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Smart Data for Resilient Forests

INSPIRES

NSF RII Track 2 FEC: Leveraging Intelligent Informatics and Smart Data for Improved Understanding of Northern Forest Ecosystem Resiliency (INSPIRES)

INSPIRES Year 1 Annual Progress Report

August 1, 2019-July 31, 2020

PI: Aaron Weiskittel, University of Maine

Co-PIs: Anthony D'Amato, University of Vermont

Ali Abedi, University of Maine

Scott Ollinger, University of New Hampshire

Mary-Kate Tisdale, University of Maine

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University of New Hampshire

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The University of Vermont

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OVERVIEW

PROJECT SUMMARY

The INSPIRES project started August 1, 2019 and is an interjurisdictional partnership between Maine, New Hampshire, and Vermont. The INSPIRES team currently involves 54 individuals with the majority being faculty from the three states (38; ME = 28, NH = 13, VT = 13), bolstered by undergraduate/graduate students (10) and professional staff (6). Although only in the early stages of the project, the team that has formed is diverse, has strong linkages across jurisdictions, and many of the faculty are early career (48%). The structure of the project is centered around four core research themes, namely: (1) Advanced Sensing and Computing Technologies; (2) Smart Environmental Informatics; (3) Integrated Ecological Modeling; and (4) Quantitative Reasoning Skills in Context. These themes, collectively applied, will build understanding of current and future changes in the Northern Forest in response to ecological and socioeconomic drivers.

The primary focus for Year One was on team building, completion of a project implementation plan, and initiation of interjurisdictional research efforts. Team building began almost immediately with a launch meeting for all participants in early September. The goals of this meeting were to introduce team members, establish regional and theme interactions, provide access for shared files, and develop theme goals. This launch set in motion numerous virtual and in-person meetings regularly conducted by the Core Leadership Team (CLT), individual research themes led largely by early career scientists, and within jurisdictions. Quarterly all-team meetings focus on project and research theme updates and discussion. Individual research themes regularly meet to understand team member research interests, complete strategic materials, including collaborative research agendas, and outline key research milestones by project year. These milestones are essential to monitoring project progress. Likewise, regular intra-jurisdiction meetings across institutions are used to help build team relationships and identify key linkages among jurisdictions as INSPIRES brings together a diverse set of disciplines such as engineering, computer science, ecology, biometrics, ecosystem modeling, and STEM education.

The project implementation plan the team developed provides the necessary structure, governance, strategic assessment, and plans for research, communications, and evaluation. This implementation plan will be revisited biannually to ensure successful project progress, interjurisdictional collaboration, and stakeholder engagement. As part of the project implementation plan, the CLT and research themes each completed key strategic materials including logic models, Strengths, Weaknesses, Opportunities and Threat (SWOT) assessments, and stakeholder matrices. This living document serves as a roadmap for project execution and management, provides each INSPIRES team member with a comprehensive summary of important project information to help guide their work, and highlights several research efforts initiated during Year 1, including applications of sensor technology to better characterize forest carbon dynamics in the region. This document will also serve as an overall orientation package for our project's advisory boards and other key external stakeholders identified in this document.

Overall, despite the highly challenging circumstances caused by the current global pandemic, the INSPIRES project has made substantial forward progress and remains on track as outlined in this annual report. Of course, high uncertainty and restrictions (e.g. travel, hiring, spending) imposed by the pandemic have led to ongoing discussions and significant contingency planning, which are outlined in this annual report. In short, the INSPIRES team remains engaged, productive, and excited about the potential of this research effort and its broader implications for the region's forest-based economy.

KEY ACCOMPLISHMENTS

- INSPIRES website created and launched in partnership with the New England Sustainability Consortium (NEST)
- Development and completion of project implementation plan, which included a project governance agreement, evaluation plan, communications strategy, strategic assessment, and identification of key stakeholders
- Creation of Slack project channel and shared calendar
- Established a Box folder for shared files, including project reports and team rosters
- Financial and communications support team established
- Theme 1 prototype of wireless low power soil moisture sensor ready for calibration
- Recruitment and hiring of 2 Post-docs, 8 graduate students, and 3 undergraduate students across the three institutions
- PI Weiskittel and Project Senior Personnel Burakowski and Contosta attended the 2019 National EPSCoR Conference hosted by the University of South Carolina where they learned about project best practices as well as networked
- Development of living document for project jargon and acronym dictionary
- Engagement with wide range of regional stakeholders on project objectives and potential applications to regional forest conservation issues
- Baseline survey of project participants completed and analyzed
- New interjurisdictional collaborations initiated through INSPIRES led to new collaborative proposals for future work

PROJECT BACKGROUND

Forests are an economically important and ecologically critical component of New England's working landscape that provide numerous benefits to society. New England's forests are also highly dynamic and diverse due to a wide variety of complex factors including changing environmental conditions, management regimes, and natural disturbances. This project leverages unique expertise from the University of Maine, University of New Hampshire, and University of Vermont to construct a digital framework to better assess, understand, and forecast this complex forest at a resolution relevant to scientists, land managers, and policymakers. This will be accomplished by integrating emerging computational, monitoring, remote sensing, and visualization technologies that will provide a more holistic and near real-time quantification of the forest at broad spatial and temporal scales. In addition, increased education on using data to effectively model and manage forests is a key focus of the project's efforts.

INSPIRES includes a broad array of disciplines including data science, ecology, and engineering such as electrical, computer, and communications. The digital Big Data framework developed from this effort would be applicable to other forested regions and ecosystems. Most importantly, the effort will help support and sustain this unique forested landscape, which many rural communities rely on for their livelihoods.

RESEARCH APPROACH

Forests in New England represent the Northern Forest ecotone, which is a complex assemblage of transitional ecosystems that have a unique history of natural disturbance and human land use. In recent decades, societal demands on these forests and the ecosystem services they provide have continued to expand at a time when key stressors such as land use, invasive pests, and extreme abiotic events are significantly on the rise. Maintaining the value and integrity of the Northern Forest for the communities that depend on them requires a better understanding of how these stressors affect this ecosystem. To address these grand challenges, faculty from the state universities of Maine, New Hampshire, and Vermont are collaborating on the development of a regional Complex Systems Research Consortium that will align with a prior NSF Track 2 team (New England Sustainability Consortium; NEST), which will help to facilitate analysis of forest ecosystem integrity and resilience from multiple scientific perspectives.

At the same time, INSPIRES faculty and students across four research-integrated themes are working to develop a novel and flexible Digital Forest framework for effectively harnessing Big Data to enhance our fundamental understanding of Northern Forest ecosystems across multiple spatio-temporal scales and under alternative scenarios of future environmental and management changes.

The four project research themes are:

1. Advanced Sensing and Computing Technologies
2. Environmental Informatics and Analytics
3. Integrated Ecological Modeling
4. Quantitative Reasoning in Context

Our **long-term goal is to extend this framework beyond the region**, particularly to other ecosystems of high interest, including marine environments. INSPIRES will link with ongoing regional efforts to improve K-20 data literacy skills, while generating valuable new approaches for supporting the natural resources–based economies and associated industries. Project participants plan to integrate traditional ecological knowledge (TEK) of Wabanaki tribes and other available qualitative data with the primarily quantitative data typically employed to analyze and model ecosystems. The formation of a regional Complex Systems Research Consortium will incorporate, extend, and sustain the strengths of all three EPSCoR jurisdictions that leverages prior and ongoing efforts.

VISION

The vision for the INSPIRES program is to harness the Northern Forest Region's complex landscape and digital information diversity to support hypothesis formulation and testing across various social-ecological dimensions.

MISSION

INSPIRES will develop a regional Complex Systems Research Consortium that facilitates analysis of ecosystem integrity and resilience from multiple perspectives.

GOALS

Maine (ME), New Hampshire (NH), and Vermont (VT) encompass major parts of the complex and highly interconnected Northern Forest Region (NFR), which has a long history of ecological integrity and service to rural communities. The economies and identities of local communities strongly depend on the health of these forests (>$15 billion in annual economic contributions and over 140,000 direct employees), but the forest is increasingly threatened by complex and dynamically interacting stressors.

In this project, we aim to harness the region's complex landscape and digital information diversity through the creation of a Digital Forest resource, which is our Big Data Science approach to integrating contrasting forest information, ownership, management units, and underlying ecology into a "natural laboratory" that can be used to support hypothesis formulation and testing across the various social-ecological dimensions that comprise the highly complex NFR.

Our Digital Forest framework and approach extends beyond current methods for assessing and projecting forest conditions, which are generally hindered by inefficient linkages between ecological models and driving data, limited flexibility to work across spatial-temporal scales, gaps in spatial and temporal data coverage, and poor capacity for quantifying and managing uncertainty, particularly with respect to belowground processes.

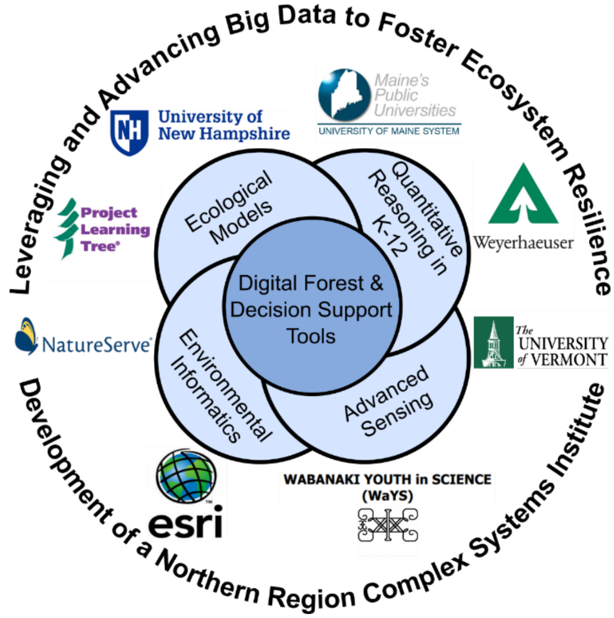


Figure 1. *INSPIRES Digital Forest Research and Workforce Development Framework*

Our efforts address the following overarching science questions:

1. How are spatio-temporal variation and uncertainty in forest extent, composition, health, and productivity driven by: (a) climate; (b) land use; (c) forest management; (d) regulatory policies; (e) invasive insects; (f) other biotic stressors like invasive plants; and (g) natural disturbances?
2. How will these changes affect ecosystem integrity and key services related to: (a) carbon storage/fiber production; (b) habitat/biodiversity; and (c) water quality/surface energy regulation?

Our overarching hypothesis is that novel Big Data acquisition, integration, and analysis will allow us to address these questions in a way that informs how we approach challenges and opportunities related to the current and future integrity of forest ecosystems.

To address these goals, the University of Maine System (UMS; [UM, UMFK, UMA]) is partnering with the UNH and UVM to advance our fundamental knowledge regarding forest ecosystem resilience and productivity by taking a new convergent approach to analyzing contrasting current and future ecosystem integrity values (fiber/carbon, biodiversity/habitat, and water/energy). Collaboration across the three jurisdictions will also build quantitative reasoning in context skills (QRC) for G6-12 students who will contribute to and use the project's research.

PROJECT ORGANIZATION

Our interdisciplinary effort is organized across four integrated themes (Table 1) that are essential to an innovative and flexible framework for harnessing Big Data across multiple spatio-temporal scales. Early career faculty lead each theme, supported by senior mentors. Each theme includes researchers and/or students from all three jurisdictions, as well as personnel cross-over to ensure sustainability and convergent approaches to problem solving.

Table 1. INSPIRES Research Approach and Goals by Theme

Research Approach	Research Goals
Theme 1. Advanced Sensing and Computing Technologies can contribute valuable Big Data that, when combined with smart environmental informatics, advances ecological models & our knowledge of the NFR ecosystem.	Improve power and wireless spectrum efficiency for a large-scale network to enable a novel in-situ forest data collection and processing system that furthers our fundamental knowledge of advanced sensing and computing technologies, while reliably quantifying the spatial-temporal variability of key forest ecosystem integrity metrics. Use ML for link quality improvement and efficient resource utilization in addition to data mining.
Theme 2. Smart Environmental Informatics can help integrate remote sensing data, sensor data, and qualitative information (e.g., TEK) to better understand spatial-temporal variability of stressors. Semantically enriching data helps to identify future measurements to predict stress.	Develop and test how a theoretical model can (1) quantify spatial & temporal variability & uncertainty and (2) incorporate qualitative & other nontraditional sources of ecological knowledge. Identify where additional sensing leads to greatest increases in data quality and model accuracy to improve the efficacy of sparse sensor networks. Build a smart data framework that leverages semantic knowledge to extract and characterize high-level places/events. Gain knowledge about how forest stressors vary across places and inform modeling by identifying where more granular models are beneficial.
Theme 3. Integrated Ecological Models can quantify the impact of stressors on ecosystem integrity indicators & predict change across NFR when refined and driven by links to Themes 1 and 2.	Integrating sensor data, remote sensing streams, and semantically enriched information from Themes 1 and 2 to better enhance as well as complete an inverse parameterization of regional ecological models for projecting forest ecosystem integrity and its uncertainty under an array of alternative futures that include variation in climate, land use, regulatory policies, and natural disturbance scenarios.
Theme 4. Improving Quantitative Reasoning in Context will connect teachers and students to locally relevant research and datasets, broadening and deepening STEM engagement.	(1) Develop/adapt materials for G6-12 that build QRC with opportunities to learn through data collection using sensors, asking & answering research questions about forests and the local environment & ecology using big data sets, and engaging in data visualization activities; (2) investigate the knowledge teachers need to support students in developing quantitative reasoning skills; (3) evaluate how students benefit from these opportunities.

Currently, the focus is on outlining the various research objectives under each theme. In the long-term, traditional ecological knowledge (TEK) of the Wabanaki tribes will help support each theme and advance our ability to use Big Data to analyze and model ecosystems. In addition, machine learning (ML) will help us to integrate and analyze Big Data across all themes of our Digital Forest framework. For example, we will use multi-objective ML algorithms to identify alternative wireless sensor network designs with efficient spatial coverage that minimize material use and cost. Sensor data will also inform our definition of the spatio-temporal semantics of different forest places and events. Consequently, we will develop these semantics using the proven classification and regression capacities of supervised ML algorithms. Semantic classifications and abstraction trees are the basis for spatio-temporally explicit inverse parameterizations used to initialize the integrated ecological models that estimate forest health and productivity. Further, these models provide uncertainty estimates to help ensure future wireless sensor network designs will provide suitable coverage and improved semantic classifications. These models of productivity and quality can then be used in multi-objective ML algorithms to help decision makers identify management practices that lead to efficient and desirable outcomes for the various ecosystem integration metrics. Each theme relies on high-performance, cloud-based data processing and storage.

SPECIFIC ROLES FOR PARTICIPATING INSTITUTIONS

The participating institutions are the University of Maine (lead), the University of New Hampshire (Co-PI) and the University of Vermont (Co-PI). The Core Leadership Team (CLT) is responsible for achieving the project's objectives and providing guidance to team members (Table 2). It is composed of the PI and co-PIs, representing the lead institutions. The CLT meets every 2 weeks via videoconference to review research progress, develop team activities, and discuss issues relevant to project governance. For full transparency, CLT meetings are regularly scheduled and open to all team members.

Table 2. Project Core Leadership Team (CLT)

Name	Role	Affiliation	Institution	Jurisdiction
Aaron Weiskittel	PI	Center for Research on Sustainable Forests	University of Maine	ME
Ali Abedi	Co-PI	Department of Electrical and Computer Engineering	University of Maine	ME
Kate Beard-Tisdale	Co-PI	School of Computing and Information Science	University of Maine	ME
Anthony D'Amato	Co-PI	Rubenstein School of Environment and Natural Resources	University of Vermont	VT
Scott Ollinger	Co-PI	Earth Systems Research Center	University of New Hampshire	NH

RESEARCH PROGRAM

OVERVIEW

The overarching goal of the INSPIRES project is to integrate novel Big Data with ecological models to understand how climate change, land use, forest management, regulatory policies, invasive pests, and natural disturbances affect forest extent, composition, health, and productivity. To do this, INSPIRES aims to (1) overcome gaps in spatial and temporal data coverage; (2) improve capacity for quantifying and managing uncertainty; and (3) enhance linkages between ecological models and driving data. The INSPIRES team will explore how to integrate the traditional ecological knowledge (TEK) of Wabanaki tribes and other available qualitative data with the primarily quantitative data typically employed to analyze and model ecosystems. Importantly, the effort will link with ongoing regional efforts to improve K-20 data literacy skills, while generating valuable new approaches for supporting the natural resources–based economies and associated industries. The formation of a regional forest ecosystems research consortium will incorporate, extend, and sustain the strengths of all three EPSCoR jurisdictions that leverages prior and ongoing efforts.

