Environment and Natural Resources Trust Fund

Research Addendum for Peer Review

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Enhancing Environmental and Economic of Woodland Grazing

Project number: **B-024**

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1. Abstract

Over 527,000 acres of unmanaged woodlands are being used for livestock grazing throughout Minnesota. Of that area, 40% (210,800 acres) is located in the central and north-central regions and represents more than 11,600 farms. Managing these grazed woodlands based on the use of best management practices will provide environmental/conservation and economic/production opportunities. Silvopasture, the practice of intentionally combining and managing trees, forage (grasses), and livestock (i.e., cattle) as one integrated practice, can improve functionality and health of the watershed, resulting in improved water quality in streams, rivers and lakes due to reduced soil erosion and minimization of nitrate leaching. Silvopasture exhibits potential to enhance environmental and economic benefits within Minnesota's hardwood transition zone where livestock production is practiced. Compared to other parts of the US where silvopasture is a common practice, barriers exist in adopting silvopasture in MN because of the lack of knowledge of how trees, forage, and cattle can be managed as one integrated system for environmental and economic benefits. This study will evaluate, assess, and monitor the effectiveness of silvopasture as a tool for enhancing woodland grazing particularly for improving water quality, reducing soil erosion, and enhancing and preserving plant species diversity while improving economic productivity of livestock producers in central and north-central Minnesota. Three sites will be established for the study. In each site, three pastoral systems serving as treatments will be established: 1) unmanaged (traditional) woodland grazing, 2) traditional (conventional) pasture, and 3) silvopasture (managed woodland grazing with trees, livestock and forage. together). Parameters to be collected will include water quality, erosion rate, and plant species diversity, forage quality and cattle performance.

2. Background

Over 527,000 acres of unmanaged woodlands are being used for livestock grazing throughout Minnesota. Of that area, 40% (210,800 acres) is located in the central and north-central regions and represents more than 11,600 farms (USDA-ERS, 2012). Grazing is a form of an agricultural practice where animals (livestock) feed on plants, such as grasses. Agriculture is an important sector contributing to Minnesota's state economy. In 2008, $16 billion was generated from the agricultural sector (MDA, 2009) where 38.4% ($6.1 billion) of this amount came from livestock products, making it one of Minnesota's top 5 export commodities. Cattle market is strong, producer want to expand herd to take advantage, this may lead to more unmanaged woodland grazing as current pasture systems may already being maximized. When unmanaged, woodland grazing can impair the functionality of the watershed and contribute to environmental degradation such as reduced water quality, increased soil erosion, and the leaching of nitrates.

However, managing these grazed woodlands based on the use of best management practices (BMPs) will provide environmental and economic opportunities. Silvopasture, an agroforestry practice that intentionally combine and manage trees, forage (grasses), and livestock (i.e., cattle) as one integrated practice, will enhance woodland grazing for environmental protection/conservation and production benefits. Managing the trees, forage and livestock together as a whole will improve functionality and health of the watershed, resulting in an improved water quality in streams, rivers and lakes due to reduced soil erosion and minimization of nitrate leaching. Nitrate leaching occurs when there is an accumulation of nitrate in the soil profile that coincides with or is followed by a period of high drainage (Di and Cameron, 2005), and is considered as non-point source pollution. Nitrogen applied in excess of what the plant uses will result in inefficient use by the crops and contributes to N leaching below the effective rooting zone (Stout and Jung, 1992; Zamora et al., 2009), and movement into the surface drainage and ground water (Ng et al., 2000).

Environmental Benefits: Several studies have shown that silvopasture can improve water quality. The complex root systems under silvopasture can mitigate the effects of nitrate leaching into the groundwater

