins
August 2011	Nutrient poor sites identified through work with MNDNR and St. Louis County
November 2011	Treatment and plot layout completed
October 2012	Pre-harvest measurements of soils and vegetation completed
March 2012	Treatment implementation completed (timber sales carried out)

Activity 2: Determine the impacts of biomass harvesting on regeneration and growth of ecologically important tree species and spread of invasive species

Date	Milestone
July 2011	Project begins
October 2013	Post-harvest measurements of soils and vegetation completed
June 2014	Data synthesis complete, final report complete, project end

Activity 3: Model long-term sustainability of biomass harvesting on nutrient poor soils

Date	Milestone
July 2011	Project begins
November 2013	Characterization of initial ecological impacts of biomass harvesting completed
November 2013	Results incorporated into ecological models of long-term impacts
June 2014	Project summaries published

VII. Dissemination and Use

The final product of this project will be an interpretive report describing (a) the early initial impacts of forest biomass harvesting on the plant communities and nutrient status of aspen forest systems growing on nutrient poor soils in northern Minnesota and (b) predictive models of the long-term impacts of repeated biomass removals on these sites. This report will be made available on the internet as a Department of Forest Resources Staff Paper Report. In addition, several manuscripts will be written based on this research and submitted for publication in peer-reviewed journals. A fact sheet summarizing principal findings of this project will be distributed to LCCMR members and legislators at the state and federal level. Results will be presented at state and national forest management and forest health conferences, and notably to agency and individual participants in the Sustainable Forests Education Cooperative. All reports and publications from this project will be made available via the Department of Forest Resources web site.

VIII. Budget

The total budget request is 350,000 over a three-year period. This budget includes salary and fringe (0.1812) for one post-doctoral research associate is budgeted for two years. This post-doc will assess the initial impacts of biofuels harvests on soil nutrient availability, forest regeneration, and plant community composition. Salary and fringe (0.3230) for one research associate (0.1 FTE) is budgeted for 3 years. This research associate will assist with field sample processing and project coordinations. One month of summer salary and fringe is budged for three years for the PI on this project, Dr. Anthony D'Amato. This salary will be used to pay for time spent on coordinating researchers, as well as analyzing and summarizing research results from this project. Salary and fringe (0.0743) for a work study student is budgeted for three years and this student will assist with summer field sampling and the processing of collected samples during the school year.

The subcontract with the U.S. Forest Service, Northern Research Station in Grand Rapids is to support salary and fringe for one full-time field technician for all three years of the study. This technician will be responsible for collecting field data, as well as for coordinating field crews. This subcontract also includes salary and fringe for two undergraduate summer employees for two years. The technician and summer students will be employed by the US Forest Service because that is the most cost-effective approach and our need to have personnel dedicated to this research study who are located close to the field sites. Finally, $12,000 of this subcontract is for lab analysis of soil samples that will be conducted in the analytical laboratory at the Northern Research Station in Grand Rapids, MN.

Due to the high number of study sites and logistics associated with establishing the harvest treatments and baseline data collection, $18,000 is budgeted for domestic travel within Minnesota. This money will be used to pay for mileage (75%) and lodging (25%) for researchers, the field technician, graduate students, and undergraduate students. Equipment for permanently marking research plots, collecting regeneration and soil samples, and measuring soil nutrient availability are budgeted at $5999.

BUDGET ITEM	**AMOUNT**
Personnel: One month of faculty summer salary and fringe (0.1934) for three years(D'Amato, PI; 0.1FTE)	$30,999
Salary and fringe (0.1812) for a post-doctoral resarcher for two years (1.0 FTE)	$100,709
Salary and fringe (0.3230) for a research associate for 2.75 years (0.1 FTE)	$40,605
Salary and fringe (0.0743) for a work-study undergraduate student for 3 years	$26,688
Contracts: U.S. Forest Service this contract includes: -funds for hiring one half-time field technician for all three years of the study (0.5 FTE; $87,000). -salary and fringe for two undergraduate summer employees for two years ($28,000). The technician and summer students will be employed by the US Forest Service because that is the most cost-effective approach and our need to have personnel dedicated to this research study who are located close to the field sites. -lab analysis of soil samples ($12,000; **reduced rate** donated by US Forest Service)	$127,000
Equipment/Tools/Supplies: Equipment includes rebar for permanently marking plot centers ($350), supplies for constructing resin bags for soil nutrient measurements ($4000), soil cores and corer ($110), Haglof distance measuring equipment ($700), stake whiskers for marking subplots ($110), scintillation vials for soil analyses ($730)	$5,999
Travel: Due to the high number of study sites and logistics associated with establishing the harvest treatments and baseline data collection, $18,000 is budgeted for domestic travel within Minnesota. This money will be used to pay for mileage (75%) and lodging (25%) for researchers, the field technician, graduate students, and undergraduate students	$18,000
TOTAL PROJECT BUDGET REQUEST TO LCCMR	$350,000