The INSPIRES research team is organized into 4 themes, namely: (1) Advanced Sensing and Computing Technologies; (2) Environmental Informatics and Analytics; (3) Integrated Ecological Modeling; and (4) Quantitative Reasoning in Context. Primary Year 1 research activities of the INSPIRES project have focused on establishing and building synergies across the broad research team, including recruiting and hiring graduate and undergraduate students and research technicians, as well as developing effective interjurisdictional collaborations with INSPIRES team members across the three jurisdictions. A key activity across research themes has been regular science and planning meetings within and across jurisdictions to develop theme-specific research agendas with clearly defined research objectives and corresponding lead personnel and milestones. This has included detailed planning around field research activities and analytical techniques for summer 2020, model parameterization and calibration for predicting regional forest dynamics, and cross-theme coordination with Theme 4 team leads to discuss integration of research outcomes into K-12 curriculum. The INSPIRES team has also actively engaged project stakeholders and partners for input and feedback on research objectives, to secure access to research sites and identify potential new experimental sites, to identify opportunities for leveraging existing long-term data collections, and to develop collaborative relationships around the INSPIRES themes. This has included many of the stakeholders identified in the Progress on Program Elements section and in our project implementation plan (Appendix 2).

As detailed in the following pages, most INSPIRES research themes in Year 1 focused on synthesis of available knowledge, identification of key knowledge gaps, refinement of research goals, hypotheses, and objectives, and outlining of research milestone maps by project year.

THEME 1. ADVANCED SENSING AND COMPUTING TECHNOLOGIES

OVERVIEW

The primary research task in Theme 1 is to overcome gaps in spatial and temporal data coverage. To do this, there needs to be the ability to address where and why sensors will be deployed, identify what sensors to use, and determine how to collect data from these sensors to maximize efficiency. Theme 1 has devoted a significant amount of time in Year 1 addressing the where, why, and what questions, and some time developing the how aspects. The original proposal, the INSPIRES leadership, and Theme participants helped to determine Theme objectives; during Year 1 we have attempted to leverage and synthesize our objectives. Key research goals, questions, and motivating hypotheses from the proposal were refined and are outlined below.

Research Goal	Research Questions	Motivating Hypotheses
1.1 Develop and deploy a regional network of cost- and energy-efficient wireless sensors for measuring critical ecosystem attributes like soil moisture, canopy cover, phenology, and water quality	• What is the scale of modeling versus the scale of ecosystem response? What role do sensors play in helping to reconcile disparities in scale? • What kind of heterogeneity do we want to capture at small to large scales? Are we interested in heterogeneity due to management or forest type? Within sites, do we want to hold heterogeneity constant, or look at spatial differences in physical and biological properties and processes between forest gaps and closed canopies, along topographic gradients, among species? What is the temporal scale of interest? Would we like to capture the instantaneous response of the system to rapid changes in temperature and precipitation, as well as to extreme weather events, or are we more interested in phenomena over seasonal timescales? • Which aspects of the ecosystem are of the greatest interest? Are we trying to understand changes in forest carbon cycling, including plant productivity, soil respiration, and decomposition, as well as some of the underlying physical drivers of these changes?	• Winter microclimatic conditions such as snow depth, soil frost depth, air temperature, and soil temperature, differ between selectively harvested and intact forests and drive the timing and duration of the vernal window? • Soil respiration varies predictably across forest types and management strategies because of differences soil moisture and temperature • Variation in soil moisture, temperature and respiration is driven by regional climate patterns of precipitation and temperature, and as a result site-to-site differences increase with distance

Research Goal	Research Questions	Motivating Hypotheses
1.2 Evaluate alternative wireless sensor network designs informed by ML that maximize power and wireless spectrum efficiency for large-scale applications	• How can we design wireless sensor networks to ensure required sensor network coverage and data rates? • How can we explore inherent relations among various data streams to achieve power and wireless spectral efficiency? • How can we scale insights about wireless and spectral efficiency to achieve maximum bitrates in our sensor networks?	• What machine learning algorithm can improve data packet movement through a network in a power- and time- efficient manner? • Can channel state estimation be used to allow individual nodes make intelligent routing decisions? • How will data nodes know whether the packet will be received correctly?
1.3 Integrate the wireless sensor network with a cloud-based processing system that serves as a digital library for storing, documenting, and linking the data across research themes	• What temporal intervals are needed for data capture and transfer? • How will database design allow the data to be most effectively accessed and used? • What data elements are most important for addressing key ecological questions	• Can a multi-actor approach be used manage the network state as a whole; the nodes must make individual decisions? • Can Long Short-Term Memory (LSTM) deep learning model be used to develop the data network?

HIGHLIGHTS

- Bi-weekly meetings with team members that have helped to identify ongoing research, current research needs, and outline a path forward
- Subgroup working on wireless soil moisture sensor meets weekly
- Recruited and integrated both undergraduate and graduate team members
- Developed protype sensors for measuring soil moisture content and greenhouse gas emissions
- Identified potential research sites and associated field season logistics for both extensive and intensive sensor deployment
- Coordinated with AMC's Maine Woods Initiative (MWI), which includes over 70,000 acres of forest in Maine that represents an ecotype not currently represented in the proposal site list (see Table 4). AMC Director of Research provided MWI site data to Theme 1 personnel to assist in structuring project design, specifically sensor deployment.
- Evaluated alternative machine learning methodologies for routing data in a sensor network in a power- and time-efficient manner
- Refined ecological and engineering research questions to be address with sensor development and network deployment

TEAM MEMBERS

Name	Affiliation	Jurisdiction	Institution	Early Career	Role
Aimee Classen	Gund Institute for Environment/ Rubenstein School of Environment and Natural Resources	VT	UVM	Y	Faculty
Ali Abedi	Department of Electrical and Computer Engineering	ME	UMO	N	Faculty
Alix Contosta	Earth Systems Research Center	NH	UNH	Y	Faculty
Andrew Ouimette	Earth Systems Research Center	NH	UNH	Y	Research Staff
Bruce Segee	Advanced Computing Group	ME	UMO	N	Faculty
Carol Adair	Rubenstein School of Environment and Natural Resources	VT	UVM	Y	Faculty
Dave Lutz	Environmental Studies	NH	Dartmouth	Y	Faculty
Gavin Briske	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Grad Student
John Den Uyl	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Grad Student
Karin Rand	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Research Technician
Kenn Bundy	Department of Mathematics	ME	UMAB	Y	Faculty
Lindsay Barbieri	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Grad Student
Olivia Vought	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Undergrad
Paulina Murray	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Grad Student
Rebecca Sanders-Demott	Earth Systems Research Center	NH	UNH	Y	Post-doc
Sarah Nelson	School of Forest Resources	ME	UMO	N	Faculty
Sonia Naderi	Department of Electrical and Computer Engineering	ME	UMO	N	Grad Student
Thayer Whitney	Dept. of Electrical & Computer Engineering	ME	UMO	N	Undergrad
Victoria Nicholas	Dept. of Electrical & Computer Engineering	ME	UMO	N	Undergrad

Photo 1. INSPIRES intensive sensor field site at Dartmouth Second College Grant Experimental Forest being used to monitor soil and wood moisture. (*Photo courtesy Dave Lutz*).

RESEARCH MILESTONES PROGRESS

Objective	Projects	Project responsible parties	Year 1 Milestones	Milestone Progress
1.1	1.1a Wireless sensor research and developmen t	Abedi, Contosta, Adair, Naderia	• Identify existing and new field sites and sensor needs at these sites; • Assess state of the art for ecological sensors • Develop, test, and calibrate protype sensors	• List of currently available and commonly used environmental sensors developed • Prioritized list of needed ecological sensor ideas and needs compiled • Protype sensors developed and being tested • List of existing and new field sites determined

Objective	Projects	Project responsible parties	Year 1 Milestones	Milestone Progress
1.2	1.2a Wireless sensor network design	Abedi, Contosta, Adair, Lutz	• Determine research needs for wireless sensor networks; • Synthesize available data from current sensor networks,	• Assessed current state of the art in ecological sensor network by evaluating various NSF NEON protocols and visiting the NEON site at Bartlett Experimental Forest in NH • Initiated compilation of available sensor network data and identified key gaps in coverage • Began field testing of alternative wireless senor network designs including multi-channel, Q-routing, and node design
1.3	1.3a Cyber-based big data harmonization, ML & interface	Abedi, Bundy	• Develop common protocols for key measurement attributes; • Test alternative machine learning algorithms • Assess alternative data capture methodologies	• Compiled and evaluated common protocols for data harmonization and synthesis • Tested several machine learning algorithms including Long Short-Term Memory (LSTM) deep learning, which showed improved overall performance • Exploring alternative temporal resolutions for most effective and efficient network data capture

FUTURE PLANS

- Collect common set of measurements across sites to create a baseline of forest and soil inventory
- Compare prototype sensor with other sensors and develop calibration methods
- Assess locations where new sensors may be installed
- Establish networking and power management for sensors

- Purchase necessary supplies for new sensors and develop soil, microclimate, and phenology sensor suite
- Program dataloggers for sensor data collection
- Deploy sensors before snowfall
- If selected for full proposal submission, complete full WCS proposal
- Look for alternative RFPs related to the use of sensor networks to support research regarding forest management as an adaptation strategy for warming winters

THEME 2. ENVIRONMENTAL INFORMATICS AND ANALYTICS

OVERVIEW

Theme 2 focuses on integrating various data such as those available from remote sensing, ecological sensor networks, and qualitative information (e.g., Traditional Ecological Knowledge (TEK)) to better understand spatial-temporal variability of stressors. The semantic enrichment of data will help to identify future measurements to predict stress. Ontological integration to digital forest modeling is possible, but will still need to assess current sources of information and their possible use in ontological modeling. In Year 1, preliminary Theme 2 meetings focused on establishing access to free data resources relevant to research objectives, and discussing various theoretical and applied research projects with collaborators among Themes 1-3. Primary research goals for the group were to develop and test theoretical models that can (1) quantify spatial and temporal variability and uncertainty and (2) incorporate qualitative and other nontraditional sources of ecological knowledge like TEK. Going forward, efforts will focus on identifying where additional sensor networks can lead to greatest increases in data quality and model accuracy to improve the efficacy of sparse sensor networks. Ultimately the goal is to outline and develop a smart data framework that leverages semantic knowledge to extract and characterize high-level places/events, which will allow managers and scientists to gain knowledge about how forest stressors vary across places and inform modeling by identifying where more granular models are beneficial.

HIGHLIGHTS

- Regular team meetings to help identify ongoing and potential research
- Currently recruiting undergraduate and graduate students to join research theme
- Development of a prototype 'Digital Forest' spatial database that allows for efficient spatio-temporal querying
- Developed a list of currently available regional datasets that can be used for machine learning development and testing
- Developed and evaluated the use of a novel deep neural network compression algorithm for analyzing Big Data

- Evaluation of combining ontological representation with statistical learning
- Identified key linkages to both Themes 1 and 3 with potential focus on the Native American culturally important black ash tree species
- Team member Roy with UM faculty developed rural community resilience metrics spanning the Northern Forest. The metrics indicate specific community challenges that could impact, and be impacted by, shifts in forest health and management practices

TEAM MEMBERS

Name	Affiliation	Jurisdiction	Institution	Early Career	Role
Salimeh Yasaei Sekeh	School of Computing and Information Science	ME	UMO	Y	Faculty
Darren Ranco	Department of Anthropology	ME	UMO	N	Faculty
Donna Rizzo	Department of Civil & Environmental Engineering	VT	UVM	N	Faculty
Jing Yuan	School of Computing and Information Science	ME	UMO	Y	Post-doc
Kasey Legaard	Center for Research on Sustainable Forests	ME	UMO	Y	Faculty
Kate Beard-Tisdale	School of Computing and Information Science	ME	UMO	N	Faculty
Larry Whitsel	Advanced Computing Group	ME	UMO	N	Faculty
Marek Petrik	Department of Computer Science	NH	UNH	Y	Faculty
Mary Martin	Earth Systems Research Center	NH	UNH	N	Faculty
Peter Nelson	Department of Biological Sciences and Environmental Studies	ME	UMFK	Y	Faculty
Sam Roy	Mitchell Center for Sustainability Sciences	ME	UMO	Y	Faculty
Silvia Nittel	School of Computing and Information Science	ME	UMO	N	Faculty
Torsten Hahmann	School of Computing and Information Science	ME	UMO	Y	Faculty

RESEARCH MILESTONES PROGRESS

Objective	Project	Project responsible parties	Year 1 Milestones	Milestone Progress
2.1	2.1a Extension of field model beyond in-situ sensors	Nittel, Petrik, Ranco	• Summarize current data availability and location of regional ecological sensor networks; • Identify potential gaps in sensor data and geographical representation	• Table of current regional datasets compiled • Current and future locations of ecological sensor networks determined • Developed procedures and methods for identifying areas of high uncertainty
2.2	2.2a Hybrid Semantic-statistical representati on of forest places	Hahmann, Beard, Legaard, .1& Martin	• Obtain requirements for inputs or outputs from Theme 3; • Identify pre-existing models/resources to work from	• Developed the framework for a semantically enabled approach in combination with spatio-temporal data layers • Tested the approach using existing data on balsam fir abundance and slope for a landscape in Maine
	2.2b Provide spatial datasets for Theme 3 objectives	Hahmann, Beard, Martin	• Obtain specific requirements for outputs from Theme 3 (e.g. LAI, tree height/stature, soil nitrogen, foliar nitrogen, tree/forest age, tree species/assemblages present, disturbance history, land use history datasets, historical aerial photography, insect outbreak cycles);	• Developed a workflow for processing remote sensing data and generating necessary spatial layers • Generated test datasets of species presence and abundance for landscapes in northern Maine • Exploring alternative approaches for generating and quantifying uncertainty in spatial data
	2.2c. Develop and evaluate alternative ML algorithms for analyzing spatio-temporal datasets	Legaard, Roy, Yasaei	• Evaluate current state of art for use of ML algorithms in environmental sciences and potential limitations • Begin testing of alternative ML algorithms	• Compiled a list of current ML algorithms used in ecology • Tested and refined common ML algorithms using a dataset from New Hampshire • Compiling additional datasets to further refine ML methods to extract features directly from regional spatio-temporal data and use for prediction and classification

Objective	Project	Project responsible parties	Year 1 Milestones	Milestone Progress
2.3	2.3a Analysis of forest place correlations and similarities	Beard, Legaard, Petrik, Hahmann, McGill, Roy, Ranco	• Obtain requirements for outputs from Theme 3; • Identify pre-existing models/resources to work from	• Developed a flexible and efficient spatial query tool • Tested developed query tool using available data • Working to classify spatial layers of regional climatic, forest type, disturbance, and potential productivity to develop new classifications

Detailed Project: Hybrid Ontological-Statistical Representation: Digital Forest

Dr. Torsten Hahmann (faculty), Dr. Kate Beard (faculty), & Dr. Jing Yuan (post-doc), University of Maine School of Computing and Information Science

Work to date on this project has involved developing the conceptual model for the digital forest. Conceptually the digital forest is a queryable repository that provides access to spatial-temporal data contributed by the informatics theme as well as data collected by the sensor network theme. The primary objective is to characterize and build understanding of differences across forest places and times: e.g., How are different areas (either spatial areas or across time) similar or different? Toward this objective, our aim is to build a "Digital Forest" as a multi-scale and multi-dimensional spatio-temporal database of forest related information that will support storage, data processing and query access to compiled data. We are designing the Digital Forest to represent baseline ecological units at different levels of spatial granularity. These ecological units provide spatial units for summarizing forest characteristics at different spatial scales and over time.

Our approach combines ontological representation with statistical learning where ontological classes and properties provide the vocabulary (features) and statistical distributions are derived ("learned") from data. A Hybrid Ontological-Statistical Representation will extend traditional ontologies with explicit representations of statistical distributions and form a representational framework for conducting traditional hypothesis-driven scientific research. Ontologies will be developed to formally capture relevant terminology from existing classification schemes (e.g. land use/cover classification, legends of currently produced data layers). The ontologies will be populated using different computational approaches focusing on specific suspected associations, in combination with data mining or machine learning. This approach will support concept-driven learning that can explain differences between different spatial/temporal areas (Figure 2).