as they (trees and forage) occupy different soil depths resulting in improved efficiency of nitrogen uptake, reducing nitrogen losses from soil compared with monoculture agronomic crop and tree plantations (Allen et al., 2004; Bambo et al., 2009). In assessing the water quality impacts of a pecan-based silvopasture system in Florida, Nair et al. (2005) observed a significant difference in the nitrate concentration of the silvopastoral system compared to traditional pasture systems. Similarly, Bambo et al. (2009) observed a reduced concentration of nitrogen in a loblolly pine-based silvopastoral system in the US Southeast (8 mg L^{-1}) compared to the open pasture (67 mg L^{-1}). A similar trend was also observed when Boyer and Neel (2007) found that nitrate concentration in silvopasture (2.2 mg L^{-1}) was less than conventional pasture (4.4 mg L^{-1}) and in hardwood forests (4.1 mg L^{-1}). In a similar study of silvopastoral systems in Florida, Nair et al. (2004) found that silvopastoral associations enhanced soil nutrient retention and reduced nutrient transport in surface and subsurface water during their monitoring of soil phosphorus concentration in pastures with and without 20 year- old slash pine (*Pinus elliottii*) trees. Using their individual studies, these researchers concluded that a silvopasture system can be employed as a grazing tool in wooded pasture for water quality improvement.

Silvopastoral practices have also been shown to promote species diversity (both flora and fauna) compared to traditional pasture and woodland grazing. In a study which assessed species diversity of silvopasture, McAdam and McEvoy (2009) reported a significantly higher diversity of plant species in grazed woods than in ungrazed woods. Ungrazed (or traditional woodland grazing) were found to have significantly more leaf litter and deadwood than grazed woods affecting species diversity. The opening of canopies during the conversion of existing traditional woodland grazing into silvopasture allows the penetration of light into the ground triggering seeds stored in the seedbank to germinate and facilitate the growth of these species (Garrett et al., 2009) which could then serve as food supplies for livestock and wildlife. Unwanted trees are removed during the conversion and good quality trees are retained based on the desired basal area. In McAdam and McEvoy (2009), managed grazed woodlands were found to have significantly more grass cover than ungrazed woodlands, translating into greater forage production. Managed woodland grazing has also been shown to have a positive association with tree regeneration. An investigation on seedling and sapling density of oak (*Quercus robusta*) showed significantly more seedlings and saplings in silvopasture systems as compared to unmanaged woodlands (McAdam and McEvoy, 2009; Harvey et al., 2008).

Economic Benefits: Silvopasture maximizes forage production in wooded pastures while building long-term capital in high quality timber. It helps avoid economic losses from reduced timber value and low quality of forage that could translate to decreased animal productivity due to inadequate nutrition (Garrett et al., 2004). Shade from trees could translate to greater forage production, nutritive value, digestibility of pasture grasses grown under trees relative to open sites and mitigation of stress to animals, hence more livestock weight gain (Belesky et al,, 2006; Feldhake et al., 2008; DeBruyne et al., 2011; Kallenbach et al., 2010).

Silvopasture has shown potential for environmental and economic benefits in other parts of the US. While it is a proven practice elsewhere, silvopasture is not commonly applied in Minnesota because of lack of locally-based research as well as exposure to and knowledge of the practice. While converting traditional forest systems to silvopasture is not encouraged, silvopasture exhibits potential to enhance environmental and economic benefits within Minnesota's hardwood transition zone where livestock production in the woods is currently being practiced. Because it utilizes best management practices, silvopasture would create a healthier working agricultural landscape and creates greater incentive for good stewardship through more deliberate and efficient land use.

3. Hypothesis

We plan to assess the following hypothesis regarding the impacts of silvopasture on water quality, plant species diversity and forage quality and livestock performance in Central and North-Central Minnesota:

1. Silvopastoral systems are more efficient at removing N from the soil profile than conventional pasture and traditional woodland grazing, and therefore contribute to the reduction of non-point source pollution and enhance the quality of water leaving the site and entering into streams, ponds, and into the ground water.
2. Silvopastoral systems promote and enhance plant species diversity compared to traditional woodland grazing and therefore provide a greater diversity of plant species for livestock grazing.
3. Silvopastoral systems will result in improved forage quantity and quality compared to the unmanaged woodland pasture treatment. This improvement in forage quality and quantity will be reflected by improved cow performance as assessed through weight gain and maintenance of body condition and greater weight gain of suckling calves.

4. Methodology

Three sites located in Central/North Central Minnesota will be selected for the study. Within each site, the following three grazing systems will be established: 1) conventional (traditional) open pasture, 2) unmanaged (traditional) woodland grazing, and 3) silvopasture (managed woodland grazing with trees, livestock and forage together). Each site will receive similar site preparation activities including brushing/removing of unwanted vegetation, fertilization and seeding. Recommended fertilization and seeding rates of the Natural Resources Conservation Service (NRCS) will be followed in the experiment. A uniform 25 ft^2/acre basal area (Garret et al., 2004) of trees will be used in the silvopasture treatment in each site. Basal area is the area of a given section of land that is occupied by the cross-section of tree trunks and stems at their base. Using logging equipment, trees will be cut and removed in the silvopasture treatment to arrive at the specific basal area (25 ft^2/acre).