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IX. Credentials

Biographical Sketches of Senior Personnel on Project

BIOGRAPHICAL SKETCH – Anthony W. D'Amato

Assistant Professor – Department of Forest Resources, University of Minnesota
1530 Cleveland Ave. North, St. Paul, MN 55108 – (612) 625-3733 – damato@umn.edu

Education and training

University of Maine	Forest Ecosystem Science	B.S., 2000
Oregon State University	Forest Science	M.S., 2002
University of Massachusetts	Forest Resources	Ph.D., 2007
University of Massachusetts	Forest Resources	Post-Doc, 2007

Research and professional experience

2007 –	Assistant Professor	University of Minnesota, St. Paul, MN
2007	Post-Doctoral Fellow	University of Massachusetts, Amherst, MA
2002–2006	Research Assistant	Harvard Forest, Harvard University/University of Massachusetts, Amherst, MA

5 Publications related to proposed project:

Domke, G.M., A.J. David, A.W. D'Amato, and A.R. Ek. In press. Hybrid aspen growth response to shearing in Minnesota: implications for biomass production and carbon sequestration. *Northern Journal of Applied Forestry*.

D'Amato, A.W., B. Palik, and C. Kern. 2010. Growth, yield, and structure of extended rotation *Pinus resinosa* stands in Minnesota. *Canadian Journal of Forest Research* 40: 1000-1010.

Bradford, J., A.W. D'Amato, B. Palik, and S. Fraver. 2010. A new method for evaluating forest thinning: growth dominance in managed *Pinus resinosa* stands. *Canadian Journal of Forest Research* 40: 843-849.

D'Amato, A.W., D.A. Orwig, and D.R. Foster. 2009. Understory vegetation in old-growth and second-growth *Tsuga canadensis* forests in western Massachusetts. *Forest Ecology and Management* 257: 1043-1052.

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5 other peer-reviewed publications

Puettmann, K.J., A.W. D'Amato, U. Kohnle, and J. Bauhus. 2009. Growth dynamics of *Abies alba* during repeated group shelterwood (Femelschlag) cuttings. *Canadian Journal of Forest Research* 39: 2437-2449.

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D'Amato, A.W., and D.A. Orwig. 2008. Stand and landscape-level disturbance dynamics in western Massachusetts. *Ecological Monographs* 78: 507-522.

Orwig, D.A., R.C. Cobb, A.W. D'Amato, M.L. Kizlinski, and D.R. Foster. 2008. Ecosystem response to hemlock woolly adelgid outbreaks in southern New England forests. *Canadian Journal of Forest Research* 38: 834-844.

D'Amato, A.W., and K.J. Puettmann. 2004. The relative dominance hypothesis explains interaction dynamics in mixed species *Alnus rubra*/*Pseudotsuga menziesii* forests. *Journal of Ecology* 92: 450-463.

Synergistic Activities

- Member, Education Advisory Committee, Sustainable Forestry Education Cooperative, 2009-2010.
- Member, Black ash management guidelines development group, Minnesota Department of Natural Resources, 2009.
- Chair. Education Development Committee, Minnesota Chapter of the Society of American Foresters, 2010.
- Session organizer, Ecological classification systems in forests. 7th North American Forest Ecology Workshop, 2009.
- Field tour organizer and leader, Improving Productivity of Minnesota's Forest Resources. Workshop coordinated by the Minnesota Forest Resources Partnership, 2007.
- Member, Silviculture Task Force, coordinated by the Minnesota Forest Resources Partnership, 2007.
- In-coming chair, Forest and Range Ecology Working Group, Society of American Foresters
- Reviewer for several interdisciplinary scientific journals, including *Ecology, Ecological Applications, Forest Science, Journal of Ecology, Journal of Forestry, Northern Journal of Applied Forestry, Forest Ecology and Management, Annals of Forest Science, The Journal of the Torrey Botanical Society,* and *Western Journal of Applied Forestry*