Environment and Natural Resources Trust Fund
2016 Request for Proposals (RFP)

Project Title: **ENRTF ID:**   014-A

Enhancing Forest Inventory Using Multiple Remote Sensing Technologies

Category: A. Foundational Natural Resource Data and Information

Total Project Budget: $ 1,053,638

Proposed Project Time Period for the Funding Requested: 3 years, July 2016 to June 2019

Summary:

Develop a robust cost-saving methodology for an enhanced stand-based forest inventory, including attributes that relate to forest structure and habitat suitability, using LiDAR, high resolution imagery, and plot data.

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Sponsoring Organization: MN DNR

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

This visual graphic demonstrates what, how, and why Resource Assessment plans to conduct the pilot project for the development of a robust cost-saving LiDAR forest inventory methodology. The first graphic illustrates the area (500K acres in northern Cass County) of our pilot project, depicting multiple landowner types and the ecological diversity throughout the area. The second graphic shows how LiDAR and high resolution photography is acquired using airplanes. Three more graphics demonstrate the amount of detail LiDAR can achieve when acquires at higher densities. This illustrates how we will map forest structure in great detail to be used for many ecological characteristics. The Next graphic is of a color infrared photograph with ecologically unique forest stands. We then illustrate the anticipated cost savings to the states inventory program if our remote sensing method is implemented

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage		_____ TOTAL _____%

PROJECT TITLE: Enhancing Forest Inventory Using Multiple Remote Sensing Technologies

I. PROJECT STATEMENT

Minnesota has an extensive and diverse forest land base important to multiple agencies and stakeholders, such as the U.S. Forest Service, DNR, counties, tribes, non-government organizations, and private citizens. **Using cutting-edge technologies, a less expensive and highly robust inventory of the forest land base will be developed through a pilot study across a diverse ecological landscape with multiple ownerships.** This pilot will assess methodology, accuracy, and costs, to evaluate the anticipated extension of this methodology statewide. After evaluation, we fully expect to establish and implement this cutting-edge inventory, thereby eliminating the need to return to the ENRTF for forest inventory funding.

➢ All agencies and stakeholders rely on forest inventory data for a wide variety of natural resource management purposes, including: assessing climate and landscape change, ecosystem fire and health risks, wildlife habitat, water resources, forest recreation, biomass estimations, and renewable timber assessments.

➢ Costs for accomplishing such forest inventories are increasingly expensive -- over $35 million is needed to inventory the 5 million acres of DNR forest land alone, out of about 17 million acres total forest land.

➢ Forest inventories are completed once every 10 to 20 years, making it difficult to respond to emerging issues.

➢ Technological advances in remote sensing and computing have now made it possible to rapidly collect, analyze, and characterize, in detail, ecological condition over large landscapes with very little ground data.

➢ Given these advancements, it is now possible to refine and apply these technological improvements to develop a revolutionary methodology for statewide forest inventory across diverse types of land ownerships.

➢ Ultimately, this project will demonstrate a highly effective, detailed, and robust method of achieving a comprehensive, accurate and regularly updated forest inventory at dramatically lower costs for the state.

The goal of this project is to create an updated, efficient, and revolutionary forest inventory technique by:

1. Developing a stand based forest inventory, including species composition, detailed attributes of the vegetation and forest structure, and characteristics that relate to wildlife and ecological habitat suitability.

2. Estimating a suite of tree attributes per stand (e.g., height, diameter at breast height (DBH), crown size, age, basal area, biomass, and volume) that relate to those ecological suitability characteristics.

Both the stand characteristics in (1) and the tree estimates in (2) are generated by acquiring cutting-edge, high density LiDAR data in concert with aerial and sub-meter satellite imagery and fewer, more detailed field reference information. The proposed work uses and builds on other recent ENRTF-funded projects such as *Improved Rapid Forest Ecosystem and Habitat Inventory* (Ek 2013), *Mapping Landscapes for Better Land and Water Management* (Knight et al. 2014), and the statewide light detection and ranging (LiDAR).