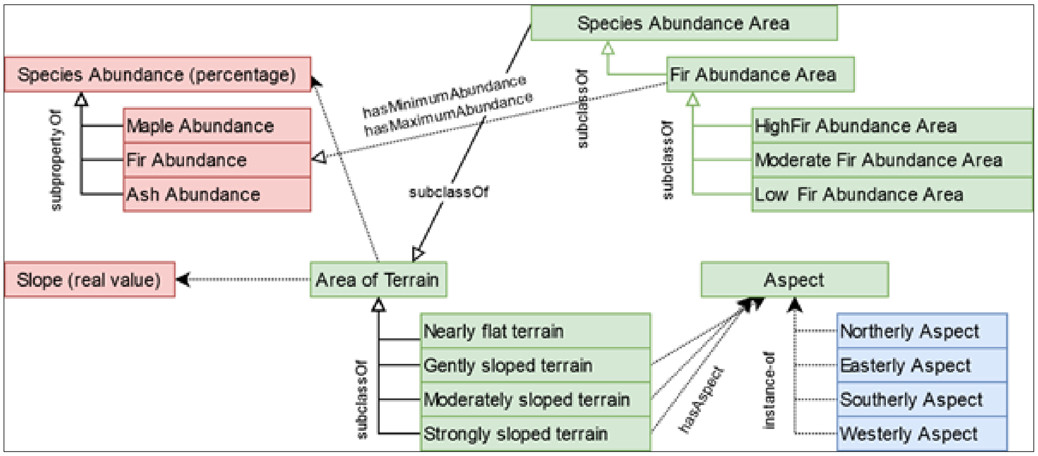


Figure 2. *Example of Forest Ontology.*

Digital Forest Progress to Date

- We are developing a workflow for populating this Hybrid Representation from spatial datasets.
- We have started implementation of a prototype based on key geospatial data layers. Digital elevation data provides the foundation. We have assembled high resolution digital elevation data for a study area in Western Maine. We are using elevation, aspect and slope class combinations as defining variables for the ecological units. Combinations, for example, are steep north facing slopes, moderate south facing slopes, flat or low-lying areas. These terrain characteristics are essentially fixed in time, so using these as baselines we can observe how forest variables may be changing with respect to these ecological units over time. From other team members we have acquired raster images of sugar maple and balsam fir biomass and images depicting disturbance/change over three-year time blocks. We are using these images to develop and test queries against ecological units.
- We are using Postgres and PostGIS as the database implementation platform. PostGIS supports spatial data including both vector (point, polyline, polygon) and raster data types (Figure 3).
- PostGIS supports vector on raster queries and raster on raster queries. We are developing query templates to create statistical distributions for various ecological units, for example: How are disturbances spatially distributed with respect to the ecological units (Figure 4).

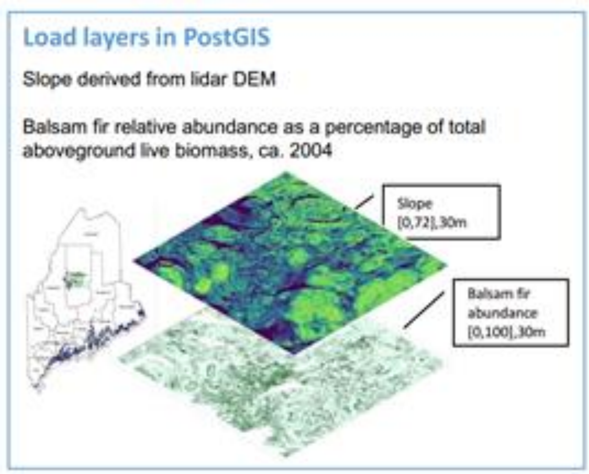


Figure 3. *Using PostGIS as spatial database to store datasets.*

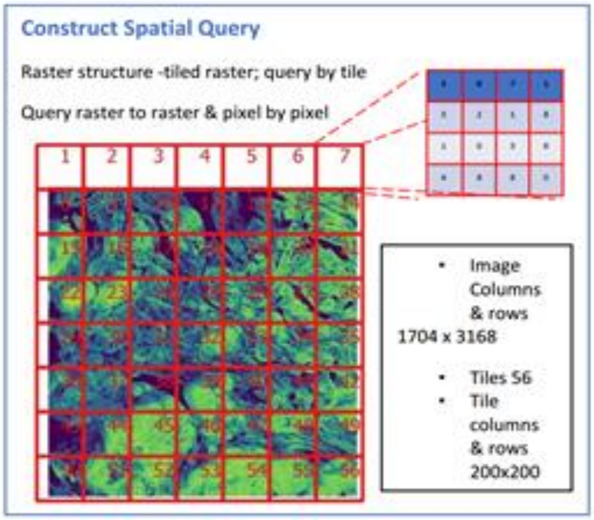


Figure 4. *Construction of spatial queries in PostGIS.*

Inter-Theme Collaborations

We have been holding joint meetings between Theme 2 and Theme 3. Discussions have addressed the idea of a case study around black ash. Black ash is an important species to the northern Maine tribal communities. It is also a species currently being threatened by the Emerald ash borer which has recently been introduced in Maine.

Plans for Remainder of Year 1

Plans for the remainder of the project year include continued development of the Digital Forest prototype as a Hybrid Ontological-Statistical Representation. Based on some cross-theme discussions we would like to consider brown ash as a possible study species. Due to the coronavirus restrictions we have been limited in planned interactions with tribal representatives to better understand traditional knowledge surrounding black ash.

FUTURE PLANS

- Continued development of hybrid ontological representation with Theme 1 statistical learning database, explore further collaborative opportunities with Theme 1
- Extension of PostGIS-constructed spatial query tool to handle and summarize individual pixels rather than tiles or polygons
- Additional testing of alternative machine learning algorithms will be conducted on various Theme 2 datasets
- Develop and extend neural network compression techniques for time-series big data
- Expand tree species occurrence and abundance to the state of Maine
- Develop improved workflows for handling forest disturbance classification from available remote sensing data
- Acquire necessary field data using UAVs or fixed-wing aircraft for selected study sites
- Improve documentation and understanding of TEK on ash
- Recruit graduate student for help with digital forest modeling
- Link rural community resilience metrics with biophysical/environmental forest data to provide a systemic understanding of current social-ecological resilience and best management practices for making improvements all-round improvements
- Contribute current findings to Digital Forest resource
- Explore research opportunities that build on current Digital Forest work, particularly use of forest place and event classification maps
- Deploy a network of ground-based cameras at field sites representing the bioclimatic variability across the state of Maine. These cameras will capture images of

vegetation phenology and other environmental conditions for each site at high temporal resolution across the full seasonal cycle. This information will inform plot-based assessment of the timing of seasonal events across the region, as well as be used to verify the satellite-based phenology metrics.

- Develop regional-scale models that attribute shifts in vegetation phenology over the 2001-2017 time period to the major drivers of change, including climate trends, disturbances, land use change and forest management.

THEME 3. INTEGRATED ECOLOGICAL MODELING

OVERVIEW

The primary goal of this research theme is to integrate several complementary ecological models with information gained in Themes 1 and 2 to improve confidence in future projections of forest ecosystem processes and answer the overarching science questions our research is designed to address. The modeling framework will provide the means for organizing and scaling the high spatio-temporal resolution data collected by this project's new sensor networks and currently available remote sensing data (e.g., Sentinel-2).

Specific objectives include: (1) use advanced informatics from Theme 2 to provide key data that allows for more effective model integration and parameterization; (2) leverage additional data across identified spatio-temporal gaps from Advanced Sensing and Computing of Theme 1 for improved model integration and decision making; (3) conduct a Big Data–driven inverse parameterization, which creates a distribution of parameters by matching model outputs and observations, for two existing mechanistic forest projection models; (4) perform broad-scale and contrasting simulations over a range of alternative futures; and (5) visualize and analyze key outputs as well as uncertainty at the regional scale.

Key research questions in this theme are: (1) How can Theme 1 provide additional data that address current knowledge gaps, which leads to improved integration with models and, ultimately, long-term decision making? (2) Are existing modeling frameworks capable of resolving and attributing changes in forest ecosystem integrity to different environmental and land use/policy drivers? (3) How can uncertainty from each model be captured and communicated in ways that are informative and allow for future model improvements? (4) Are there emergent properties that result from the integration of the models? (5) Can qualitative data provided by TEK or other sources from the Informatics and Analytics Theme add value to these ecosystem models?

Focus of Theme 3 in Year 1 was synthesizing past work with the focal ecological models such as PnET-II, LANDIS-II, CLM, and the Forest Vegetation Simulator (FVS), beginning to assess model behavior, identifying potential model test landscapes for evaluation, and outlining potential alternative future scenarios useful for key projections.

HIGHLIGHTS

- Began benchmarking of key ecological models including PnET, LANDIS-II, and Community Land Model (CLM).
- Regularly met to discuss past jurisdictional experience and outcomes using ecological models, particularly model parameter uncertainty and sensitivity.
- Led cross-theme meetings to better understand research linkages and build collaboration.
- Brainstorming meetings between Themes 3 & 2 led to identification of black ash as a species of shared interest, which is now serving as the initial focal species to kick off development of the Digital Forest.
- Facilitated active meeting participation by Theme 4 team members to encourage co-generation of knowledge and provide open access during the research development process
- Completed a sensitivity analysis of the ecological model PnET under contrasting species and climate change scenarios to better understand model behavior, which can help guide Theme 1 sensor development.
- Identified potential test landscapes for model testing and assessment, which are currently being compiled.
- Preliminary results synthesizing data to integrate into the ecological modeling using remote sensing, sensor data, and ground-based plots.
- Working to better calibrate and harmonize the process/work-flow for model use, particularly landscape models like LANDIS-II.
- Outlined a variety of alternative future scenarios based on different levels of disturbance, climate change, and forest management.

TEAM MEMBERS

Name	Affiliation	Jurisdiction	Institution	Early Career	Role
Aaron Weiskittel	Center for Research on Sustainable Forests	ME	UMO	N	Faculty
Anthony D'Amato	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Faculty
Daniel Hayes	School of Forest Resources	ME	UMO	Y	Faculty
Elizabeth Burakowski	Institute for the Study of Earth Oceans and Space	NH	UNH	Y	Faculty

Name	Affiliation	Jurisdiction	Institution	Early Career	Role
Erin Simons-Legaard	School of Forest Resources	ME	UMO	Y	Faculty
Jane Foster	Rubenstein School of Environment and Natural Resources	VT	UVM	Y	Faculty
John Gunn	Department of Natural Resources and the Environment	NH	UNH	Y	Faculty
Lisa Scott	Department of Natural Resources and the Environment	NH	UNH	N	Grad Student
Mark Ducey	Department of Natural Resources and the Environment	NH	UNH	N	Faculty
Scott Ollinger	Earth Systems Research Center	NH	UNH	N	Faculty
Valeria Briones	School of Forest Resources	ME	UMO	N	Grad Student
Zaixing Zhou	Earth Systems Research Center	NH	UNH	Y	Research Staff

RESEARCH MILESTONES PROGRESS

Objective	Projects	Project responsible parties	Year 1 Milestones	Milestone Progress
3.1	3.1a Inverse parameterization of ecological models	Foster, Simons-Legaard	• Identify necessary inputs for model development and refinement; • Prioritizing information needs and sites for model evaluation;	• Began discussion on past work with various ecological models • Shared prior and current findings that can help guide futures efforts • Identified past locations of modeling work and potential overlaps with Themes 1 and 2 • Started efforts to compile necessary data required for model initialization
3.2	3.2a Model integration	Hayes, Burakowski, Ollinger	• Assess model strengths and weakness;	• Developed model overviews of required inputs and available model outputs

Objective	Projects	Project responsible parties	Year 1 Milestones	Milestone Progress
	and application		• Initiate model sensitivity analyses; • Outline a potential multi-model comparison	• Initiated discussions about possible linkages across models • Completed a global sensitivity analysis of LANDIS-II and PnET, which will help guide Theme 1 and 2 efforts • Outlined potential locations for conducting a multi-model comparison to help better assess model strengths and weaknesses
3.3	3.3a Scenario assessment & trend analysis	Weiskittel, D'Amato, Ducey, Gunn	• Synthesize prior regional research and needs; • Outline potential research questions and necessary scenarios; • Identify key stakeholders	• Discussed prior scenarios and outline logical future scenarios • Connected with key regional stakeholders and worked to identify future scenarios of interest to them • Began preliminary scenarios that involved climate change, changing disturbances, and modified harvesting practices

FUTURE PLANS

- Use FIA and long-term locations plots (e.g., Howland, Hubbard Brook) to complete an initial inverse parameterization of Landis-II and PnET to identify key model parameter uncertainty
- Complete sensitivity analyses and evaluation of additional ecological models.
- Set up and run "point mode" simulations using CLM's Functionally Assembled Terrestrial Ecosystem Simulator (FATES) model; calibration, data assimilation and structural updates for this project will be carried out at intensive research sites across the region (e.g., Howland, Bartlett and Hubbard Brook research forests).
- Continue to refine model representation of disturbance and species response to climate
- Conduct model comparison at selected study sites and landscape test locations.
- Compile and harmonize spatial-temporal extrapolation datasets (e.g., climate, atmospheric chemistry, plant functional types, soils, land use and disturbance history) needed to drive regional-scale simulations with CLM-FATES.
- Complete initial regional baseline projections and assess outcomes.

- Consider additional Representative Concentration Pathways (RCPs), which our greenhouse gas concentration trajectory adopted by the IPCC and used to evaluate potential future effects of climate change.
- Build additional features into the online decision-support tool, Forest Ecosystem Status and Trends (ForEST).
- Extend landscape projection timespan to 2100.
- Initiate focus group and stakeholder input on completed projection scenarios and potential barriers to implementation.
- Conduct additional simulations using contrasting management strategies.
- Hold at least two additional University of Maine intra-theme meetings and one Theme 3 intra-jurisdictional meeting in Year 1.
- Theme 3 members actively preparing grant proposals related to INSPIRES.
- Develop a Bayesian parametrization routine for PnET and test it using Bartlett tower data
- Add a Farquhar biochemical module to PnET to accommodate analysis of increased CO_2 and temperature on leaf photosynthesis and respiration.
- Set up and run “point mode” simulations using CLM’s Functionally Assembled Terrestrial Ecosystem Simulator (FATES) model; calibration, data assimilation and structural updates for this project will be carried out at intensive research sites across the region (e.g., Howland, Bartlett and Hubbard Brook research forests).
- Compile and harmonize spatial-temporal extrapolation datasets (e.g., climate, atmospheric chemistry, plant functional types, soils, land use and disturbance history) needed to drive regional-scale simulations with CLM-FATES.

THEME 4. QUANTITATIVE REASONING IN CONTEXT

OVERVIEW

In the past year, Theme 4 has made significant progress in building a collaborative three-state team, refining our research plan, and identifying strategies for connecting classroom teachers with the work of INSPIRES. Members of the UMaine and UNH Theme 4 team traveled to UVM for a face-to-face Theme 4 meeting and to participate in the Northeast Association for Science Teacher Education (NE-ASTE) conference in October 2019. At this time, we also met with a high school teacher in VT who conducted her Master's research in Maine, focused on quantitative reasoning in science classrooms, advised by Theme 4 team member Franzi Peterson. We held another face-to-face Theme 4 meeting at the all-team meeting in December in Portsmouth, NH with all members of the Theme 4 team attending. The three-state team has met four additional times via Zoom and will meet monthly via Zoom for the remainder of Year 1. In addition, the UMaine team has held more than six Theme 4 meetings, as well as participating in all-team meetings and in meetings with each of the other Theme groups to build collaborative relationships and gain understanding of the full scope and plans for the project. Senior Personnel Regina Toolin has also attended the monthly all-team meetings at UVM to support building relationships across the project. Gaining understanding of the work of Themes 1-3 is important to the work of Theme 4, as part of our task is to help integrate classroom teachers into the work of Themes 1-3 and to design professional learning to support teachers in incorporating the work of INSPIRES into their classrooms.

We have also begun working to adapt the research plan to the current situation with COVID-19. Our original research plan was to conduct sequences of baseline interviews and observations of classroom instruction of quantitative reasoning in context (QRC). With schools no longer in session, we are adapting our interview sequences for this spring and summer to focus on examples of lesson plans that teachers use in their current practice of teaching QRC. We will also complete recruitment of Maine teachers, hold our first Theme 4 meeting that will include Maine teachers, and conduct our baseline interviews with Maine teachers in the next 2 months. We will continue to follow the plan from the original grant proposal of recruiting Maine teachers to the project during Year 1, and recruiting New Hampshire and Vermont teachers to the project during Year 2.

Our progress in the past year has included sharing about existing projects with K-12 teachers across the three states, discussing theoretical frameworks and compiling literature to support our collaborative research, and sharing resources developed through prior projects. These resources include lesson plan templates for place-relevant projects and a theoretical framework for QRC. Theme 4 presented a poster at the Maine Environmental Education Association conference in March 2020 and had been accepted to present about the Theme 4 work at the Maine Sustainability and Water Conference in March 2020 (conference was cancelled due to COVID-19). We also had a research presentation focused on QRC that was accepted to the New England Educational Research Organization (NEERO) conference that was to be held in May 2020. In addition, the UMaine group was scheduled to host our partners from UNH and UVM at our annual June Conference, which has now been rescheduled to 2021. Due to the strong relationships developed through our work on INSPIRES this year, members of the Theme 4 team are collaborating on a white-paper proposal for making longitudinal study of mathematics education a legislative funding priority.