The study will be set-up using a randomized complete block design (RCBD), with the sites serving as research blocks, and the three grazing systems serving as treatments. Each grazing system/treatment will cover 4 acres (a total of 12 acres for each farmer cooperator or site.) Electric fencing will be installed around the perimeter of each 4-acre treatment to contain experimental cows. A 100-foot buffer will be installed between each treatment area to facilitate measurement of treatment effects. During each experimental period, four cow/calf pairs will graze each treatment area and will be rotated between treatment areas every 30 days. Parameters to be assessed during two consecutive years include water quality and soil erosion rate, plant species diversity, and forage quality and quantity, and livestock performance.

Analysis of Variance (ANOVA) will be used to determine treatment differences on water quality, erosion rate, plant species diversity, forage quality and livestock performance.

Result 1: Determine the impacts of managed woodland grazing (Silvopasture) on soil erosion rate and water quality and compare them with traditional open pasture grazing, and traditional woodland grazing.

The rate of soil erosion in each of the three systems will be quantified using erosion pins. Twelve erosion bar pins will be installed in each treatment area prior to the beginning of the experiment. An erosion pin is a long metallic pin or stake that is driven into the ground to serve as a stationary point of reference to measure the amount of water driven erosion. Detailed landscape surveys, tied to reference bar pins, using survey grade GPS (Global Positioning System) and/or laser level/rod measurements will be performed

before, during and after establishment of each treatment area. The measurements should capture degradation or aggradation of site sediment.

Water infiltrating through the vadose zone into ground water through leaching will be monitored and assessed in each of the three treatments for biogeochemical change. Twelve pan lysimeters will be installed in the vadose zone in each treatment area to assess and measure nitrogen leaching into the ground water. Pan lysimeters sample only water that freely drains from the soil matrix (Anderson, 1986), which relies entirely on gravity to supply water to the sampler. This zero-tension lysimeter has been determined to be better at monitoring the soil-water flux that recharges ground water; pan systems perform better than suction lysimeters (Hornby et al., 1986). Water quality in the site ponds and surrounding terrain will be monitored through the use of water table access tubes (pvc tubes cored into the soil and capped at the ground surface) positioned perpendicular to flow paths into the pond with supporting parallel tubes to quantify spatial variability. The array of tubes will provide a minimum of seven locations, including a pond water grab sample. Water samples will be collected monthly for biogeochemical indicators (stable isotopes, selected cations/anions and nutrients) during the soil thaw/snowmelt, following major precipitation events and monthly during the entire growing season when livestock are actively grazing in each treatment area. A data logger will be placed in each management system to continuously track water stage, temperature and specific conductance.

Result 2: Determine the impacts of managed woodland grazing (Silvopasture) on plant species diversity and compare them with traditional open pasture, and traditional woodland grazing.

Plant species diversity will be sampled using 1m x 1m plots systematically arranged on a grid (Mayer and Houvinen, 2007) with 10 plots per treatment at each site. Plant species diversity assessment will be done immediately before and after cattle are introduced in each system as described in result 3 below (***forage quality and livestock (cattle) quality assessment)***. Data collection will be done from May to October in years two and three of the project representing the growing season of the year. To characterize species richness, species will be categorized or sorted based on botanical composition: 1) grasses (cool or warm season), 2) forbs, 3) legumes, and 4) tree/seedlings. The Shannon-Wiener Diversity index will be used to analyze richness of species diversity, as this is the most widely used index for comparing diversity between habitats (Clarke and Warwick, 2001) or plant communities (Krebs, 1985; Ricklefs and Schuler, 1993; Gimaret-Carpenter et al., 1998). That index represents both evenness and abundance of species and is calculated as:

$$H = \sum_{i=1}^{s} p_i \ln p_i$$

where H is the Shannon-Wiener Diversity Index, the proportion of species *i* relative to the total number of plants is calculated and multiplied by the natural logarithm of this proportion. The resulting product is summed across species and multiplied by -1.