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Acquisition, processing, and utilization of remotely sensed and ground data   Budget: $759,995

We will use an object-based individual forest stand segmentation (polygon mapping) approach with newly acquired high density LiDAR (this proposal) and other remotely sensed imagery to identify a suite of forest stand attributes and tree estimates. Each stand will be populated with detailed forest metrics using a statistical imputation process developed by Dr. Alan Ek derived from newly collected and existing inventory data. Further refinement to estimate more detailed tree measurements will be done by correlating the new plot data with the high density photon level LiDAR and imagery. The pilot project area will consist of 500,000 acres across multiple landowners in northern Cass County.

Outcome	Completion Date
1. Acquire high density LiDAR data for 500,000 acres in the pilot study area ($0.80/acre)	October 2016
2. Segment the forested land-cover data to individual stand polygons	April 2017
3. Develop forest stand metrics based on imputation with existing plots	March 2018
4. Develop stand metrics based on new LiDAR data	February 2019

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Activity 2: Relating field plot data to remotely sensed data for tree level forest metrics   Budget: $241,879

Extensive plot information will be collected (750 plots) across the project pilot area to build a strong relationship between ground reference data and high density LiDAR and other imagery. We will use this large dataset to examine the use of Alan Ek's imputation methodology to populate stand inventory with detailed tree attributes pertinent to wildlife and ecological applications. A sample of these plots will also be assessed with very high resolution aerial photography taken from an unmanned aerial system (UAS) provided by partners at Northland Community and Technical College (NCTC) to assess the cost savings for such a data collection method.

Outcome	Completion Date
1. Establish and collect field plot data for use with LiDAR and imagery data (Fig. 1)	September 2016
2. Training and verification of new and existing LiDAR data and imputation on new field data	March 2017
3. Acquisition of very high resolution photography via UAS, including training, verification, and analysis of this imagery with LiDAR and imputation from field data (performed by NCTC)	September 2017

Activity 3: Analyses of the methodology: comparing accuracies, cost, and value   Budget: $51,764

To determine cost savings and identify overall efficiencies and information gains achieved using the above approaches, a rigorous cost-benefit analysis and accuracy assessment will be developed to compare traditional inventory methods to our use of high density LiDAR and high resolution imagery using fewer ground reference plots. This analysis will also be reviewed by selected forest inventory experts. Results, i.e., approaches, costs, and benefits will be summarized and distributed to all stakeholders via technical and Executive Summary reports, a public webpage, the Interagency Information Cooperative, and in the form of refereed journal articles. Finally, the completed datasets will be disseminated through the Minnesota Geospatial Data Commons.

Outcome	Completion Date
1. Develop a cost-benefit analysis comparison to forest inventory methods from 2010-2015	March 2019
2. Develop a manual with protocols for practical application	May 2019
3. Submit final reports, including methods of outreach and technology transfer	June 2019

III. PROJECT STRATEGY
A. Project Team/Partners
The Project Team will be led by Dennis Kepler from the Minnesota DNR, Resource Assessment Program. Collaborators include the University of Minnesota, providing expertise, resources, and staff time (professors Alan Ek, Joe Knight, and Michael Falkowski); U.S. Fish & Wildlife Service providing free sub-meter satellite imagery and feedback; Chippewa National Forest and Cass County Land Department will also be giving in-kind and financial support; Northland Community and Technical College will provide high resolution imagery via UAV; and the Minnesota Forest Resources Council will providing a venue for information dissemination and feedback; Ronald McRoberts from the USFS Northern Research Station will also provide analytical and feedback support.

