Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2015 Work Plan

Date of Report: 11-03-2014

Date of Next Status Update Report: 02-01-2016

Date of Work Plan Approval:

Project Completion Date: 06-30-2018

Does this submission include an amendment request? No

PROJECT TITLE: Foundational Dataset Characterizing Historic Forest Disturbance Impacts

Project Manager: Michael Falkowski

Organization: University of Minnesota – Department of Forest Resources and Cloquet Forestry Center

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Location: Carlton, Lake, and St. Louis Counties

Total ENRTF Project Budget:	**ENRTF Appropriation:**	**$200,000**
	Amount Spent:	**$0**
	Balance:	**$200,000**

Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 03q

Appropriation Language:

$200,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to quantify forest disturbance impacts over the past forty years on water quality, wildlife demographics, and wood fiber supply to identify management strategies that better respond to disturbance impacts and improve and sustain forest resources. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Foundational Dataset Characterizing Historic Forest Disturbance Impacts

II. PROJECT STATEMENT:

Forest disturbance dynamics (arising from harvesting, fire, land conversion, etc.) have a fundamental control on the health and resilience of multiple forest resources including water quality, wildlife habitat, and wood resources, among others. Disturbance impacts on forest resources can persist across a landscape for decades and ultimately impact the sustainability of resources, positively or negatively. Understanding disturbance dynamics and associated impacts is readily recognized as being critically important to developing forest management responses that that improve and sustain forest resources. Despite this recognition, until recently it has been nearly impossible to quantify and interpret disturbance configurations (type, timing, and pattern) that have persistent impacts on forest resources. Recently the United States Geological Survey made a revolutionary decision by allowing open access to a 40-year historic archive of Landsat satellite data, providing a new opportunity to assess historic forest disturbance dynamics. These satellite-derived disturbance observations can be used to (i) determine the fundamental drivers of past disturbance and (ii) assess the impacts of disturbances on current forest resources.

The overarching objective of this project is to leverage historical satellite images in the archive to develop a foundational dataset that characterizes trends and patterns in historic forest disturbances Across Minnesota's arrowhead region. As a secondary objective we will demonstrate the utility of foundational disturbance dataset to sustainable resource management in two key areas: wildlife habitat and wood resource management.

We will develop the foundational dataset characterizing trends and patterns in forest disturbance by processing and analyzing Landsat satellite images (1974-present) from the aforementioned archive. This step will involve: (i) acquiring cloud free imagery across each growing season from 1974-present, (ii) preprocessing the imagery to ensure intra-seasonal and inter-annual comparability of the images, and (iii) running semi-automated image classification procedures that characterize disturbance type (e.g., fire, insect outbreak, blow-down, etc.) and duration of impacts and ecosystem recovery (e.g., how long did the disturbance last and how long did it take the ecosystem to return to its pre-disturbance state). The utility of this dataset to resource management will be demonstrated in specific applied examples. For the case of wildlife habitat we will integrate disturbance data with historic demographic data characterizing moose populations across Minnesota's Arrowhead region to understand how disturbance can enhance or degrade moose habitat quality and ultimately population sustainability. For the wood resource example we will link information from the disturbance dataset with repeated forest inventory data (e.g., data from the US forest service FIA (Forest Inventory and Analysis) program) to understand the impacts of different disturbance types on wood resources across Minnesota's Arrowhead region. In this example we will specifically develop an understanding how disturbances impact the amount (e.g., biomass, volume, etc.) and quality (e.g., species composition, age, etc.) of the forest resource landscape, which ultimately impact long term resource sustainability.

The foundational dataset will be a powerful tool for identifying threshold disturbance patterns that positively or negatively impact multiple forest resources across Minnesota. This foundational dataset will allow end users to evaluate how the type, timing, duration, and configuration of disturbances influence forest resources over the last forty years, and will ultimately help in the identification of management responses that improve and sustain forest resources into the future.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of *February 2016***:**

Project Status as of *September 2016***:**

Project Status as of *February 2017***:**

Project Status as of *September 2017***:**

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Project Status as of *February 2018***:**

Overall Project Outcomes and Results:

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Process Landsat satellite imagery into a useable format
Description:
Although Landsat satellite data are now available free of charge from the USGS archive, processing is required to convert them into a useable format. We will acquire and process archived Landsat imagery that encompasses the Arrowhead region of Minnesota (~4.5 million acres). Specifically, this imagery will be obtained on a bi-monthly basis during all growing seasons over the last 40 years (1974-Present). The raw imagery will be processed to correct for atmospheric and geometric related errors to ensure image comparability. In total we will acquire and process approximately 500 images across the Arrowhead region. The total number of images acquired and processed will depend upon availability of suitable, cloud-free imagery. Our original plan was to process and analyze imagery for the entire forested region of Minnesota. However, due to the reduced level of funding recommended for this project we have decided to constrain the total area considered in this project. The reduction in acres processed is not directly proportional to the reduction in funding due to economies of scale. Specifically, the cost per acre of processing imagery decreases with an increase in total area. This is due to the fact that a baseline processing capacity (e.g., creating processing protocols and computer programming of processing algorithms) needs to be built regardless of the total area processed, and the cost associated with developing this baseline capacity is the same regardless of the total area of imagery processed.

Summary Budget Information for Activity 1:   **ENRTF Budget: $ 43,817**
                                                                                     Amount Spent: $ 0
                                                                                              Balance: $ 43,817

Outcome	Completion Date
1. *Complete Acquisition and Local Storage of Landsat Imagery*	October 2015
2. *Complete Pre-processing of Landsat Imagery*	January 2016

Project Status as of *February 2016***:**

Project Status as of *September 2016***:**

Project Status as of *February 2017***:**

Project Status as of *September 2017***:**

Project Status as of *February 2018***:**

Final Report Summary:

ACTIVITY 2: Disturbance database development and classification
Description:
We will employ a Landsat time series image analysis algorithm to detect forest disturbances from 1974-present. The basic approach involves using change detection to identify where disturbances occurred on the landscape as well as their severity and duration. In addition to detecting the disturbance, we will use semi-automated procedures to classify the type (i.e., cause) of each disturbance identified. At a minimum, disturbance type will be classified into the following categories (and subcategories): Harvesting (clear-cut, partial harvest, land use

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conversion) and Natural Disturbance (Insect Outbreak, Fire, and Blow Down). The semi-automated disturbance classification procedure attributes disturbance type to areas where disturbance has occurred based upon spatial and temporal patterns in the satellite image time series. An abrupt disturbance (e.g., clear-cut or high severity fire), for example, would likely be characterized by a sharp decline in the time series that is also spatially contiguous. Conversely, a more gradual or subtle disturbance (e.g., defoliating insect or low severity fire) will likely be characterized by a gradual decline in in the time series that is spatially variable (i.e., not spatially contiguous). Forest recovery rates, which are indicative of disturbance severity, will also be readily available for the time-series. Following disturbance identification and classification, historical information (e.g., FIA data, aerial photography, forest health surveys) and field data collected specifically for this project will be used to validate and assess the accuracy of the disturbance products.

Summary Budget Information for Activity 2:   **ENRTF Budget:**   **$ 73,994**
                              Amount Spent: **$ 0**
                                 Balance: **$ 73,994**

Outcome	Completion Date
1. *Disturbance patterns from 1974-2015 Identified*	June 2016
2. *Disturbances classified into primary categories*	October 2016
3. *Database with validated disturbance patterns over time completed*	January 2017

Project Status as of *February 2016***:**

Project Status as of *September 2016***:**

Project Status as of *February 2017***:**

Project Status as of *September 2017***:**

Project Status as of *February 2018***:**

Final Report Summary:

ACTIVITY 3: Development of spatial descriptors and application of findings
Description:
Statistical descriptors of the disturbance patterns will be derived from the disturbance database. These statistical descriptors will be integrated into models assessing disturbance impacts on the current status of two critical resources: wildlife habitat (specifically moose) and wood resources (specifically the amount, type, and quality). In these example applications, we will compare existing moose population demography data and forest inventory data with disturbance descriptors in a modeling framework. This modeling framework will provide a quantitative assessment of how the temporal and spatial configurations of specific disturbance types can either enhance or degrade the sustainability of the resources (Figure 1). Through this process we will identify management responses that will sustain and or improve forest resources under future disturbances. Results quantifying the impacts of disturbance dynamics on the health and resilience of forest resources will be summarized in public project reports and conveyed to forest managers through outreach activities.