Photo 2. The Theme 4 three-state team collaborating at the all-team INSPIRES meeting in December, while a member of the evaluation team observes. *(Photo courtesy CRSF.)*

In the coming year, we look forward to continuing to collaborate across the project themes, to developing our collaborative research across the three states, and to bringing teachers from Maine into our team for this year. In the coming year, we will also recruit teachers from VT and NH into the project and will work with members of the other project themes to design professional learning opportunities for teachers that will support lesson development for classrooms in ME, NH, and VT. We also plan to pursue external funding for other shared interests, such as improving mathematics education for all rural students.

HIGHLIGHTS

- Members from all three states met for face-to-face meeting in Vermont and participated in NE-ASTE conference.
- Team members regularly attend other Theme meetings in order to design professional learning to support K-12 STEM teaching.
- Working on a white-paper proposal for making longitudinal study of mathematics education a legislative funding priority.
- Adapting plans for K-12 teacher interviews and observations in response to COVID-19 limitations.

TEAM MEMBERS

Name	Affiliation	Jurisdiction	Institution	Early Career	Role
Franziska Peterson	Maine Center for Research in STEM Education (RiSE Center)	ME	UMO	Y	Faculty
Laura Millay	Maine Center for Research in STEM Education (RiSE Center)	ME	UMO	N	Professional Staff
Laura Nickerson	Leitzel Center for Mathematics, Science, and Engineering Education	NH	UNH	N	Faculty
Marina Van der Eb	Maine Center for Research in STEM Education	ME	UMO	N	Professional Staff
Regina Toolin	College of Education and Social Services	VT	UVM	N	Faculty
Sara Lindsay	School of Marine Sciences	ME	UMO	N	Faculty
Susan McKay	Maine Center for Research in STEM Education (RiSE Center)	ME	UMO	N	Faculty

RESEARCH MILESTONES PROGRESS

Objective	Projects	Project responsible parties	Year 1 Milestones	Milestone Progress
4.1	4.1a Design and implementation of Big Data modules integrated into G6-12 curricular materials	Peterson, Toolin, Millay, Lindsay, McKay, Shulman, Nickerson	• Teachers have an understanding of the research being conducted by the project	• Theme 4 provided information to Maine teachers about the project through the Maine Environmental Education Association conference in March 2020 and is currently recruiting Maine teachers to the project.
	4.1b Use local Big Data to answer student- and community-relevant science questions	Peterson, Toolin, Millay, Lindsay, McKay, Shulman, Nickerson	• Theme 4 researchers will have an understanding of the research being conducted by the project	• Theme 4 researchers have participated in all-team meetings as well as attending meetings of each of the other project themes in order to gain understanding of their work and to build relationships across the project. In the coming year, Theme 4 team members will continue to attend these meetings and will work to build connections between teachers and project researchers.
4.2	4.2a Investigate teacher needs to build students' QRC	Peterson, Toolin, Millay, Lindsay, McKay, Shulman, Nickerson	• Teachers participate in interviews focused on their use of context-driven quantitative reasoning in the classroom	• Maine teachers will participate in an initial round of interviews, via Zoom, with Theme 4 researchers this spring and summer.

FUTURE PLANS

- Finish recruiting to project/schedule initial meeting of Maine high school teachers.
- Develop interview protocols and conduct baseline interviews with Maine high school teachers.
- Begin analysis of baseline interview data.
- Continue meeting monthly as a Theme 4 three-state team.
- Submit a three-state conference submission for the fall Northeastern Educational Research Association (NERA) conference.

PROJECT OUTCOMES

Inter-jurisdictional and multi-institutional research collaborations are a key focus of the NSF EPSCoR RII Track-2 program. The INSPIRES project promotes such collaborations by enabling its participants to work across four integrated research themes. Responses from the external baseline survey (see Evaluation section) clearly demonstrate the multi-jurisdictional, multi-institutional, and multi-disciplinary nature of the project, and illustrates alignment with the focus to involve early-career faculty across project activities. Project participants are encouraged to work on or across more than one theme or research project, this has resulted in several important project outcomes. In addition, the NSF EPSCoR RII Track-2 program is intended to enhance research competitiveness and develop research capacity by increasing access to knowledge, expertise, equipment, and collaborators through the participation in collaborative research networks. This has not only happened between jurisdictions, but has also occurred within jurisdictions.

For the first year of INSPIRES effort, the number of research products were 8 (4 published; 1 in press; 3 under review) peer-reviewed articles, 17 presentations, and 9 proposals with 5 funded. The publications were in top tier ecological and remote sensing journals including *Global Change Biology* (Impact Factor = 8.88), *Remote Sensing* (Impact Factor = 4.51), and *Ecosystems* (Impact Factor = 4.47) with INSPIRES trainees, early-career, and senior faculty as co-authors. Presentations were primarily by early-career (11) and senior (6) INSPIRES faculty given at regional (10), national (4), and international (3) meetings. A total of $3,327,404 was requested in funding, with $2,257,694 secured. The proposals were led primarily by early-career faculty (5) that were submitted to a variety of sources including the National Science Foundation (5), other Federal agencies (2), state agencies (1), and private foundations (1). Two of the proposals led by early-career INSPIRES faculty were inter-jurisdictional. Details on the specific research proposals are provided in Table 3.

Table 3. List of research proposals submitted in Year 1 of INSPIRES

PI	Proposal Title	Funding Organization	Amount Requested	Status
Weiskittel (UM)	IUCRC Phase III at University of Maine: Center for Advanced Forestry Systems (CAFS)	NSF	$500,000	Awarded
Rizzo (UVM)	Anticipating risks and benefits of precision agriculture (PA) for the future of agricultural work and workforce: A multi-stakeholder research agenda	NSF	$150,000	Awarded
Roy (UM)*	Data-driven support for pollution-based closure decisions in shellfish growing areas of Maine	Maine Water Resources Research Institute	$36,000	Submitted and Pending

Roy (UM)*	Need and opportunities for improved data and tools to support river-basin-wide, multi-objective energy and water planning efforts	Department of Energy	$100,000	Awarded
Simons-Legaard (UM)*	Fostering forest landscape planning and adaptive capacity in anticipation of a regional insect outbreak	USDA AFRI	$487,717	Awarded
Simons-Legaard (UM)*	Perceptions of ecological risk and the landscape dynamics of forest management, insect outbreaks, and climate change+	NSF	$746,700	Declined
Contosta (UNH)*	Snowed Under: The influence of beneath-canopy snow dynamics on ecosystem processes in eastern United States temperate forests +	NSF	$1,119,977	Awarded
Classen (UVM)	Low cost & high frequency quantification of soil nutrients in ecosystems undergoing rapid global change	Gund Institute Catalyst Grant	$50,000	Awarded
Weiskittel (UM)	Supplemental RII Track-2 FEC: Leveraging Intelligent Informatics and Smart Data for Improved Understanding of Northern Forest Ecosystem Resiliency (INSPIRES)	NSF	$57,010	Declined

*Early-career faculty

+Inter-jurisdictional proposal

THEME SPECIFIC OUTCOMES

THEME 1

- Several research study sites were identified and are currently being evaluated for sensor deployment (Table 4).
- A prototype soil moisture and temperature sensor has been designed and tested in the lab that is capable of measuring soil moisture and wirelessly transmitting the measurements to a base station.
- Prototype is currently being calibrated for potential deployment to the field.
- Use of UAV with a low greenhouse gas sensor mounted on it is being tested to evaluate field-scale CO_2 concentrations.

- Development of a low-cost autochamber for measuring CO_2 that is currently being compared to concurrent measurements using a photoacoustic gas analyzer with highly promising results (Figure 5).
- Development and deployment of a wireless sensor network for measuring soil and wood moisture that is characterized by use of low-cost data loggers, the ability to collect/store data autonomously, and capacity to send data from remote locations to campus.
- Evaluation of alternative range and power requirements in the field using TI SmartRF software connected to Rx board to receive with measurements taken three times a day and averaged together, which showed highly promising results.
- Use of Q routing and multi-actor approach based Long Short-Term Memory (LSTM) deep learning model allowed individual nodes to make intelligent routing decisions for improved wireless sensor network design.
- Pre-proposal submitted to the WCS (Wildlife Conservation Society) Climate Adaptation Fund that would use the INSPIRES sensor network to support research regarding novel forest management as an adaptation strategy for warming winters in the Northern Forest.

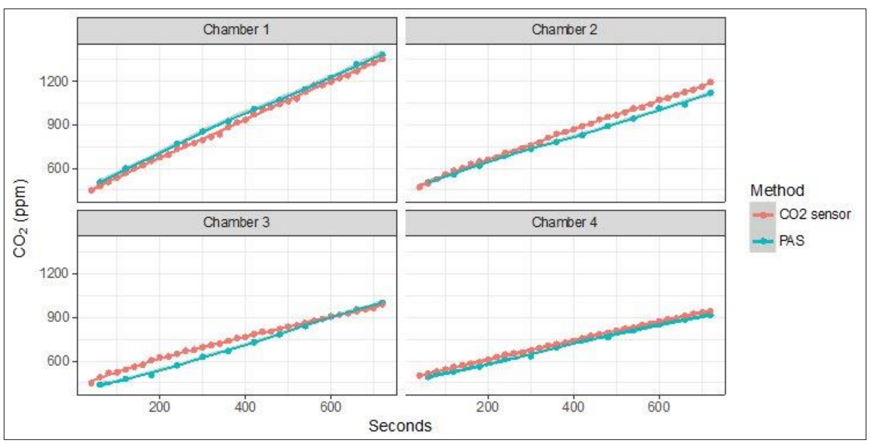


Figure 5. Comparison of a low-cost autochamber (orange line) for measuring CO_2 concentration (ppm) that is currently being compared to concurrent measurements using a photoacoustic gas analyzer (PAS; blue line) with nearly equal agreement across a range of conditions. Graph provided by INSPIRES Senior Personnel Adair.

Table 4. List of potential Theme 1 study sites for extensive and intensive wireless sensor network deployment across the three jurisdictions.

State	Site	Forest type	Bedrock	Management	Existing sensors	Cell service	Non-solar Power
VT	Corinth/ Washington	Hardwood	Dolomite/ limestone	Single tree small group selection (family forest)	-	No	No
VT	Victory Bog SF	Spruce fir hardwood	Granitic	Patch cut, VT-industrial	-	No	No
VT	Proctor Maple	Hardwood	Greenstone / schist	Sugar bush – selective for maple	-	Yes	Yes

State	Site	Forest type	Bedrock	Management	Existing sensors	Cell service	Non-solar Power
NH	Second College Grant	Hardwood/ spruce-fir	Phyllite	Experimental	nearby met station, air temperature, RH, soil temp, soil moisture	Yes	No
NH	Bartlett	Hardwood	Granitic	Experimental	Phenology, soil moisture, temperature, soil respiration, eddy covariance, micrometeor-ology	Yes	Yes
NH	Hubbard Brook Experiment al Forest	Hardwood	Schist	Experimental/ not much management	soil temperature, soil moisture, soil respiration, air temperature, relative humidity, snow depth	Yes	Yes
NH	Thompson Farm	Red oak white pine	Outwash/till	Patch cuts	Snow depth, phenology, soil moisture, temperature, soil respiration, eddy covariance	Yes	Yes
ME	Old Town	Mixed hemlock American beech	Glacial lacustrine	-	-	Yes	No
ME	AMC - MWI (Maine Woods Initiative)	Acadian mixed wood (spruce-fir-northern hardwoods)	Mostly acidic meta sedimentary Some acidic and inter-mediate granitic	Approximately equal mix of natural area and active management; natural dynamics silviculture to restore former industrial lands (75,000 acres total)	None, some measurements of snowpack by facility staff; nearest NWS site is Greenville	Limited	Availa ble at three sporti ng camps on prope rty
ME	Baxter	Spruce-fir	-	-	-	No	No

State	Site	Forest type	Bedrock	Management	Existing sensors	Cell service	Non-solar Power
ME	Schoodic	Coastal spruce-fir	-	Limited management, conserved	meterological	Yes	Yes
ME	Deboullie	Spruce-fir	-	Limited management, conserved	meterological	No	No
ME	Holt	Oak mixed hardwood	-	Mixed management with a new set of treatments planned for fall 2020	None	Yes	Yes
ME	Howland	Acadian mixed wood	-	Natural, mature with limited past harvesting	AmeriFlux tower	Yes	Yes

THEME 2

- Mapped trends in the abundance of subalpine spruce-fir tree species (*Abies balsamea* and *Picea rubens*), quantified with dense time series of Landsat satellite data from 1984-2012 across the three jurisdictions. The results show strong increases in Maine and New Hampshire, while Vermont forests experienced general declines (Figure 6).
- Analysis of US Forest Inventory and Analysis data from the three jurisdictions support findings from remote sensing as spruce-fir growth and recruitment exceed mortality, based on changes in aboveground carbon in biomass (AGB-C), while for paper birch (*Betula papyrifera*) had high mortality that led to negative net change (Figure 7).
- Developed a framework in PostGIS that allows available data from sensors and remote sensing as well as existing spatial data layers to be integrated, which will help us to characterize differences in time and space and better understand the ecological processes we are evaluating.
- Developed an efficient and flexible spatial query tool for PostGIS and PostgreSQL spatial databases that allows for quick spatial gridding and summarization of available raster spatial layers.
- Evaluated alternative neural network algorithms and developed a new method called Mutual Information-based Neuron Trimming (MINT), which was tested on stream water quality data from New Hampshire. MINT was shown to outperform other commonly used neural network approaches like MNIST, CIFAR-10, and ILSVRC2012.
- Regional available datasets were compiled, harmonized, and documented (Table 5).
- Key field sites identified for detailed remote sensing acquisitions in summer of 2020.

- Use of hyperspectral imaging to better identify key tree species that occur in the region (Figures 8 and 9) and their health
- Development of a strategy for improved spatial mapping and monitoring of black ash, which has strong importance to indigenous users for basketmaking. This includes distinct opportunities to leverage traditional ecological knowledge to inform or interpret new forest classes or "forest places" based on qualitative attributes and associations between qualitative or quantitative attributes. These classes could be mapped and analyzed with additional development of machine learning models in a spatially explicit way using existing analytical capacity and data. The next steps would be to integrate existing airborne imagery from NASA's G-LiHT and UAVs to generate a larger sample of training data for developing models based on Landsat and Sentinel imagery.
- Compiled new data sets and conducted preliminary analysis of regional-scale phenology metrics as measured through satellite data products from the Moderate Resolution Imaging Spectroradiometer (MODIS) collection. These data are being analyzed for spatial patterns and temporal trends as indicators of shifting seasons across the variability in forest conditions and changes in climate (Figure 10).