B. Project Impact and Long-Term Strategy
The long-term strategy is to benefit Minnesota's natural resource stakeholders by developing a revolutionary, enhanced forest inventory method at a significantly reduced cost that can be used across all ownerships. This project will enable Minnesota to continue its leadership role of using emerging technologies to collect and maintain modern and valuable information for a plethora of natural resource management objectives. It also coincides well with other long-term initiatives, such as the permanent plots being established by DNR project partners in the 2016 ENRTF proposal, *Assessing Long-Term Change in Minnesota's Diverse Habitats*.

C. Timeline Requirements
The project duration is three years. This timeframe is necessary to acquire, process, and analyze the high density LiDAR, remotely sensed imagery, and field reference plot data that will create a viable forest structure dataset.

2016 Detailed Project Budget

Project Title: *Enhancing Forest Inventory Using Multiple Remotely Sensing Technologies*

IV. TOTAL ENRTF REQUEST BUDGET 3 years

| BUDGET ITEM	AMOUNT
Personnel: 5 - classified (3.3 FTE), 12 - unclassified interns (1.9 FTE)	
Project Manager: est. $111,760 (74% salary, 26% benefits), 1 classified @ 0.38 FTE for three years; 11% FTE for year-1, 11% FTE for year-2, and 15% FTE for year-3	$ 43,620
Remote Sensing Analyst - 1: est. $90,100 (78% salary, 22% benefits), 1 classified @ 1.3 FTE for three years; 26% FTE for year-1, 59% FTE for year-2, and 46% FTE for year-3	$ 117,130
Remote Sensing Analyst - 2: est. $95,270 (71% salary, 29% benefits), 1 classified @ 1 FTE for three years; 35% FTE for year-1, 40% FTE for year-2, and 25% FTE for year-3	$ 95,270
Biometrician: est. $107,140 (75% salary, 25% benefits), 1 classified @ 0.36 FTE for three years; 7% FTE for year-1, 13% FTE for year-2, and 16% FTE for year-3	$ 38,769
Forester est. $80,075 (75% salary, 25% benefits), 1 classified @ 0.27 FTE for three years; 7% FTE for year-1, 17% FTE for year-2, and 4% FTE for year-3	$ 26,462
14 Interns est. $12.84/hr. for 3 months temp. position (93% salary, 7% benefits) @ 1.4 FTE for two years; 40% FTE for year-1, 80% FTE for year-2	$ 38,520
Professional/Technical/Service Contracts:	
Ecognition Consulting (UMN): Image Segmentation	$ 50,000
Unmanned Aerial System (Northland Technical College): Plot Level Aerial photo acquisition	$ 50,000
Software Purchase and Maintenance: LP360 Light Detection and Ranging (LiDAR)	$ 15,000
High Density LiDAR Acquisition: RFP will be issued	$ 400,000
Equipment/Tools/Supplies:	
Field equipment: 3-survey grade GPS units ($10,000 each) Resource Assessment will provide data loggers	$ 30,000
Travel:	$ -
1 Forester (3 - 5 day trips ~ 15 field days) Lodging = $1,200 / Meals = $1,080	$ 2,280
14 Interns (13.2 - 5 day trips ~ 66 days) Lodging = $36,960 / Meals = $33,264	$ 70,224
Fleet est. - 1 Forester (3 -5 day trips) = $393.90 / 12 Inters (13.2 - 5 day trips) = $12,526.02	$ 12,526
Additional Budget Items:	
Direct and Necessary Services for the Appropriation: *Direct and Necessary expenses: HR Support (~$16,791), Safety Support (~$3,958), Financial Support (~$12,457), Communication Support (~$1,236), IT Support (~$28,331), Planning Support (~$829), and Procurement Support (~$235) necessary to accomplishing funded.*	$ 63,837
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 1,053,638