Result 3: Assess the impacts of managed woodland grazing (Silvopasture) on forage quantity and quality and performance of cattle and compare results with traditional pasture grazing and traditional woodland grazing.

Figure 1 illustrates the proposed Latin Square experimental design in RCBD for the evaluation of cattle performance. At the onset of pasture spring growth, twelve cow/calf pairs will be assigned by age, body weight (BW), body condition score (BCS; 1 to 9 scale; 1 = emaciated, 9 = obese), calving date, and breed to one of three experimental cow/calf groups (A, B, and C). Each group will be assigned to one pasture treatment for 30 days of grazing. Following the 30 days of grazing, cow/calf pairs will be removed from the pasture treatment and be comingled in a common pasture for 30 days. This "resting period" will allow forage regrowth in each of the pasture treatment paddocks. Following the 30-day resting period, cow/calf groups will be rotated to a different pasture treatment for an addition 30 days as illustrated in

Figure 1. Following the second 30-day on trial period, another 30-day resting period will occur, followed by a third, 30-day experimental period.

At the onset and conclusion of each of the three 30-day experimental period, cow BW and BCS will be assessed and calf BW will be taken. Similarly, at the onset and conclusion of each experimental period, forage quantity and quantity will be assessed in each experimental pasture treatment area. Forage quantity is defined as pounds of forage dry matter per acre and assessed using standardized methodologies that involve taking forage height measurements at set intervals within the treatment area. Forage quality will be assessed by taking 20 forage samples in a grid pattern through the pasture, combining collected samples, and sending a homogeneous forage sample to a certified laboratory for quantification of dry matter, crude protein, acid detergent fiber (ADF), neutral detergent fiber (NDF), total digestible nutrients (TDN), net energy (NE), and relative feed value (RFV).

Utilizing the Latin Square design increases the statistical power of the proposed research experiment. Furthermore, it allows for critical assessment of both animal performance and forage productivity. The experiment is designed to allow a period of pasture regrowth to closely represent the rotational pasture management system often implemented by beef producers in Minnesota. In grazing livestock systems, animal productivity is dictated by available forage (quantity) and quality of the forage consumed.