Summary Budget Information for Activity 3:   **ENRTF Budget:**   **$ 82,189**
                              Amount Spent: **$ 0**
                                 Balance: **$ 82,189**

Outcome	Completion Date
1. *Develop statistical descriptors of disturbance patterns*	August 2017

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| **2.** *Model impacts of disturbance dynamics on forest resources* | January 2018 |
| **3.** *Publish project summaries and conduct outreach activities* | June 2018 |

Project Status as of *February 2016***:**

Project Status as of *September 2016***:**

Project Status as of *February 2017***:**

Project Status as of *September 2017***:**

Project Status as of *February 2018***:**

Final Report Summary:

V. DISSEMINATION:
Description:
The final product of this project will be a digital geospatial database characterizing disturbance trends and types across the forested regions of Minnesota. In addition we will prepare an interpretative report detailing case studies that demonstrate how the geospatial disturbance database can be used to assess the impacts of historic disturbances on the resilience of three key forest resources: water quality, wildlife habitat, and wood fiber We will work in conjunction with the Minnesota Department of Natural Resources to make the geospatial database publically available for download from the GIS Data Deli website (http://deli.dnr.state.mn.us). The interpretative 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 (www.forestry.umn.edu).

Project Status as of *February 2016*:

Project Status as of *September 2016*:

Project Status as of *February 2017*:

Project Status as of *September 2017*:

Project Status as of *February 2018*:

Final Report Summary:

VI. PROJECT BUDGET SUMMARY:
A. ENRTF Budget Overview:

Budget Category	$ Amount	Overview Explanation
Personnel:	$ 193,500	-Salary and fringe (0.336) for three years for Falkowski - PI; 0.083 FTE each year (0.25 FTE over entire project) -Salary and fringe (0.336) for a post-doctoral researcher; 1.0 FTE for 2.5 project years (2.5

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		FTE over entire project) -Salary and fringe (0.336) for a technician; 0.083 FTE for 2 years (0.16 FTE over entire project).
Equipment/Tools/Supplies:	$ 1,500	Equipment and supplies include $1,500 for data hard drives for storing the satellite data and archiving the final geospatial disturbance database.
Travel Expenses in MN:	$ 5,000	This money will be used to pay for mileage ($3,750) and lodging ($1,250) for researchers when performing validation of the disturbance dataset.
TOTAL ENRTF BUDGET:	**$ 200,000**	

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than $5,000: N/A

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 2.91

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: N/A

B. Other Funds: N/A

VII. PROJECT STRATEGY:
A. Project Partners:

In addition to the project leader, Michael Falkowski other project partners are included below.

Dr. Alan Ek, Department of Forest Resources – University of Minnesota (not receiving funding). Role: Dr. Ek will serve as a liaison to several county forestry departments in the State of Minnesota who will be able to assist with database validation by providing disturbance datasets, and will ultimately be end users of the final disturbance database.

Dr. Joe Knight, Department of Forest Resources – University of Minnesota (not receiving funding). Role: Dr. Knight will assist with some remote sensing aspects of this project primarily by providing feedback to the post-doctoral researcher.

Dr. Matthew Russell, Department of Forest Resources & and Extension– University of Minnesota (not receiving funding). Role: Dr. Russell will assist with characterizing insect and disease related disturbances in the final database. In addition he will assist in project dissemination via his role in the University Extension program.

Dr. Linda Nagel, Department of Forest Resources – University of Minnesota (not receiving funding). Role: Dr. Nagel will assist with characterizing harvest related disturbances in the final database

Dr. Robert Slesak, Minnesota Forest Resources Council. Role: Dr. Slesak will assist with the water quality related applications of the disturbance database. Dr. Slesak will also serve as a liaison to Forest Resource Council members who will ultimately be end users of the final disturbance database. In addition he will integrate efforts of this project with other projects he's currently working on in conjunction with the Minnesota Department of Natural Resources Resource Assessment and Wildlife groups.

Collaborators will include the Minnesota Department of Natural Resources Resource Wildlife and Assessment groups, the Superior National Forest, University of Minnesota Extension, and several counties in northern Minnesota.