V. OTHER FUNDS

| SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:		
Cass County - Contribution for LiDAR data acquisition	$ 30,000	*Pending*
Chippewa National Forest - in-kind quality assessment field inventory work + contribution for LiDAR data acquisition.	$ 20,000	*Pending*
U.S. Fish & Wildlife Service - in-kind sub-meter satellite imagery + contribution for LiDAR data.	$ 20,000	*Pending*
In-kind Services To Be Applied To Project During Project Period:		
Cass County - in-kind quality assessment field inventory work.	$ 10,000	*Pending*
Funding History: N/A	$ -	
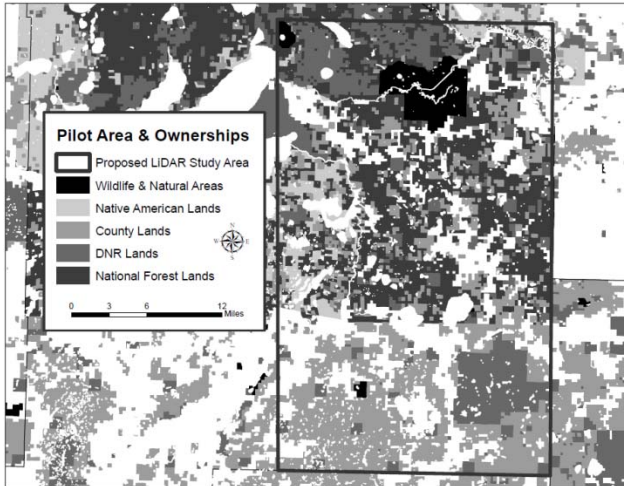
Multiple landownership types
Ecological Diversity

Acquire new high density LiDAR & high resolution imagery
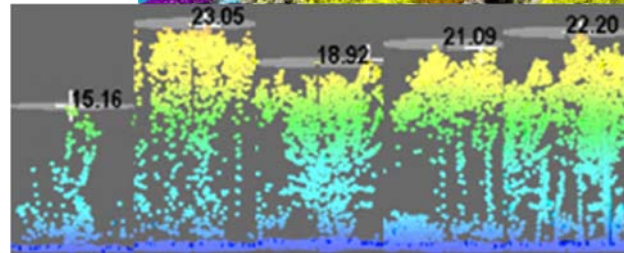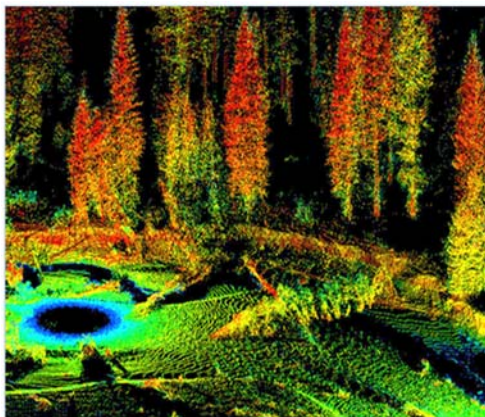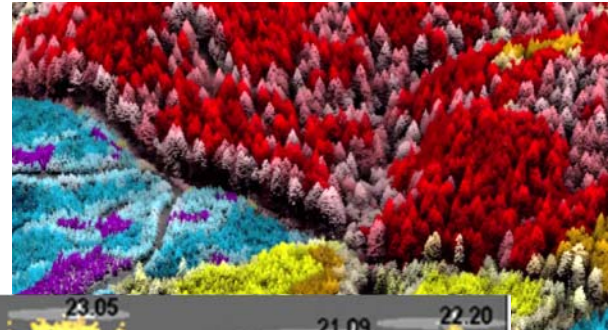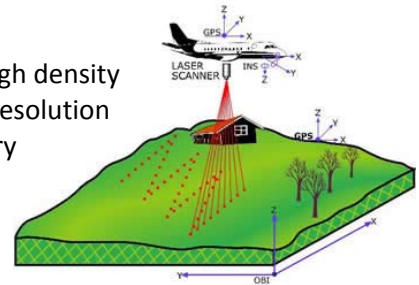
Use the LiDAR data to generate detailed forest structure and habitat suitability estimates, **enhancing wildlife and ecological applications**

Provide **accurate, detailed** stand based forest inventory using remotely sensed data, correlated to a small sample of field data