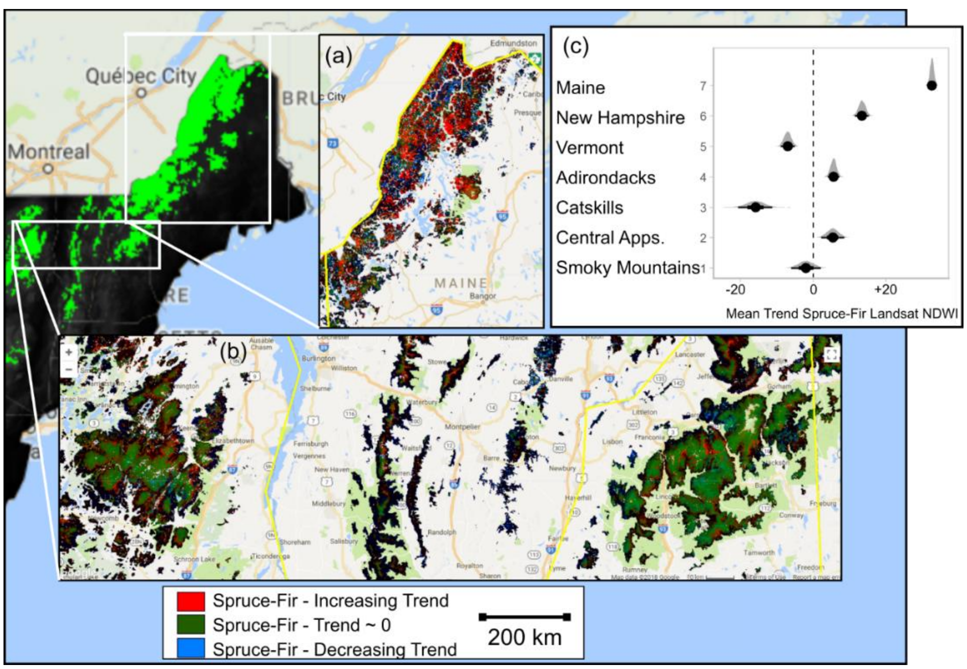


Figure 6. *Mapped trends in the abundance of subalpine spruce-fir tree species (a,b), Abies balsamea and Picea rubens, quantified with dense time series of Landsat satellite data from 1984-2012. In subalpine zones, spruce-fir increased in abundance (red), stayed stable (green) or decreased in number (blue). Means and Bayesian credible intervals (c) show strong increases in Maine and New Hampshire, while Vermont forest experienced decline on average.*

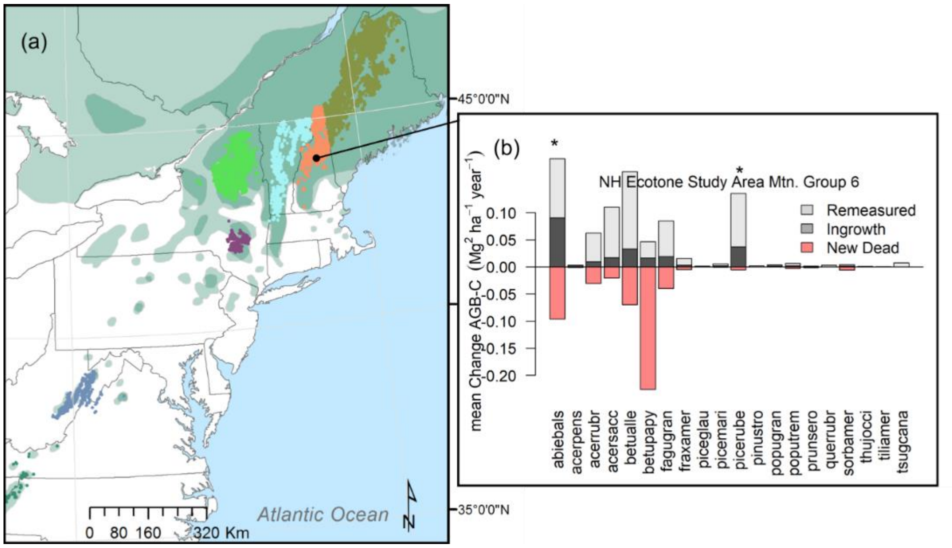


Figure 7. *Analysis of US Forest Inventory and Analysis (FIA) data (plot locations in (a)) shows demographic changes between 2010 and 2015 (data for New Hampshire shown (b)) for tree species growing in the subalpine zone. In NH and ME, spruce (*Picea rubens*) and fir (*Abies balsamea*) growth and recruitment exceed mortality, based on changes in aboveground carbon in biomass (AGB-C), while for paper birch (*Betula papyrifera*), high mortality leads to negative net change. Subalpine spruce and fir have increased in overstory and sapling layers in many regions.*

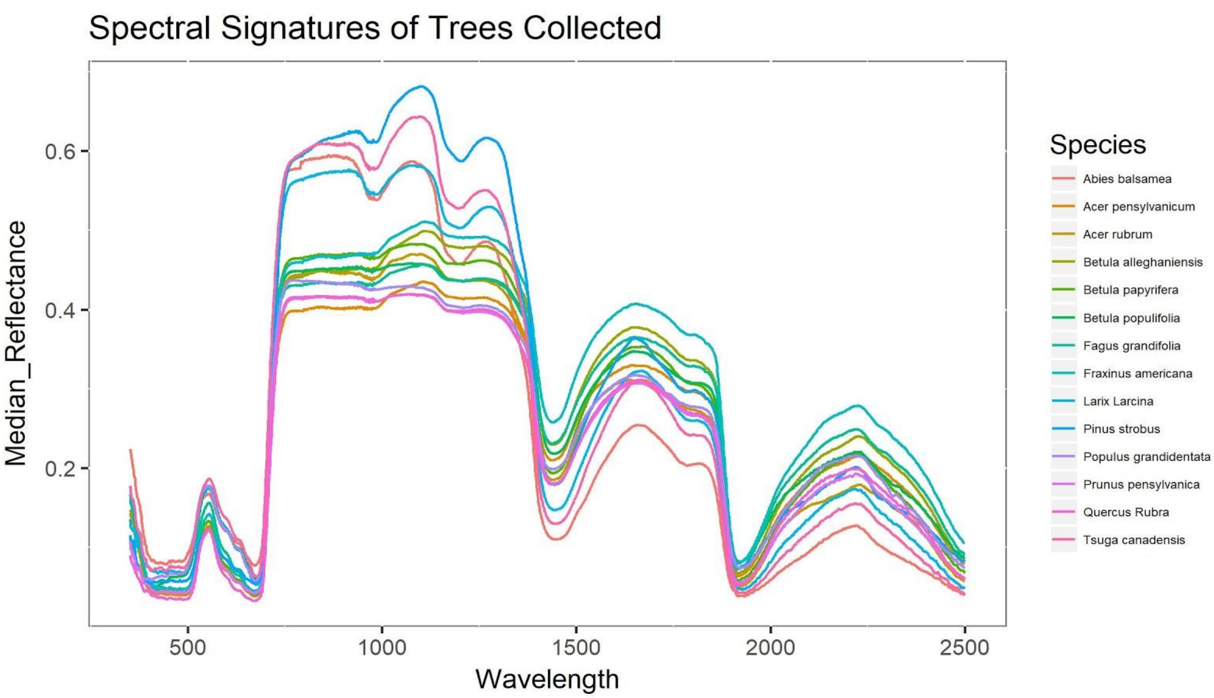


Figure 8. *Spectral profiles of shrub and tree species collected in Maine during the fall of 2019 using a Spectral Evolution PSR+ 3500 instrument on a UAV. Graph provided by INSPIRES Senior Personnel Peter Nelson of the University of Maine Fort Kent.*

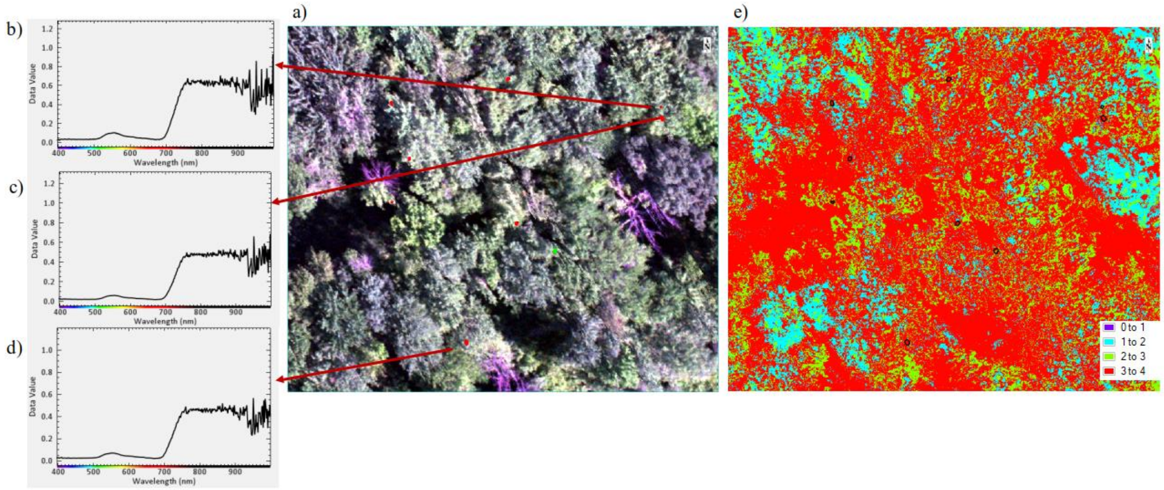


Figure 9. *Use of hyperspectral imaging to evaluate foliage health. The image shows a) true color image with overlaid samples of classified health on a scale 1-4, 1 = healthy, 4 = unhealthy (in red and green); b) the spectral profile of a white ash tree with health class 1; c) the spectral profile of a white ash tree with health class 3; d) the spectral profile of a white ash tree with health class 4; and e) a classified image of former extent through a random forest model using the rated health samples.*

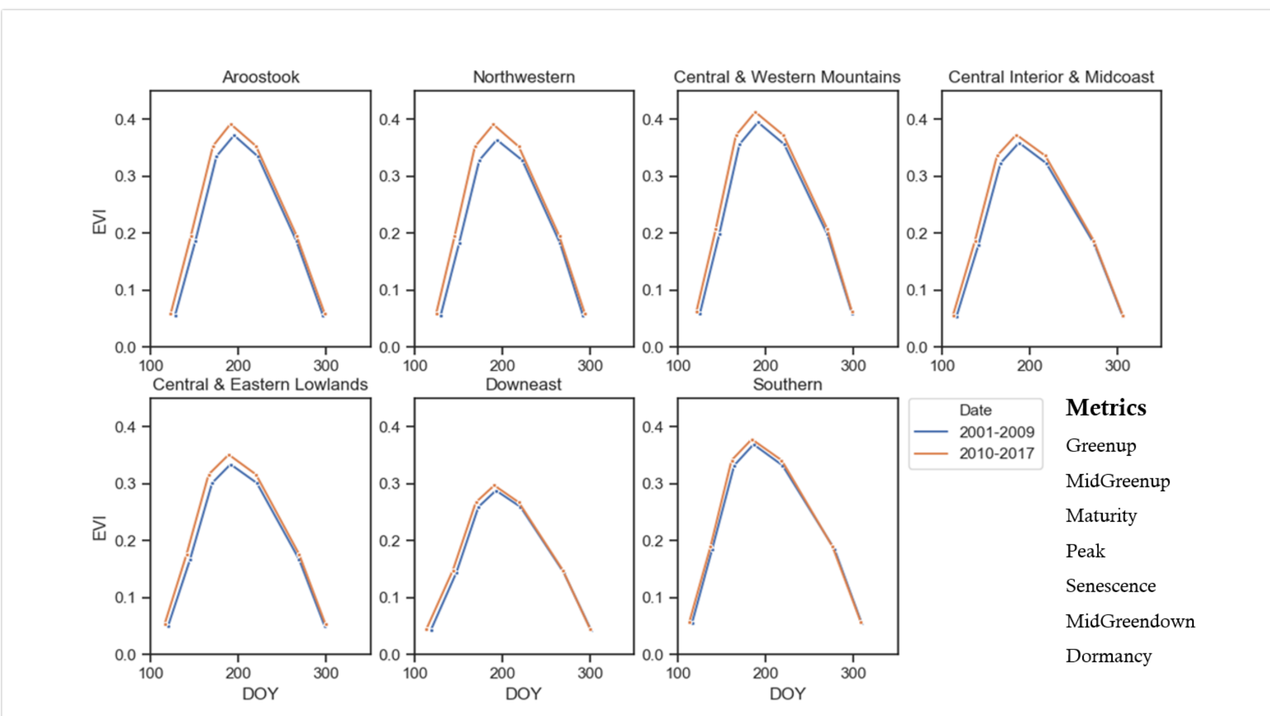


Figure 10. *The set of phenology metrics shown in the seasonal cycle of a satellite index of vegetation "greenness" (MODIS Enhanced Vegetation Index, EVI) to compare changes in seasonal timing between two time periods (2001-09 vs. 2010-17) and among the different climatic regions of Maine.*

Table 5. Available regional datasets for Theme 2.

Type	Source	Dataset	Description	Availability
Field Site	Professional	US Forest Service, FIA	Statewide and nationally consistent plot-level measurements that includes trees, downed woody materials, vegetation, and lichens	https://apps.fs.usda.gov/fia/datamart/datamart.html
Field Site	Professional	Howland	Long-term AmeriFlux site in central Maine that has 30+ years of eddy-flux and environmental measurements	https://ameriflux.lbl.gov/sites/siteinfo/US-Ho1
Field Site	Professional	Hubbard Brook	Long-term watershed in central New Hampshire that has assess ecosystem change	https://hubbardbrook.org/d/hubbard-brook-data-catalog
Field Site	Professional	Holt Research Forest	Long-term ecosystem study in an oak-pine coastal forest in southern Maine	https://www.uvm.edu/femc/data/archive/project//holtbasics
Field Site	Professional	Bartlett Experimental Forest	USFS and NSF NEON long-term research site in the White Mountains of New Hampshire; long-term Ameriflux site with 16 year of eddy flux data, phenocam and plot-based measurements of forest carbon cycling	https://www.neonscience.org/field-sites/field-sites-map/BART
Field Site	Professional	Penobscot Experimental Forest	USFS long-term research site in central Maine that has examined response to forest management	https://www.nrs.fs.fed.us/ef/locations/me/penobscot/data/data_catalog/
Field Site	Professional	Forest Ecosystem Monitoring Cooperative	Regional repository of long-term forest data of mixed nature	https://www.uvm.edu/femc/data/archive/project/themes
Remote Sensing	Professional	G-LiHT	NASA airborne sensor with LiDAR, hyperspectral, and thermal imaging capacity that has	https://glihtdata.gsfc.nasa.gov/

Type	Source	Dataset	Description	Availability
			multiple acquisitions in the region	
Field Site	Professional	Maine Ecological Reserve Network	Network of ecological reserves throughout Maine with permanent plots that have repeated measurements	https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecy.2500
Field Site	Professional	Northeast Temperate Network	Network of ecosystem monitoring protcol of plants and animals throughout the Northeast on National Park Service lands	https://www.nps.gov/im/netn/inventory-reports.htm
Environmental Network	Citizen Science	Community Snow Observations	Citizen scientist observations of snow cover and depth	http://app.communitysnowobs.org/
Environmental Network	Professional	Maine Cooperative Snow Survey	Statewide survey of equivalent water content, and density of the snowpack in Maine	https://www.maine.gov/dacf/mgs/hazards/snow_survey/
Field Site	Citizen Science	eBird	Citizen scientist observations of bird occurrence and abundance	https://ebird.org/region/lower48?yr=all
Field site	Professional	Bear Brook Watershed in Maine	Long-term paired watershed study in eastern Maine with FIA-style forest veg, watershed geochemistry, measurements since 1986 and soil temp since 2000s.	https://umaine.edu/bbwm/

THEME 3

- Demonstrated that relative importance of model parameters in ecological models can vary with climate scenario (RCP 2.6 vs. RCP 8.5). Importance of climate parameters in PnET-II (Figure 11) increased, particularly maximum temperatures in summer months, under the high emission scenario when projecting spruce-fir forest productivity; higher temperatures had a negative effect on spruce-fir resulting in large part from projected summertime temperatures exceeding species' optimum temperature for photosynthesis (PsnTOpt), which also increased in importance relative to the low emission scenario.

- Completed preliminary development of an online digital application called ForEST (https://forestapp.acg.maine.edu/) for displaying and summarizing spatial data that can be used by scientists and land managers (Figure 12)
- Based on the GSA results, identified influential model parameters with limited empirical data support that could be informed by the Theme 1 sensor network (e.g., maximum monthly temperature) or Theme 2 geospatial data science (e.g., foliar nitrogen concentration).
- Identified data linkages and potential feedbacks between ecological models that could be leveraged to improve productivity estimation and spatial extrapolation.
- Initiated detailed canopy disturbance analyses that will form the basis of annual maps that will inform collaborative forest modelling experiments at these forests (Figure 13).
- Shared and synthesized prior regional projections research across ecological models and jurisdictions.
- Identified suitable ecological reserves in each jurisdiction for collaborative model calibration, benchmarking, and projection comparison.
- Completed model simulations of a 4.5 million ha landscape using LANDIS-II that compared contrasting strategies for enhancing forest carbon sequestration (Figure 14).
- Recruited PhD student for fall 2020 to work on cross-theme (Themes 2 and 3) project at UNH "Using Big Data and Machine Learning to Predict Future Forest Condition in Response to Silvicultural Activities"
- Cross-team work by PhD student Jason Carter who is working with Dr. Marek Petrik and Dr. John Gunn to develop a new machine learning method to improve upon Classification and Regression Tree techniques by computing the optimal solution rather just a heuristic solution and by accounting for variable costs of misclassification. The method is being applied to support decision-making around the carbon implications of the decision to salvage true mortality during a spruce budworm outbreak.