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B. Project Impact and Long-term Strategy:
Due to the multiple disturbance threats (e.g., insect outbreaks, fire, conversion to agriculture, and climate related stress) facing Minnesota's forest resources, as well as the fact the these threats will only increase under projected climate change, there is a critical need for datasets that can be used to assess the impacts of disturbance on the long term sustainability of Minnesota's forest resources. In addition, understanding how past disturbances have influenced current forest resources is essential to improving and sustaining future resource conditions under existing and eminent threats. This 3 year project will develop a foundational dataset characterizing historic forest disturbance dynamics -and related resource impacts- which will be a powerful tool for identifying threshold disturbance patterns that impact multiple forest resources across Minnesota*.* This foundational dataset will allow us to evaluate how disturbance and landuse configuration over the past 40 years have influenced the current status of forest resources and help to identify management responses that improve and sustain forest resources into the future, and will ultimately guide forest management response aimed at avoiding or mitigating persistent detrimental impacts of forest disturbance on forest resources. For example, forest managers will be better equipped to strategically plan disturbance mitigation practices where risks to forest resources are high, or manipulate disturbed areas to enhance forest response in a manner beneficial to multiple resources. Given the long-term nature of forest disturbance dynamics and associated management, we will link our work with on-going work in the MNDNR resource assessment office that is focused on using similar technology to understand future disturbance impacts. We also plan to explore additional funding opportunities from federal sources such as NASA, the National Science Foundation, and the US Forest Service to build upon and extend this work into the future.

C. Funding History: N/A

VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS: N/A

IX. VISUAL COMPONENT or MAP(S):

See attached Figure 1

X. RESEARCH ADDENDUM: N/A

XI. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted no later than September 2015, February 2016, September 2016, February 2017, September 2017, February 2018. A final report and associated products will be submitted between June 30 and August 15, 2018.

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Environment and Natural Resources Trust Fund
**M.L. 2015 Project Budget**

Project Title: *Foundational Dataset Characterizing Historic Forest Disturbance Impacts*

Legal Citation: *M.L. 2015, Chp. 76, Sec. 2, Subd. 03q*

Project Manager: *Michael J. Falkowski*

Organization: *University of Minnesota*

M.L. 2015 ENRTF Appropriation: $ *200,000*

Project Length and Completion Date: 3 *Years, June 30, 2018*

Date of Report: 10/15/2014

| ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	Process Landsat satellite imagery into a			Disturbance database development and			Development of spatial descriptors and				
Personnel (Wages and Benefits)	$42,317	$0	$41,687	$71,494	$0	$71,494	$79,689	$0	$79,689	$193,500	$193,500
Michael Falkowski, Project Manager: $8,684 (66.4% Salary, 33.6% benefits); 0.083 FTE each year (0.25 FTE over entire project).											
TBD, Postdoctoral Researcher: $167,000 (66.4% Salary, 33.6% benefits); 1.0 FTE each year for 2.5 years (2.5 FTE over entire project).											
TBD, Technician: $6,948 (66.4% Salary, 33.6% benefits); 0.083 FTE for 2 years (0.16 FTE over entire project)											
Equipment/Tools/Supplies											
Equipment and supplies include $1,500 for data hard drives for storing the satellite data and archiving the final geospatial disturbance database.	$1,500	$0	$1,500							$1,500	$1,500
Travel expenses in Minnesota											
This money will be used to pay for mileage (3,750) and lodging (1,250) for researchers when performing validation of the disturbance dataset.				$2,500	$0	$2,500	$2,500	$0	$2,500	$5,000	$5,000
COLUMN TOTAL	**$43,817**	**$0**	**$43,187**	**$73,994**	**$0**	**$73,994**	**$82,189**	**$0**	**$82,189**	**$200,000**	**$200,000**