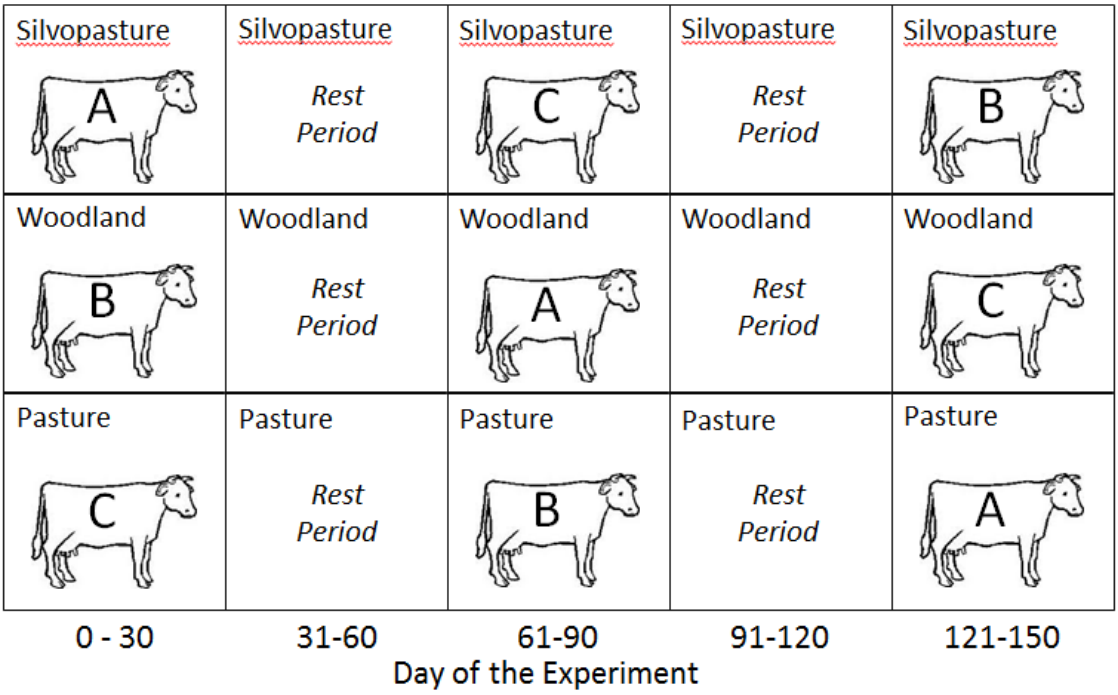

Figure 1. Experimental Design. Within each location, each treatment (silvopasture, unmanaged woodland grazing, and, conventional traditional pasture) will be represented in 4 acre paddocks. Each cow group (A, B, & C) will consist of 4 cows/calf pairs. Following 30 days on treatment, cow/calf pairs will be removed and maintained in common pasture and pastures will be ungrazed for 30 days to allow for forage regrowth.

Result 4: Conduct needs assessment and offer educational programs

A survey will be designed and conducted to help us better understand barriers pasture owners with woodlands may have to adopting silvopasture within the target counties. The survey will implement

strategies described by Dillman et al. (2009). Those strategies include contacting the target audience prior to initiating the survey to describe its purpose, mailing the survey (cover letter and survey), sending a thank-you/reminder notice a week after mailing the survey to everyone on the mailing list, and sending a second mailing of the survey two weeks later to non-respondents.

The survey protocol (e.g., survey instrument, correspondence to be sent to individuals) will be developed by the Project Team in cooperation with one or more nongovernmental organizations (NGOs) (e.g., MN Cattleman's Association, Minnesota Milk Producers Association) who have knowledge of our target audience. The participating NGOs will provide mailing lists as well as input about how best to contact members. Survey protocol will be approved by the Institutional Review Board (IRB) at the University of Minnesota prior to mailing any correspondence to the target audience.

Survey questions will be developed around: 1) demographics (respondent age, farm size, woodlot size, herd size, water and fencing resources), 2) satisfaction with current grazing practices, 3) current use(s) of their woodland, 4) use of woodlands for grazing (prior use for this purpose, perceptions about its use in the future), 5) prior knowledge about and perceptions of silvopasture, 6) how they prefer to learn (e.g., face-to-face workshops, field day visits to plots, printed content, digital text, webinars); and 7) time of year they prefer to learn. Survey data will be entered into Excel and analyzed using descriptive and regressing techniques to identify factors which contribute most significantly to implementing silvopasture approaches as well as to help us determine the "best" approaches for creating effective educational offerings to increase adoption of silvopasture.

5. Results and Deliverables

The deliverables of the project will be (1) operational-scale field experiments and demonstration that will serve to inform scientists, natural resource managers, and farmers/livestock producers about the environmental and economic benefits of enhanced woodland grazing; (2) data sets that will enable evaluation of the impacts of managed-woodland grazing on soil and water quality, plant species diversity, forage quality, and livestock performance; (3) best management practices manual containing methodologies and approaches of establishing silvopasture that could be easily understood by farmers and livestock producers wishing to adopt the practice; and (4) policy-maker, land manager, farmers/livestock producers, and public education accomplished via a combination of workshops, seminars and web-based information.

6. Timetable

Results 1 - 3: Determine the impacts of managed woodland grazing on soil erosion rate and water quality, plant species diversity, forage quality and livestock performance and compare them with traditional open pasture grazing, and traditional woodland grazing.

Date	Milestones/Deliverables
July 2013	Project begins
April 2014	Research plots established in each site. This will include site preparation (brushing, and cutting down trees), installing of infrastructures (fencing and water systems) and seeding forages, and installing water quality and soil erosion monitoring devices
October 2014	2014 Soil erosion rate and water quality measurements completed; 2014 Species diversity assessments completed; 2014 Forage quality and livestock performance measurements completed.
October 2015	2015 soil erosion rate and water quality measurements completed; 2015 Species diversity assessments completed; 2015 Forage quality and livestock performance measurements completed.
March 2016	Economic analysis completed using research data collected.
June 2016	Data synthesis complete, final report complete, project end

Result 4: Conduct needs assessment and offer education programs.