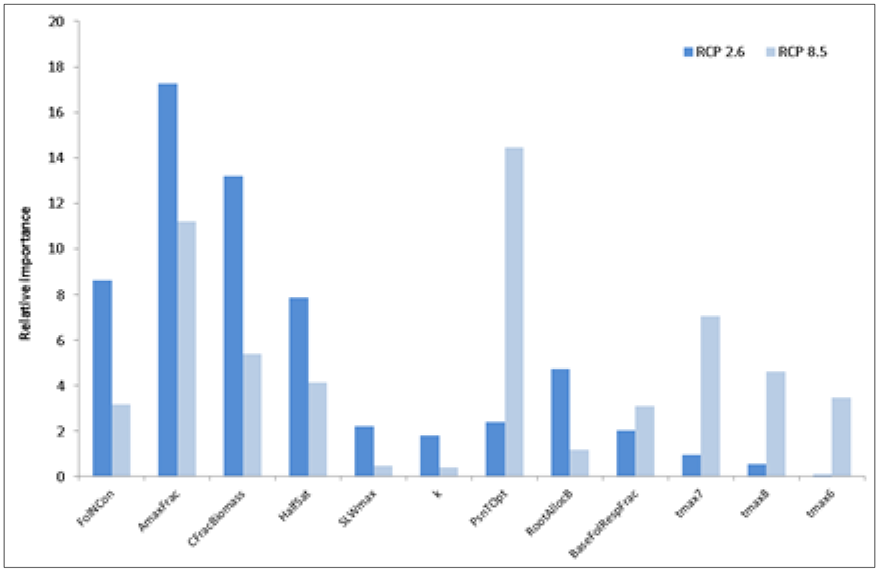


Figure 11. *Relative importance of top-ranked PnET-II model parameters[1], based on a global sensitivity analysis including vegetation and climate parameters, under a low (RCP 2.6) and high (RCP 8.5) emission climate change scenario.*

[1]FolNCon = Foliar nitrogen concentration; AmaxFrac = Daily Amax as a fraction of integral of instantaneous rate; CFracBiomass = Carbon fraction of biomass; HalfSat = Half saturation light level; SLWmax = Top sunlit canopy specific leaf weight; k = Canopy light attenuation constant; PsnTOpt = Optimum temperature for photosynthesis; RootAllocB = Slope (B) of relationship between foliar and root allocation; BaseFolRespFrac = Dark respiration as fraction of Amax; tmax7 = Max July temperature; tmax8 = Max August temperature; tmax6 = max June temperature.

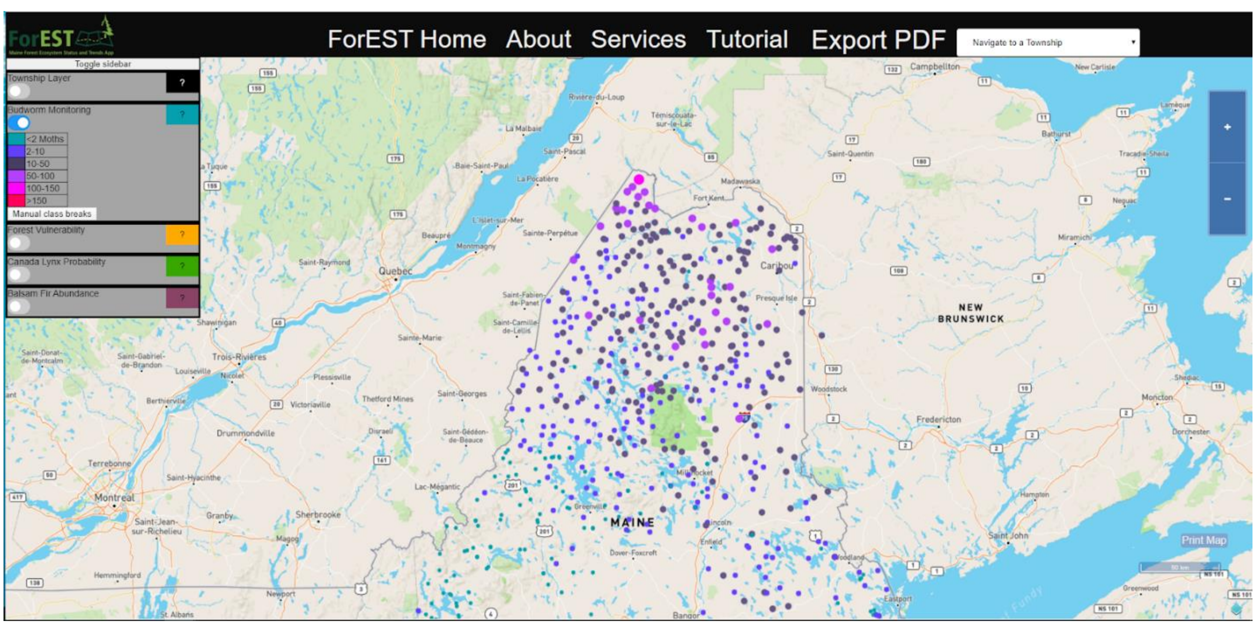


Figure 12. *Screenshot of ForEST web-based application developed by INSPIRES Senior Personnel Legaard, Simons-Legaard, and Hahmann. ForEST is designed to easily display and summarize geospatial data, which will provide near real-time information about changing forest landscape conditions resulting from the spruce budworm outbreak and ongoing management. Available online: https://forestapp.acg.maine.edu/.*

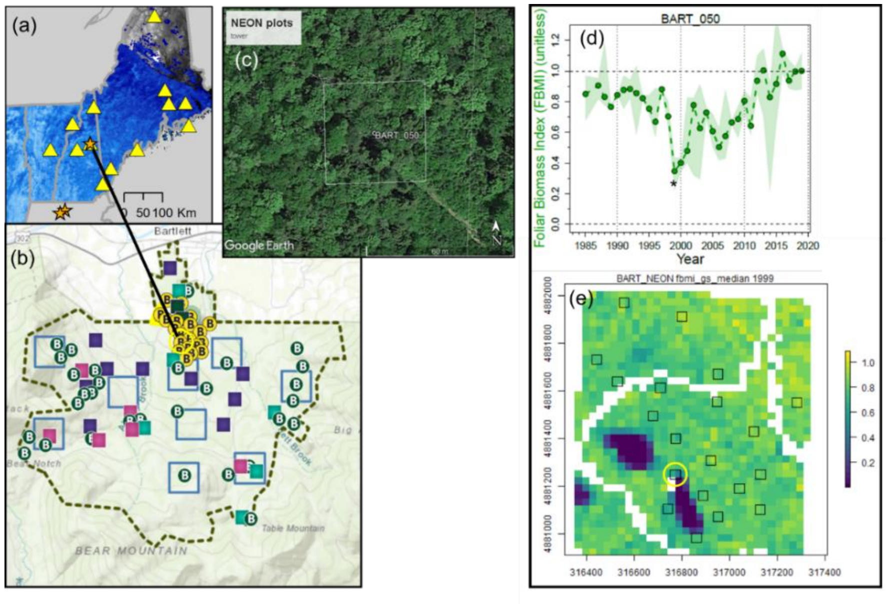


Figure 13. *Maps of partial-canopy disturbances with Landsat remote sensing time series (1984-2019) at existing and new intensively monitored forest sites (symbols in (a)), including NSF NEON sites at Bartlett Experimental Forest in NH (b-e). Example Landsat timeseries of our derived Foliar Biomass Index (FBMI) shows canopy reductions in 1999 followed by gradual recovery for NEON tower base plot BART_050 (d).*

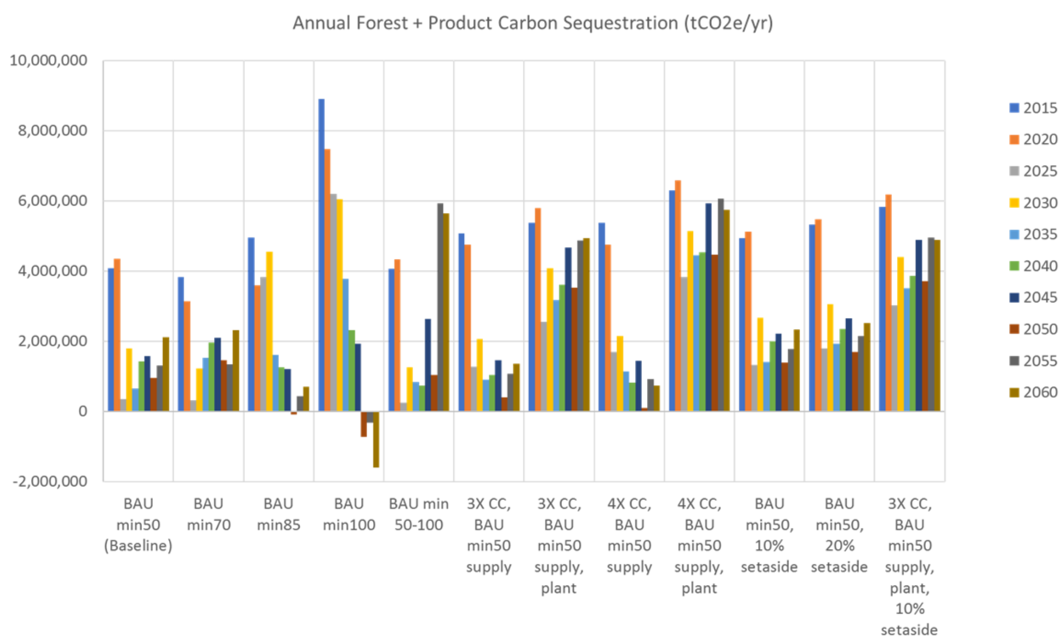


Figure 14. *Annual forest and product carbon sequestration (tons of CO_{2e} per year) for different management strategies projected using LANDIS-II for a 4.5 million ha landscape in northern Maine. A Business as Usual (BAU) scenario emulated the average rate of harvesting in the study area, as observed by a Landsat-derived time series of forest disturbance (2000-2010). Additional scenarios were: (1) Extended Rotation with increased minimum stand age eligible for harvest (from 50 year to 70, 85, or 100 years); (2) Clearcut/Partial harvest distribution: increased % of the harvest (from 10% to 30% or 50%). Supply was held constant by reducing overall harvest footprint; (3) Planting after clearcut with a mix of red and white spruce; and (4) Reserve 10% or 20% of land area. These options were modeled singly and in combination.*

THEME 4

Theme 4 presented a poster at the Maine Environmental Education Association Conference in March 2020. A proposal focused on QRC was accepted to the New England Educational Research Organization (NEERO) conference in May; however, that conference was cancelled due to COVID-19. We also had a presentation proposal accepted to the Maine Sustainability and Water Conference that was scheduled for April, but has also been cancelled. Laura Millay presented about the Theme 4 work at a forum focused on Broader Impacts organized by UM's Office of Research Development.

As mentioned above under the collaborations section, the Theme 4 team also prepared a separate, collaborative proposal across the three states focused on making mathematics education a legislative funding priority. This proposal was submitted to the UM’s VPR office. The three-state collaboration underpinning this mathematics proposal was developed entirely as a result of the INSPIRES grant.

JURISDICTIONAL SPECIFIC OUTCOMES

MAINE

Within Maine, INSPIRES has brought 20 faculty, 2 undergraduates, 2 graduate students, a post-doctorate fellow, and 3 project staff from across three different institutions together. The INSPIRES team within Maine brings several disciplines across 10 different academic units or research centers together. As outlined in the external baseline survey, most of the INSPIRES team members in Maine had not worked together previously. Several of the senior INSPIRES faculty in Maine (PI Weiskittel, Co-PI Beard, Senior Personnel Segee, and Senior Personnel McKay) serve important roles as leaders and mentors and will continue to facilitate team relationship formation.

To help focus efforts and strengthen team relationships, several Maine-specific INSPIRES team and theme meetings have been held and are regularly scheduled for the future. Initially, the focus of these meetings was to introduce team members, learn about past as well as ongoing research related to INSPIRES, and discuss institutional needs and challenges. These meetings were particularly important for connecting the undergraduate and graduate student team members with each other as well as with INSPIRES faculty. INSPIRES team members participated in several important Maine events including Wabanaki Tribal Economic Conference, Maine’s Forest Climate Change Initiative's Forest Climate Change and Adaptation Forum, Maine’s Chapter of the Society of American Foresters annual meeting, and Maine’s Climate Council Scientific and Technical Subcommittee public meeting.

NEW HAMPSHIRE

Within New Hampshire, the team was comprised of 9 faculty, 3 project staff, 1 post-doctorate fellow, and 2 graduate students with representation from two institutions and five research centers or academic units. Most of the faculty had little prior collaboration, so the first phase of Year 1 (through December 2019) focused on team building and collaborative planning via bi-weekly team meetings. The NH team also had representation on all four project themes, which allowed cross-theme exchange of information and ideas prior to, and following, the online and in-person (Portsmouth, NH) all-team meetings. Additional planning activities included the Theme 1 meeting at the University of Vermont to discuss site selection, sensor deployment and data collection (March 3), and a meeting at the Society for the Protection of New Hampshire Forests, attended by co-PIs Ollinger and D'Amato on November 14.

Activities and plans through Year 1 resulting from these discussions include coordination of inter-jurisdictional Theme 1 meetings (by A. Contosta), identification of field sites, parameterization and testing of the PnET ecosystem model, integration of eddy covariance data and soil sensor date (Theme 1) with modeling and remote sensing data sets (Theme 3), analysis of winter-to-spring carbon balances using eddy covariance data at the Thompson Farm research site, recruiting of two PhD students and one MS, programming of data loggers to be used for soil sensors, development of machine learning methods for predicting forest condition response to silvicultural activities, and development of remote sensing techniques to be used for identification of forest composition and foliar nitrogen concentrations. Preliminary results and upcoming plans were presented at the Bartlett Experimental Forest Cooperator's meeting (March 12, 2020), an event that also provided additional opportunity for collaboration between University of New Hampshire and University of Vermont.

VERMONT

Similar to the other jurisdictions, University of Vermont includes participants (7 faculty, 1 undergraduate, 4 graduate students, and 1 research technician) from multiple (4) academic units or research centers. The faculty had limited past collaborations and has been working closely over the past 9 months to build the necessary relationships for this project. Considerable progress in the direction was accomplished by monthly meetings of all Themes and associated PIs and collaborators at University of Vermont beginning in September 2019. In addition, several additional meetings were attended to build synergies within the team and key external stakeholders.

These meetings and events included: (1) a meeting of Theme 4 PIs from University of Maine, University of New Hampshire, and University of Vermont in conjunction with 2019 Northeast Association for Science Teacher Education Conference, Burlington, VT (October 9-12, 2019); (2) meeting of Theme 1 PIs and collaborators from University of Maine, Dartmouth College, Plymouth State University, USDA Forest Service Northern Research Station, and University of Vermont to discuss CO_2 and soil/deadwood moisture sensor development at Forest Ecosystem Monitoring Cooperative Annual Meeting, Burlington, VT (December 13, 2019); (3) meeting of Theme 1 PIs and collaborators from University of New Hampshire, Dartmouth College, Plymouth State University, and University of Vermont on Vermont's campus to discuss field sites for sensor deployment and field season logistics (March 3, 2020); (4) presentation and planning at the Bartlett Experimental Forest Cooperator's meeting (March 12, 2020) for interjurisdictional collaboration between University of New Hampshire, University of Vermont, University of Maine, and USDA Forest Service that leverages long-term eddy flux and inventory data and new sensor deployments at the Bartlett Experimental Forest, Bartlett, NH; and (5) a field tour of a new extensive sensor site, Dartmouth College's Second College Grant, with foresters from Vermont Forests, Parks and Recreation led by Co-PI D'Amato on September 25, 2019 and attended by 25 foresters. A research team meeting is planned at Bartlett Experimental Forest (intensive field site) in June 2020 for a cross-theme discussion of research questions and integration with STEM education, which is currently contingent on national and regional COVID-19 guidelines for safe and healthy work environments.

BROADENING PARTICIPATION

TEAM DEMOGRAPHICS

Significant focus in Year 1 was on building and formalizing research teams, recruiting new research members, and inter-team collaboration. Currently, the team comprises 38 faculty (20 early career), 3 undergraduate students, 7 graduate students, and 6 staff across 6 different institutions. According to the Data Outcomes Portal (DOP) for Year 1, of those who disclosed their gender, there is nearly equal female-male representation (F=18, M+19) on the research team, 1 female postdoc, 3 female grad students, and 1 male undergrad. Furthermore, the DOP reported 1 senior researcher and 1 undergraduate student self-identified as underrepresented race/ethnicity. Significant recruitment efforts are underway for undergraduate and graduate students for Year 2. Continued engagement and support of early-career faculty as well as team diversity will be a key priority for the remainder of Year 1 and going forward. A summary of current team member composition across the three jurisdictions is provided in Table 6, while a detailed list of all personnel is given in Appendix 5.