Utilize historic satellite imagery to quantify the timing, type, and magnitude of disturbance
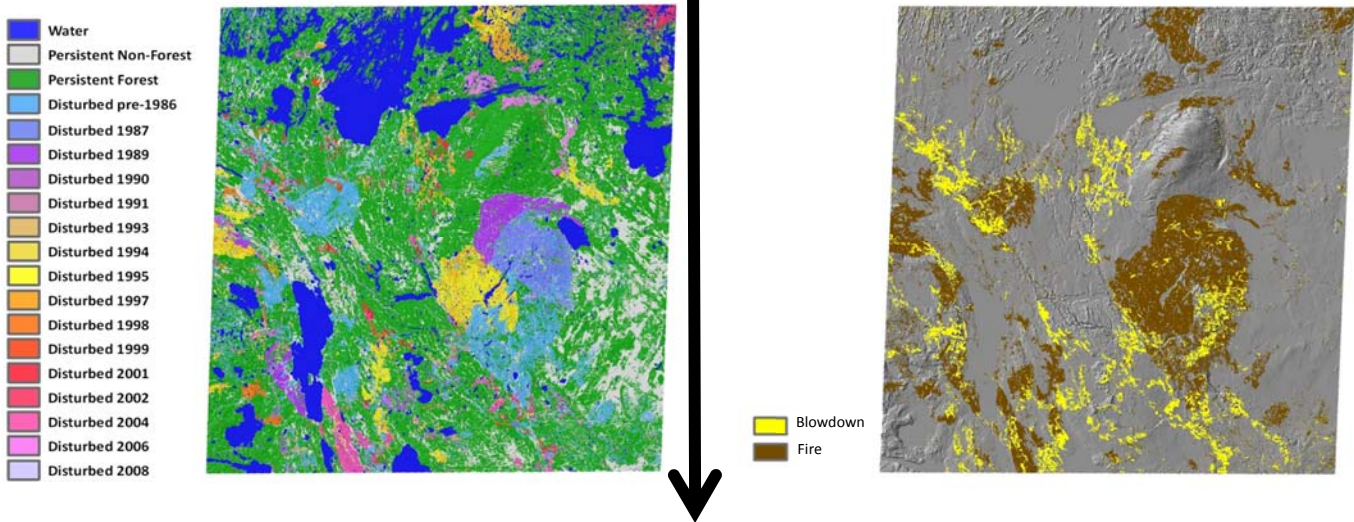
Develop disturbance metrics that describe disturbance dynamics and recovery over time
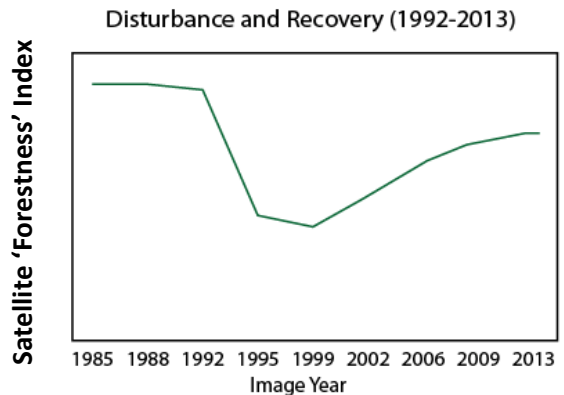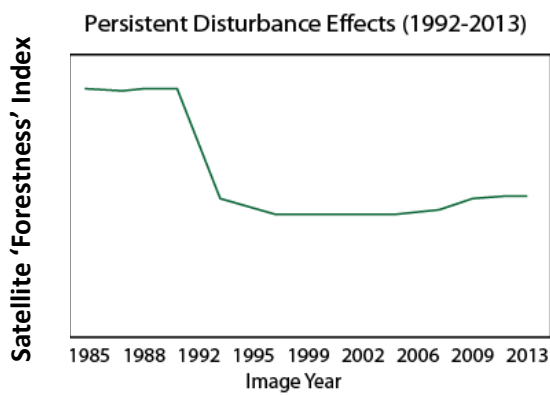
Relate the metrics to water, wildlife, and wood fiber datasets to determine the influence of disturbance patterns on natural resources
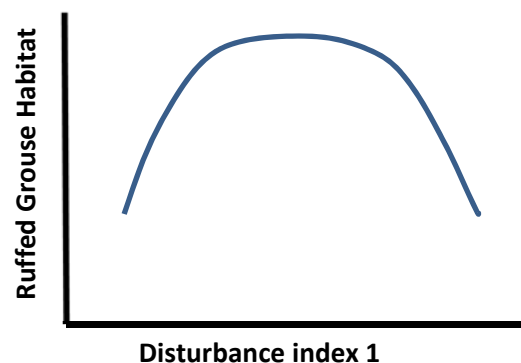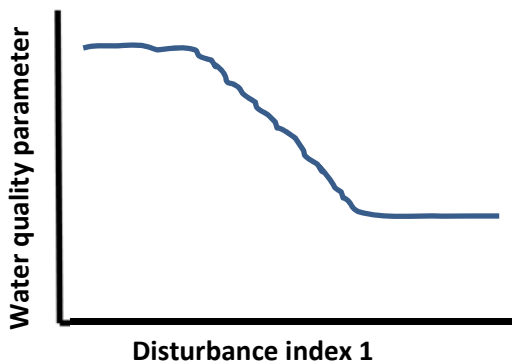
Incorporate information into strategic planning efforts to achieve ideal disturbance configurations arising from natural events and management actions (e.g. timber harvest)

Figure 1. Example of the workflow we will employ in this project

06/07/2015 Subd. 03q