Date	Milestones/Deliverables
July 2013	Project begins
December 2013	Survey questionnaires approved by UMN Institutional Review Board (IRB), beta-tested, and sent-out to livestock producers/woodland owners.
March 2014	Survey data analysis completed and educational framework developed
August 2014	Summer field tour completed
January 2015	Winter workshop completed
August 2015	Summer field tour completed

January 2016	Winter workshop completed
March 2016	Post survey conducted assessing changes in attitudes, practice and behavior of livestock producers, woodland owners and natural resource managers; woodland grazing best management practices manual developed
June 2016	Final report complete, project end

7. Budget - The total budget request is $190,000 over a three-year period with specifics as shown in Table 1 below. These funds will be used to support a 50% FTE salary of one graduate student over three years and fringe benefits (46%) that includes tuition for the academic year, health care for the fiscal year, and social security and Medicare for 6.5 day periods (summer). The total salary and fringe of the Graduate Student over three years is $111,423. The graduate student will be responsible for collecting and analyzing data associated with results 1-3, and will provide assistance in completing tasks associated with Results 4. These funds are also for supporting salary (3% = $4,500) of CINRAM (Center for Integrated Natural Resources and Agricultural Management) Economist to conduct the economic analysis of silvopasture in year 3 using data generated by the study. An hourly laborer ($12/hour) is also budgeted to help the project team implement the project for a total of $3,600 for a total of 3 years. A professional/technical/service contract will also be made to implement the project including contracts to a professional Forester to conduct tree inventory and mark trees to be cut for the silvopasture treatment ($750), a Logger to cut down trees marked by the forester ($5,550), and a contractor to clear and prepare the site for the study ($4,500).

The funds will also be used to purchase supplies and tools for the study including soil erosion rate and water quality monitoring devices ($8,060), 3 field monitoring weather stations ($1,500), rectal thermometer ($300), and other field supplies such as seeds, fertilizers, and vials. A total of $12,420 is also budgeted to cover the cost of soil, water and tissues analysis necessary for the conduct of the study. A fee ($2,400) is budgeted for maintenance of chute and scale for assessing cattle performance.

A total of $11,240 is also allocated to cover cost associated with Results 4 of the project which includes outreach activities (2 field tours and 2 workshops) to share project results ($3,000), survey cost involving printing and mailing of postcards for pre and post surveys ($2,000), land rental fee ($3,240) to landowners for allowing us the use of their land for our research study. A farmer cooperators fee ($3,000) is also budgeted for cooperators' time involved in preparing and hosting field days.

Due to having three sites and logistics associated with establishing research plots in each site, $19,845 is budgeted for domestic travel within Minnesota. This money will be used to pay for mileage (93%) and lodging (7%) for researchers, and the graduate student. Mileage includes trips from UMN St. Paul to 3 sites in central/north-central Minnesota. An amount of $1,412 is also budgeted to cover the cost of one trip of our collaborator from the University of Missouri to help project team establish research plots.

BUDGET ITEM	**AMOUNT**
Personnel: 1 UMN Graduate Research Assistant Student (50% time) Salary ($81417) + Fringe (Tuition and Health Insurance, Social Security and Medicare) for 3 years	$111,423
CINRAM Economist (Dean Current) (3% Salary and Fringe)	$4,500
Labor @ $12/hour for 100 hours/year	$3,600
Professional/Technical Service Contracts	$10,800
Equipment/Tools/Supplies	$12,360

Travel to pay for mileage, lodging and one trip of our collaborator (University of Missouri) to Minnesota	$21,257
Other Costs (Soil, Water, Forage analyses, outreach activities, land rental, farmer cooperator fees, and survey costs)	$26,060
TOTAL PROJECT BUDGET REQUEST TO LCCMR	$190,000

V. Other Funds

Source of Funds	***$ Amount Proposed***	***$ Amount Spent***	***Use of Other Funds***
Non-state			
	$	$	
State			
In-kind services during project period: (UMN Extension In-Kind contribution through staff and salary fringes) PI – (Zamora) – Salary ($24, 554) + Fringe ($8,287) @ 15% time/year = $32,841 Co-PI – (Burkett) - Salary ($23, 943) + Fringe ($8,356) @ 15% time/year = $32,299 Co-PI (Bridges) (1%) – Salary ($2,245) + $757) = $3,002 Co-PI (Wyatt) – Salary ($1,202+ +Fringe (419) @ 2% time/year = $1,621)	$ 69,763	$	In-kind contributions of UMN Extension staff working on the project.
Other Sources (Central Region Sustainable Partnership)	$9,000		Cost to cover infrastructure for the project such as fencing, and water systems
TOTAL OTHER FUNDS:	**$78,763**	**$**	