Based on an independent assessment by external evaluator AAAS (see Appendix 3), INSPIRES faculty had equal representation of females (51.7%) with males (44.8%). In addition, INSPIRES faculty composition leans towards early-career investigators (55.2%) composed of a high percentage of those identifying as female (53.3%). INSPIRES faculty are also highly diverse in terms of academic rank (Table 7) and the number of disciplines (15) represented (Figure 15) are relatively high for current team size. Current representation of early-career investigators and involved disciplines are well balanced across the four research themes with 7-12 disciplines and 14-78% early-career investigator composition on the themes. The DOP Demographics report for INSPIRES showed similar trends with a good balance between gender and representation of races.

Table 6. Summary of INSPIRES team personnel by role and jurisdiction.

Role	Jurisdiction			Total
	Maine	**New Hampshire**	**Vermont**	
Faculty (Early-career)	20 (9)	11 (7)	7 (4)	38 (20)
Staff (Professional, Post-doctorates, Support)	4	1	1	6
Students (Undergraduate/ graduates)	4 (2/2)	1 (0/1)	5 (1/4)	10 (3/7)
Total	28	13	13	54

Table 7. INSPIRES survey participants by academic rank/title by the AAAS and DOP surveys. The reported values might not align because of different response rates for the two surveys and not all questions were addressed by respondents.

Academic Rank/Title	AAAS		DOP				
	Number	**%**	Male	Female	Asian	Native American	White
Professor	8	28	9	10	-	1	17
Associate Professor	3	10	-	-	-	-	-
Assistant Professor	4	14	10	8	2	-	15
Research Assistant Professor	6	21	-	-	-	-	-
Research Scientist	2	7	-	-	-	-	-
Professional Staff	3	10	-	-	-	-	-
Postdoctoral Researcher	2	7	1	1	-	-	2
Other	1	3	3	1	-	-	3

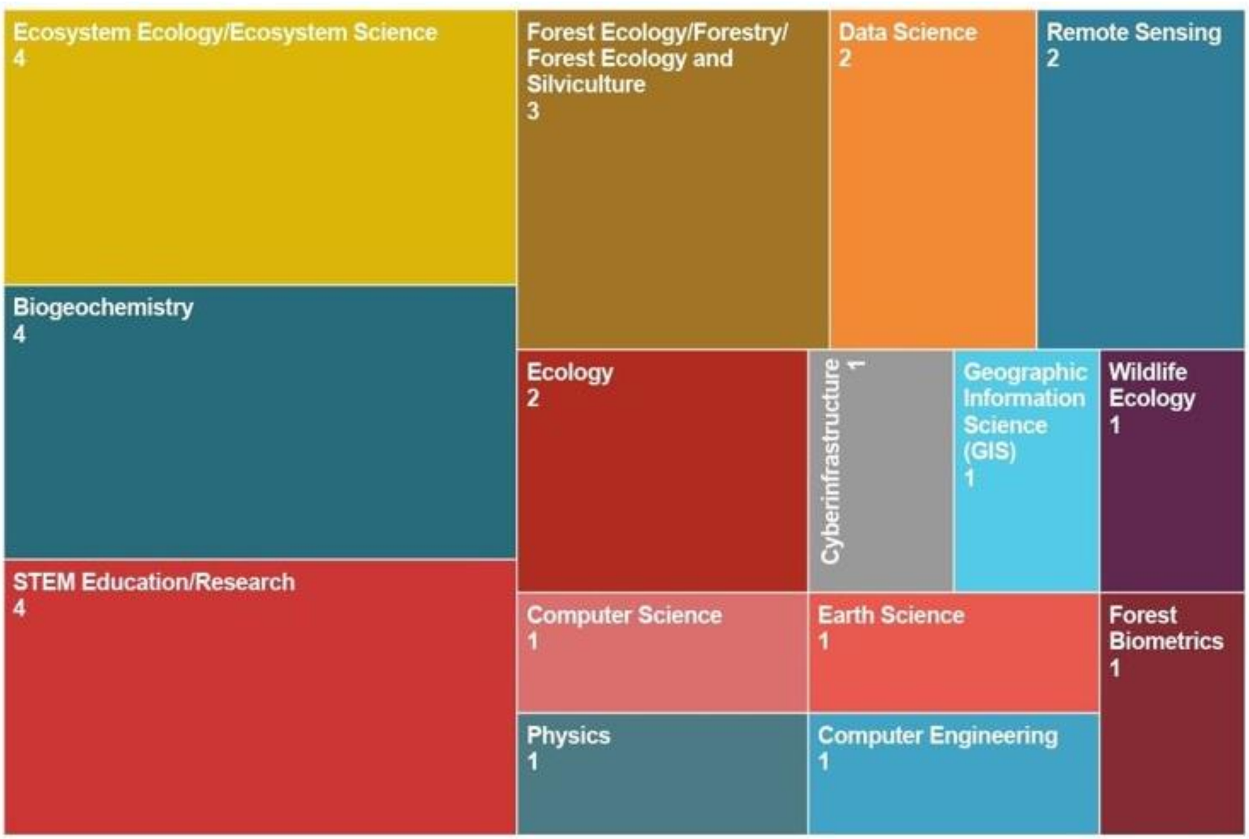


Figure 15. Disciplines currently represented by INSPIRES faculty.

INTERJURISDICTIONAL COLLABORATION

The emerging research projects, which extend across the four integrated themes, are convergent in nature, engaging senior and early career faculty from diverse fields (including education, electrical/computer engineering, forestry, computer science, ecology, ecological modeling, statistics, remote sensing, data science, and anthropology). Each theme is cross-jurisdictional with early career faculty leads, senior faculty mentors, and supporting members that include postdoctoral researchers, graduate and undergraduate students, and staff. In addition to collaborations with University of New Hampshire and University of Vermont, this project involves several campuses that comprise the University of Maine System. The inclusion of these smaller campuses is important to Maine's research infrastructure, and should help to mitigate the isolation that can impact early career faculty in rural areas and/or institutions that primarily serve undergraduates. These smaller campuses also often function as a conduit to remote areas and rural communities where faculty and citizens that can interact with the results of this project.

INSPIRES has been structured to encourage the three jurisdictions to share best practices and address potential deficiencies in a way that strengthens complex systems work in all three states and creates greater strength overall in terms of research and education that is relevant for the region. All jurisdictions have identified strengths that can be linked to the region's natural resource base and rural nature, while each jurisdiction brings key strengths to the project that will benefit the other jurisdictions. University of Maine System strengths include deep and historic relationships with the forest industry and related organizations through an existing NSF I/UCRC led by PI Weiskittel, long-term forest research sites, state-wide relationships with teachers through the Maine Center for Research in STEM Education (RiSE), work with underrepresented in STEM students and teachers through two INCLUDES projects and other endeavors like the recent NRT in conservation science, expertise in TEK and working with Native American communities, deep spatial informatics expertise (National Center for Geographic Information and Analysis), and strong collaborations between scientists and 4-H personnel for STEM outreach. University of New Hampshire strengths include both undergraduate and graduate-level Analytics and Data Science programs as well as an existing Earth Systems Research Center (ESRC) and a recently developed statewide terrestrial and aquatic sensor network (EPS-1101245). University of Vermont strengths include a Complex Systems Center with associated undergraduate- and graduate-level degrees in Complex Systems and Data Science, as well as expertise in developing sensor networks and managing Big Data over time to examine complex socio-ecological questions, such as the interactive effects of climate change and land use on the Lake Champlain basin, as a result of past EPSCoR funding (OIA-1556770).

HIGHLIGHTS

- Theme 3 organized several cross-theme meetings that help build inter-jurisdictional relationships and initiated new dialogs for continued collaboration

- Theme 2 initiated collaborations with Theme 1 participants who are interested in sensor network design for optimizing spatial coverage, signal quality, and cost of sensors.
- Ongoing collaborations between Themes 2 and 3 that focus on mapping of forest places and events that can be modified and used as input for Theme 3 forest ecosystem modeling.
- The ontological representation and modeling by Theme 2 impacts Theme 4, and initial discussions show real promise of collaboration with the Wabanaki Youth Science Programs (WaYS).
- Themes 2 and 3 together identified black ash as a species of shared interest, which is now serving as the initial focal species to kick off development of the Digital Forest.
- Theme 1 submitted a pre-proposal that would leverage the INSPIRES sensor network across all three project states, and build on Theme 1's topical focus on winter and spring climate change. Members from all three jurisdictions contributed to the pre-proposal.
- Created a project jargon dictionary that helps to minimize barriers in team member participation and understanding (see Table 8)
- Created a publication author template (Appendix 4) to help determine authorship and minimize potential conflict
- Created a student participation and faculty mentoring guidelines (Appendix 5, 6) that help define roles and responsibilities, expectations, and best practices
- Develop and implemented a project communication strategy that outlined measures to ensure effective internal and external project communications
- UM and UNH collaborators travelled to UVM in October for a face-to-face Theme 4 meeting and to participate in the Northeast Association for Science Teacher Education (NE-ASTE) conference. This trip included a field trip on the Melosira Research Vessel which is used to support place-based science instruction about Lake Champlain for VT teachers and students through the Champlain Research Experience for Secondary Teachers (CREST) program. This field trip showcased part of the work being conducted through CREST that provides one model for the type of place-relevant science instruction that we would like to support implementing with regard to northern forests and Big Data.
- Members of the Theme 4 team have attended meetings held by each of the other themes to build collaborative relationships and to keep up-to-date about the plans and progress of each part of the project.
- Theme 4 has held four Zoom meetings that have included all members of the team across the three states and will continue meeting monthly though this spring.
- Theme 4 collaborated across the three states on one conference poster presentation and will collaborate on additional conference proposals in the coming months.
- In a separate collaboration, members of the three-state Theme 4 team brought together an expanded team to propose a longitudinal study of mathematics education in the elementary and middle levels and ways that deeper mathematical reasoning could be developed among

all students, with an emphasis on the rural student populations of the three-state region. This proposal was presented as a white paper in response to a solicitation from the UM Vice President for Research, as a possible high priority for future federal legislative funding.

- Co-PI Weiskittel and Project Senior Personnel Burakowski and Contosta attended the 2019 National EPSCoR Conference hosted by the University of South Carolina

Table 8. Project jargon and acronym dictionary developed to facilitate team members' understanding of key cross-theme concepts that will help to minimize barriers to collaboration.

Theme	Word/Acronym	Definition
ALL	Model	A conceptual representation of reality that can be used to understand potential relationships
1	NEON	National Ecological Observatory Network
1	Dendrometers	Equipment used to continuously monitor tree trunk swelling/shrinking to assess growth
1	respiration	Biological release of carbon dioxide
1	AMC	Appalachian Mountain Club
2	ontologies	Set of concepts and categories in a subject area or domain that shows their properties and the relations between them.
2	TEK	Traditional Ecological Knowledge, use of non-Western knowledge to understand, explain, and forecast ecological phenomena
2	UAV	Unmanned aerial vehicle
2	G-LiHT	NASA's Goddard LiDAR, Hyperspectral, and Thermal Imaging sensor;
2	LAI	leaf area index
2	FIA	US Forest Service, Forest Inventory & Analysis
2	AI/ML	Artificial Intelligence/Machine Learning
2	SfM	Structure for Motion
2	ICESat	NASA's Ice, Cloud, and land Elevation Satellite
2	GEDI	Global Ecosystem Dynamics Investigation (GEDI) High resolution laser ranging of Earth's forests and topography from the International Space Station (ISS)
3	LANDIS	A landscape-scale forest ecosystem model for simulating fundamental ecological processes
3	FVS	Forest Vegetation Simulator
3	PnET	Photosynthetic / EvapoTranspiration is a nested series of models of carbon, water, and nitrogen dynamics in forest
3	CLM	Community Land Model
3	GMF	Green Mountain National Forest
3	WMF	White Mountain National Forest
3	MODIS	NASA's Moderate Resolution Imaging Spectroradiometer sensor
3	TEM	Terrestrial Ecosystem Model is a process-based ecosystem model that describes carbon, nitrogen and water dynamics of plants and soils for terrestrial ecosystems
3	EFI	Enhanced Forest Inventory
3	NAIP	National Agricultural Imagery Program

DEVELOPMENT/RECRUITMENT OF DIVERSE EARLY CAREER FACULTY

At this early stage of the project, the immediate benefit for workforce development are the project, theme, and institutional cross-collaborations that are enhancing research and analytical skills for early career faculty, with multiple opportunities helping to identify and resolve problems as they arise within themes and projects. Currently, there are 20 early-career with nearly equal representation in gender.

The four research themes are all being led or co-led by early-career faculty with support from senior faculty members, which is helping build to leadership and organizational skills. Conference travel, equipment, as well as support of undergraduate and graduate students has been provided to early-career faculty members. As highlighted above, early-career faculty members have successfully submitted inter-jursidictional research proposals with both being submitted to the National Science Foundation and one of them being successfully funded. Currently, the Mentoring, Education, & Engagement (MEE) is working to develop project best practices for better for engaging and supporting INSPIRES early-career faculty members.

DEVELOPMENT/RECRUITMENT OF DIVERSE STUDENTS

Currently, there are 3 undergraduate (2 female, 1 male) and 7 (4 female, 3 male) graduate students across the three institutions that are involved with the project. In particular, there are two undergraduate and one graduate student engaged with the wireless soil moisture development group at the University of Maine, providing valuable real-world computer science experiences and mentoring from senior faculty. As stakeholder engagement continues to expand, undergraduate and graduate students as well as post-doctorate fellows will have opportunities for industry internships and training.

Despite the current pandemic, 2 undergraduate and 5 graduate students have been successfully recruited across each of the institutions for participation in the project for Year 2. PI Weiskittel with Co-PIs D'Amato and Ollinger have welcomed all students on the INSPIRES project and they have all been successfully introduced to the team. Students have been using Slack to communicate across jurisdictions and opportunities have been provided for presenting findings during both all-team and theme virtual meetings. Future meetings will highlight and feature ongoing student research to ensure successful collaboration and development. Guidelines for effective guidelines for student mentors and mentorees has been developed by the Mentoring, Education, & Engagement (MEE). Recruitment for future years will continue to focus on underrepresented groups, particularly women and Native Americans.

LEADERSHIP AND GOVERNANCE

The Core Leadership Team (CLT) as (outlined in Table 2 above) has regularly met to assess project progress, potential issues, and team needs. In fact, within two weeks of receiving the funds, the CLT gathered for a planning meeting with key outcomes that included a shared management structure, development of cross-state and cross-discipline research theme teams, coordination of recruitment and hiring efforts, and began drafting documents for team governance, project communication, and an implementation plan. Year 1 efforts focused on the selection of research sites, a complex matter given the subject of this project, and recruitment of diverse post-doctoral associates and PhD students. Recruitment efforts, although launched in the fall, were not successful in most cases until late spring: the timing of the award after the beginning of the academic year proved to be a factor.

As outlined in our original proposal and our current governance document, an additional key project element will the formation of several important committees including an External Advisory Board (EAB), a Tri-Jurisdictional Institutional Advisory Board (IAB), and two project committees, namely Collaborative Research Committee (CRC) and Mentoring, Education, & Engagement (MEE) Committee. The EAB will include expertise from a range of disciplines and institutional contexts across jurisdictions and will: (1) help INSPIRES achieve its research and education goals and outcomes; (2) respond to NSF and AAAS reviews; (3) identify potential jurisdictional barriers to minimize their potential impact on the project; (4) promote the relevance of INSPIRES to industry, NGOs, and other sectors; and (5) assist with sustainability by helping to identify related research opportunities. The IAB will consist of Provosts, Vice-Presidents of Research, and Deans across the three jurisdictions and will address potential institutional barriers to collaboration and align resources to help sustain as well as broaden the impacts of INSPIRES. The MEE Committee (led by Co-PI D'Amato) will help foster a culture of shared mentorship and effective advising across the project and lead educational and professional development activities, including offering courses, writing retreats, and field trips to promote cross-project learning and research advancement, and will work closely with the CRC (led by Co-PI Ollinger) to plan quarterly all- team meetings and annual retreats. Using a Science of Team Science approach, the CRC will establish an ongoing research program to study and inform the development of the organization, promote interdisciplinary research efforts, and strengthen relationships with stakeholders.

In Year 1, the CLT discussed these various committees and felt the project was too early in its development to begin forming them, particularly given the focus on building the research theme teams and promotion of inter-jurisdictional collaboration. INSPIRES faculty were asked about the two project committees and willingness to serve on them. In addition, INSPIRES faculty and the CLT have formed a list of potential EAB members and will work on forming that in Year 2 with the completion of the project implementation plan. Likewise, the CLT can now better engage university upper administrators on the IAB with the project implementation plan and PI Weiskittel has now scheduled regularly meetings with the University of Maine's Vice President of Research, who will be the IAB Chair, to discuss next steps and project needs.