Perform comprehensive, statewide, enhanced forest inventory at **significantly reduced costs**
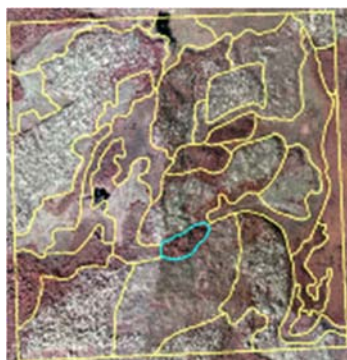
Preliminary Comparison	
Proposed Method	**Traditional Inventory**
➢ 500,000 acres (pilot)	➢ 500,000 ac (comparison)
➢ 20,000 forest stands	➢ 20,000 forest stands
➢ 750 plots field visit for statistical imputation	➢ 10,000 plots field visit at approx. 5 plots/stand
➢ 10-yr cycle @ $2.5/ac	➢ 20-yr cycle @ $8/ac

Project Manager: Dennis Kepler, MN Department of Natural Resources, Division of Forestry, Resource Assessment (RA) Program Supervisor

Qualifications:

Dennis Kepler has over 20 years of experience in both forest inventory and remote sensing. He's been involved with developing and implementing large-scale mapping projects throughout the Pacific Northwest, Alaska, and Minnesota using both plot and transect based inventory to create Landsat satellite derived data. He has also been in charge of multiple mapping and aerial photography projects and conducted both U.S. Forest Service Forest Inventory and Analysis (FIA) and Cooperative Stand Assessment (CSA) inventory for the State of Minnesota. Dennis holds a Bachelor of Science degree in Forest Management from Oregon State University.

As the Resource Assessment Supervisor, Dennis provides strategic policy and operational direction in the planning, management and administration of the Program to develop and maintain appropriate markets, customer relations, staff expertise and technological capabilities. Working with multiple agencies both inside and outside the state is of critical importance to the RA Program, one that Dennis has worked hard to maintain. In the management of this project, Dennis will rely on the administration, supervisory, and communication skills he uses on a daily basis to secure, develop, and direct the RA Program's budget and staff to complete projects and meet customer expectations.

Project Responsibilities: The project manager will be responsible for: providing overall project management and technical direction for the project, hiring and supervising project staff, contracting for professional and all other services in support of the project, coordinating with project partners, directing the development of project reports and any other deliverables, and preparing and submitting project work plans, updates and final reports.

Organization Description: The Minnesota Department of Natural Resources works to integrate and sustain the interdependent values of a healthy environment, a sustainable economy, and livable communities. DNR's integrated resource management strategy shares stewardship responsibility with citizens and partners to manage for multiple interests. DNR protects the state's natural heritage by conserving the diversity of natural lands, waters, and fish and wildlife that provide the foundation for Minnesota's recreational and natural resource-based economy (M.S. 84, M.S. 97A). DNR manages natural lands such as forests, wetlands, and native prairies; maintains healthy populations of fish and wildlife; and protects rare plant and animal communities throughout the state. DNR manages the state's water resources, sustaining healthy waterways and ground water resources. DNR provides access to enrich public outdoor recreational opportunities, such as hunting, fishing, wildlife-watching, camping, skiing, hiking, biking, motorized recreation, and conservation education through a state outdoor recreation system that includes parks, trails, wildlife management areas, scientific and natural areas, water trails, and other facilities (M.S. 86A). DNR supports natural resource-based economies, managing state forest lands for multiple forest values (M.S. 89), ensuring the maximum long-term economic return from school trust lands (M.S. 127A), and providing other economic opportunities in a manner consistent with sound natural resource conservation and management principles. The mission of the Minnesota Department of Natural Resources is to work with citizens to conserve and manage the state's natural resources, to provide outdoor recreation opportunities, and to provide for commercial uses of natural resources in a way that creates a sustainable quality of life.