8. Credentials

Dr. Diomy Zamora (Principal Investigator) is an Associate Extension Professor and Extension Forester with the University of Minnesota Extension focusing on agroforestry and biomass energy (bioenergy). Dr. Zamora is actively involved with implementing Extension's agroforestry and bioenergy program for woodland owners, agricultural producers, and Natural Resource Professionals. He received his PhD in Forest Resources and Conservation at the School of Forest Resources and Conservation, University of Florida, Gainesville, Florida in 2005 specializing in Agroforestry. Dr. Zamora promotes the establishment of different forms of agroforestry in Minnesota's landscapes for environmental and economic benefits. These agroforestry practices include silvopasture (managing trees + forage + livestock together as one practice), riparian forest buffers, alley cropping (planting rows of trees wide enough to create alley ways to allow production or planting of agronomic crops), windbreaks, and forest farming (farming non-timber forest products in the forests). Dr. Zamora is also implementing a number of bioenergy-related projects

including the use of agroforestry practices to produce feedstock for energy. Having been with the University of Minnesota Extension for over six years now, Dr. Zamora has developed, authored and published a number of peer-reviewed extension publications and technical journal articles about the use of agroforestry for achieving environmental protection and conservation while enhancing economic productivity among farmers in Minnesota.

Dr. Zamora teaches a course on "Agroforestry – Role in Watershed Management" at the Department of Forest Resources, College of Food Agriculture and Natural Resource Sciences (CFANS), University of Minnesota. He also serves as a Principal Investigator and Co-PI for number of projects including: 1) Educating Woodland Owners in Minnesota (Forest Stewardship funded), 2) A Decision Support Tool to Restore Impaired Waters (Pollution Control Agency funded), and 3) Production and Economics of Perennial-based Woody Herbaceous Biomass Crops under Alley Cropping Systems.

As Project Manager, Dr. Zamora will implement the research component of the project in collaboration with project team members including Dr. Joe Magner and Ms. Eleanor Burkett who will provide co-leadership role in assessing the environmental benefits of managed woodland grazing on water quality and species diversity, Dr. Allen Bridges who will take leadership role in assessing impacts of the managed woodland grazing on cattle performance, and Dr. Dean Current who will perform the economic analysis of managed woodland grazing. In addition to providing leadership role in the outreach component of the project with assistance from Mr. Gary Wyatt and Dr. Charlie Blinn, Dr. Zamora, along with project team members, will supervise and mentor the graduate student who will be working with the project.

Dr. Allen Bridges (Co-Principal Investigator) is an assistant professor at the University of Minnesota North Central Research and Outreach Center focusing in the area of beef cow/calf production and reproductive management. Dr. Bridges received his B.S. from the University of Missouri in Animal Sciences, M.S. from the University of Florida in Animal Sciences, and Ph.D. from The Ohio State University where he specialized in reproductive physiology in beef cattle. Prior to starting with the University of Minnesota in 2010, Dr. Bridges was on faculty at Purdue University (2007-2010). Currently, his appointment is 60% research and 40% extension. His research includes: 1) investigating the role of nutrition at mediating reproductive processes including its impact on oocyte viability and early embryonic development, 2) endocrine regulation of follicular function and fertility, and 3) systematic approaches to control the estrous cycle in cattle. Dr. Bridges is also a member of the University of Minnesota Beef Team and contributes significantly to its extension activities.

Ms. Eleanor Burkett (Co-Principal Investigator) is an Extension Educator of the University of Minnesota Extension. She provides water resources programs throughout the state of Minnesota. Topics include understanding watersheds, shoreland landscaping, erosion and maintenance, rain garden, aquatic plant identification, landscaping with native plants and realtor education. She has experience in developing trainings for natural resource professionals, nursery and landscape professionals, master gardeners and master naturalist. Eleanor worked in the landscape and garden industry for over nine years, prior to joining Extension in 2000. She taught Environmental Landscaping at the University of Minnesota, Crookston. Eleanor has an AAS in Horticulture from the University of Minnesota Crookston, as BS in Agriculture Extension from North Dakota State University, and a Masters Degree in Education from the University of Minnesota Duluth.

Dr. Joe Magner (Co-Principal Investigator) received degrees from the University of Wisconsin and Minnesota and has served as technical advisor for over 33 years for the Minnesota Pollution Control Agency, several consulting firms, David Letterman, The Institute of Groundwater Studies, (Bloemfontein South Africa), University of Qingdao, (China) and numerous local units of government throughout Minnesota. Dr. Magner uses varying tools to assess and restore hydrologic and hydrogeologic function. Dr. Magner is a research professor in the Department of Bioproducts & and Biosystems Engineering at the University of Minnesota. He teaches classes in water quality, hydrology and watershed management and advises graduate students seeking to learn more about watershed systems. Joe has 70 publications and

is a co-author of the 4th edition of *Hydrology and the Management of Watersheds* to be published by Wiley-Blackwell in March 2012. Recent publication related to grazing: Magner, J.A., Vondracek, B., and Brooks, K.N. (2008) Channel stability, habitat and water quality in south-eastern Minnesota (USA) streams: assessing managed grazing practices. *Environmental Management*, 42:377-390.

Dr. Charlie Blinn (Co-Principal Investigator) is Professor and Extension Specialist in the Department of Forest Resources, University of Minnesota. He has been with the University since 1984. He conducts teaching, research, and outreach/Extension educational programs. His research interests are focused on a broad range of forest management issues. Specific research areas include: assessing how public land management timber sale programs and policies impact environmental and economic outcomes, evaluating the effectiveness of forest management guidelines to moderate environmental impacts within forested riparian areas, and assessing how forest management guidelines impact environmental and economic outcomes. He also conducts Extension education programs for loggers and natural resource professionals which focus on a wide variety of forest management topics including presenting research results, demonstrating how to apply forest management guidelines, reviewing various aspects of timber harvesting and road planning, how to select and install stream and wetland crossing options, and using global positioning systems for work and recreational purposes. Charlie has published many peer reviewed and non-technical articles which report results and present management implications for the broad range or forest management issues he addresses through his research and outreach work.

Dr. Dean Current (**Co-Principal Investigator**) is a Research Associate in the Department of Forest Resources at the University of Minnesota and is Program Director of the Center for Integrated Natural Resources and Agricultural Management at the University of Minnesota. Dr. Current is a Natural Resource Economist and has researched the costs and benefits of agroforestry systems and biomass harvest from forests and perennial crops in Minnesota. Dr. Current has managed several projects related to agroforestry including an international, region wide analysis of the costs and benefits of agroforestry systems including silvopastoral systems; and the costs and benefits of agroforestry options in Minnesota.

Mr. Gary Wyatt (Co-Principal Investigator) is an Extension Professor and Extension Educator with the University of Minnesota Extension. Gary specializes in the areas of Agroforestry, invasive species, biomass and renewable energy. Other areas of programing include eco-system services, perennial conservation systems, tree selection, biodiversity, living snow fences, riparian buffers and windbreaks. Gary develops and delivers educational programs for natural resource managers, landowners and youth. He promotes sustainable Agroforestry practices that are economical and protect our soil, water, wildlife and natural resources. He has partnered with state, federal and non-government agencies to create and distribute educational fact sheets, resources and new releases on important issues to Minnesota residents. Gary received his B.S. and M.S. from Iowa State University and has over 28 years of Extension experience.

9. Dissemination and Use: The final product of this project will be an interpretative report describing the impacts of managed woodland grazing (Silvopasture) on 1) water quality 2) species plant species diversity, 3) forage quality, and 4) livestock performance. The first-two parameters comprise the assessment of the environmental benefits of woodland grazing, while the latter parameters provide assessment of the economic benefits of silvopasture. Extension publications materials such as fact sheets and a best management practices manual will be developed and made available online through the University of Minnesota Extension website. Copies of these extension materials will be distributed to LCCMR and legislators at the state and federal levels. Results will also be shared during field days and workshops which will be offered in conjunction with the educational events of the Leader Lions Forage Council. In addition several manuscripts will be written based on this research and submitted for publication in peer-reviewed journals. Results will be presented at state and national forest management and sustainable agriculture conferences, and notably to natural resource managers working on land management issues with landowners.

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