PROGRESS ON PROGRAM ELEMENTS

COLLABORATIVE RESEARCH DEVELOPMENT

The INSPIRES project started August 1, 2019 and is a relatively large multi-jurisdictional, multi-disciplinary effort. Over the last nine months, the project has been focused on team building as it is essential to take the time to organize the project effectively to produce optimum, synergistic outcomes over the long-term. In the first few months of this project, the CLT relied on the effective team-building strategies outlined in *Strategies for Team Science Success* (edited by Hall et al., 2019), which resulted in the incorporation of various integrative practices such as in-person/virtual team meetings, use of cloud-based collaborative tools (e.g., Slack and Box [Figures 16 & 17]), and regular electronic team updates. In addition, key online documents and resources to help foster team collaboration have been created, including a team website (Figure 18), shared project calendar (Figure 19), project jargon or acronym dictionary (*see* Table 8), and summary of project resources.

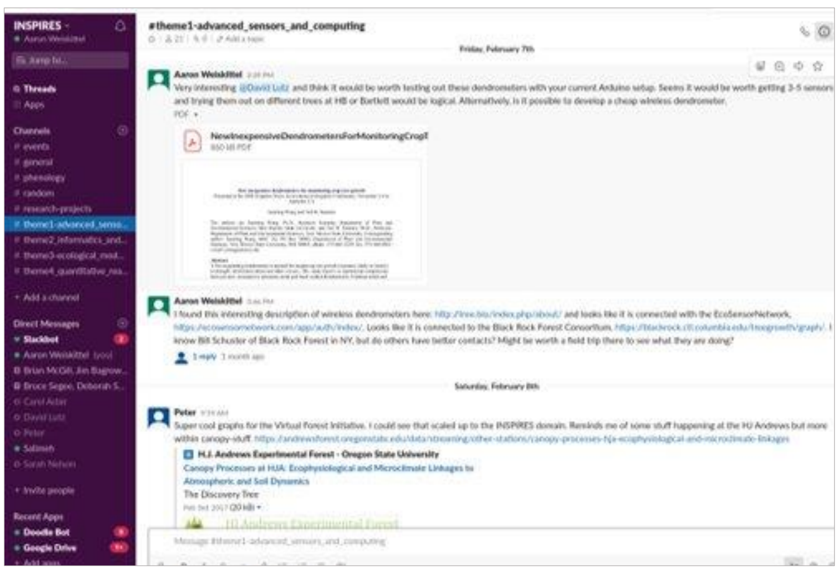


Figure 16. INSPIRES Slack Channel that is used for project updates, research theme communications, and document sharing.

A primary focus during Year 1 has been on the completion of a project implementation plan (Appendix 2) and initiation of research efforts. Team building has been ongoing with numerous virtual and in-person meetings by the CLT, individual research themes, and within individual jurisdictions. For example, quarterly all-team meetings where project and research theme updates are provided and discussed; individual research theme meetings to explore team member research interests, complete strategic materials, and outline key research milestones by project year; and

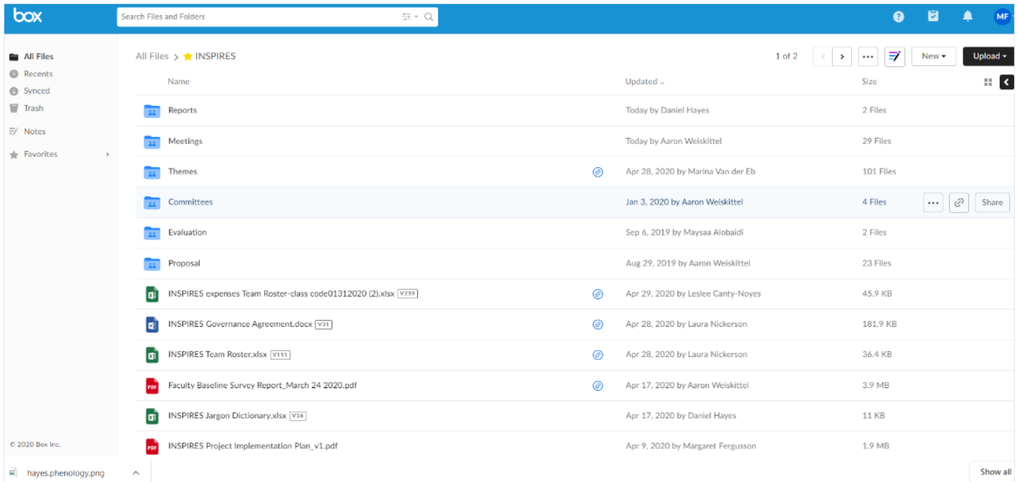


Figure 17. INSPIRES Box folder used for online collaboration of shared documents for the project and research themes as well as repository for project outputs like presentations, publications, and team rosters.

intra-jurisdiction meetings to help build team relationships and identify key linkages as INSPIRES brings together a diverse set of disciplines such as engineering, computer science, ecology, biometrics, ecosystem modeling, and STEM education.

The **project implementation plan** was developed over several months with team input to provide the necessary structure, governance, strategic assessment, and plans for research, communications, and evaluation. The plan strategically assesses our current conceptual framework for the project and maps a path forward that leverages existing synergies, available resources, and the team's expertise. The project implementation plan will be regularly revisited to ensure successful project progress, intra-jurisdictional collaboration, and stakeholder engagement. The **governance agreement**, within the implementation plan, is intended to build a cohesive team with mutual respect and trust. It sets forth guidelines for roles and responsibilities, conflict resolution, data sharing, authorship of publications, and mentoring. Each team member is expected to annually review and digitally sign this document.

In developing the project implementation plan, the CLT and research themes each completed key strategic materials including logic models, Strengths, Weaknesses, Opportunities and Threat (SWOT) assessments, and stakeholder matrices. In addition, research milestone maps were developed by theme, which will be used for the basis of project evaluation and reporting. This is a living document that serves as a roadmap for project execution and management, and provides each INSPIRES team member with a comprehensive summary of important project information to help guide their work. This document will also serve as an overall orientation package for our project's advisory boards and other key external stakeholders. Going forward, our project implementation plan will be used by research theme leads, the INSPIRES CLT, and our external evaluators to assess progress against our initial motivating project goals and objectives. Finally, we hope this plan will provide the necessary baseline, structure, and overall framework for effective project reporting.

Project implementation started with the CLT organizing a kick-off meeting and inviting all members of the project team to participate. The meeting was held virtually in early September 2019. The meeting successfully introduced the effort to ensure participants' understanding of the project's vision and objectives, brought participants from different institutions and departments together, and began the project team building process. Of the 29 survey participants in the January external survey (see Appendix 3), the vast majority (72.4%) indicated that they participated in the kick-off meeting. In December 2019, INSPIRES held a two-day in-person meeting that was well attended (despite a snowstorm impeding travel) by team members and the project's external evaluators. As highlighted in the meeting agenda (Figure 20), the meeting provided an opportunity for project participants to get to know each other, share their ideas and collective expertise to inform the development of specific, collaborative objectives and implementation plans for each of the project's four themes, and to set expectations across the entire project team in terms of roles and responsibilities and key milestones. A total of 25 respondents in the external survey (86.2%) indicated that they participated in the all-team meeting. The meeting was strategically structured to learn from past NSF Track 2 projects, external evaluation, project reporting, open data standards, and team science. Team interactions were maximized by various icebreakers and breakout sessions.

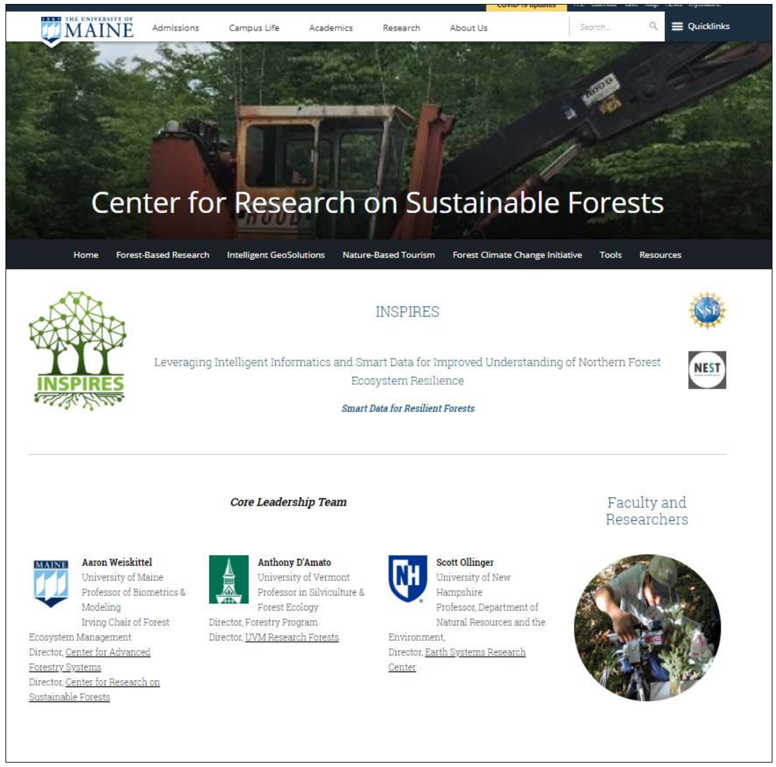


Figure 18. *INSPIRES Team Website (**https://crsf.umaine.edu/inspires/**).*

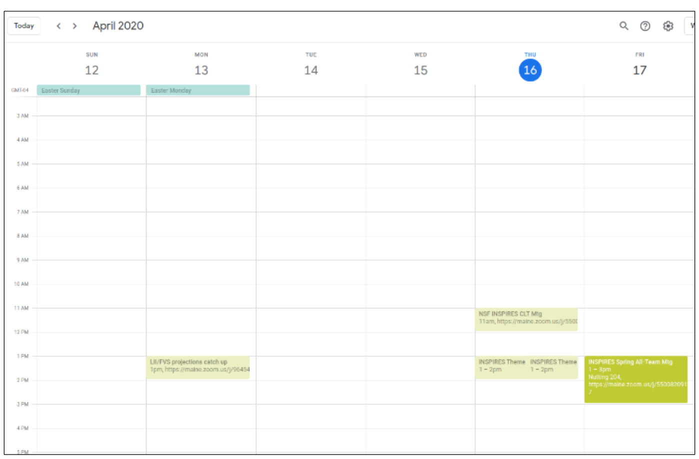


Figure 19. *INSPIRES Team Calendar that highlights project events, details, and team member participation to help promote cross-theme and inter-jurisdictional collaboration.*

INSPIRES All-Team Meeting
December 18-19, 2019
Hilton Garden Inn
100 High St
Portsmouth, NH 03801

Time	Item	Lead Person
Wednesday December 18, 2019		
7:30 - 8:30 AM	Continental Breakfast	-
8:30 - 9:00 AM	Welcome, Introductions, and Overview	Aaron Weiskittel
9:00 - 9:30 AM	UM, UNH, and UVM Overview	Aaron Weiskittel, Scott Ollinger, Tony D'Amato
9:30 - 10:30 AM	Team Introductions	All
10:30 – 11:00 AM	Break	-
11:00 – 12:00 PM	Lessons Learned from Prior NSF Track 2 Projects	Kevin Gardner, Michelle Gregoire (UNH)
12:00 – 1:00 PM	Lunch	-
1:00 – 1:15 PM	Data Management & Distribution	Mary Martin (UNH)
1:15 – 1:30 PM	Project Data Outcomes Portal Overview & Discussion	Michelle Gregoire (UNH)
1:30 – 1:45 PM	Governance Overview & Discussion	Aaron Weiskittel
1:45 PM – 2:30 PM	Evaluation Overview & Discussion	Heather McInnis, Maysaa Alobaidi (AAAS)
2:30 – 3:00 PM	Break	-
3:00 – 5:00 PM	Research Theme Breakouts (Logic Model, Research Milestones, and SWOT Analysis)	All
5:00 – 5:30 PM	Theme Report Out and Wrap-Up	All
5:30 PM	Adjourn	-
6:00 PM	Group Dinner	-
Thursday, December 19, 2019		
7:30 - 8:30 AM	Continental Breakfast	-
8:30 – 9:00 AM	Outcomes and Overview; Next Steps and Implementation	Aaron Weiskittel
9:00 – 10:00 AM	Table Discussion (e.g. Research Questions, Publications, Data Needs, Potential Scenarios, Key Ecosystem Metrics)	All
10:00 – 11:00 AM	Table Discussion (e.g. Research Questions, Publications, Data Needs, Potential Scenarios, Key Ecosystem Metrics)	All
11:00 – 12:00 PM	Open Discussion and Next Steps	All
12:00 – 1:00 PM	Lunch	-
1:00 PM	Adjourn	-

Figure 20*. Agenda for the two-day INSPIRES All-Team Meeting in Portsmouth, NH in December 2019.*

The external survey conducted by AAAS in early 2020 had 42 questions for faculty INSPIRES team members covering participant background, project implementation, research collaborations, research productivity, mentoring, professional development, external stakeholder engagement, and anticipated project impacts. The survey was completed by 38 INSPIRES faculty for a response rate of 76% and equal representation across the three jurisdictions. The vast majority of participants (75-82%) have a clear understanding of the project, its goals and priorities, their involvement, and current project communication (Figure 23).

Finally, two surveys of INSPIRES team members were conducted to better understand the team, its desired outcomes for the project, and to build a baseline for future assessments. The first survey was an informal team poll conducted internally by the CLT, while the second was an external and formal assessment conducted by AAAS (Appendix 3). The informal survey had 33 respondents and primarily focused on desired outcomes, potential barriers, and specific research interests. Respondents primarily defined success by "increased collaboration," "key outcomes," and improved relationships with "colleagues" (*see* Figures 21 & 22). Highest priorities for INSPIRES were conducting novel research (44%), improved research capacity and infrastructure (25%), and regional collaboration (16%) (Figure 22). In addition, a team motto of "Smart Data for Resilient Forests" was voted on and adopted.

Figure 21. *Word cloud based on 33 respondents' definition of success at the end of INSPIRES research effort.*

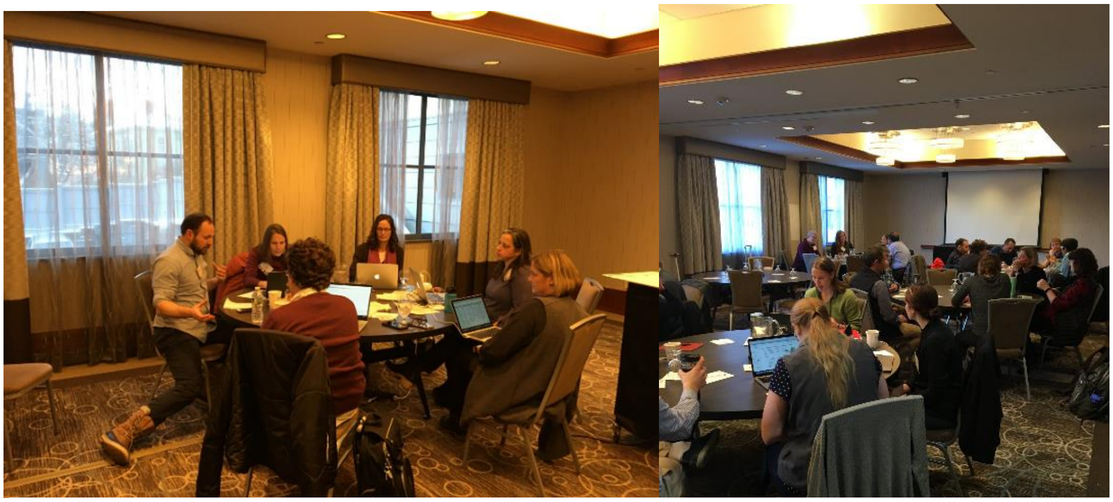


Photo 3. Images from the INSPIRES All-Team Meeting in Portsmouth, NH in December 2019. The meeting included talks and team interactive breakout sessions. *(Photos courtesy CRSF.)*

The primary limitation for INSPIRES project implementation team members was time constraints (62.1%), followed by funding (34.5%) and access to critical infrastructure (10.3%). In terms of prior collaborations, the survey findings indicated that a research collaboration network among members of the project team already existed prior to INSPIRES. These pre-existing connections offer opportunities to strengthen relationships around shared interests and-long term goals, and thus, may enhance coordinated efforts to achieve the goals of the INSPIRES project. In addition, responses indicated that involvement in the INSPIRES project enabled early-career researchers to establish connections (higher average number of connections compared to prior and current non-INSPIRES networks and compared to established investigators). Insufficient time and high workload were cited by approximately two thirds of the survey participants as the main reason they did not pursue professional development opportunities in the previous year, which the CLT will work to address in the coming years of the project.

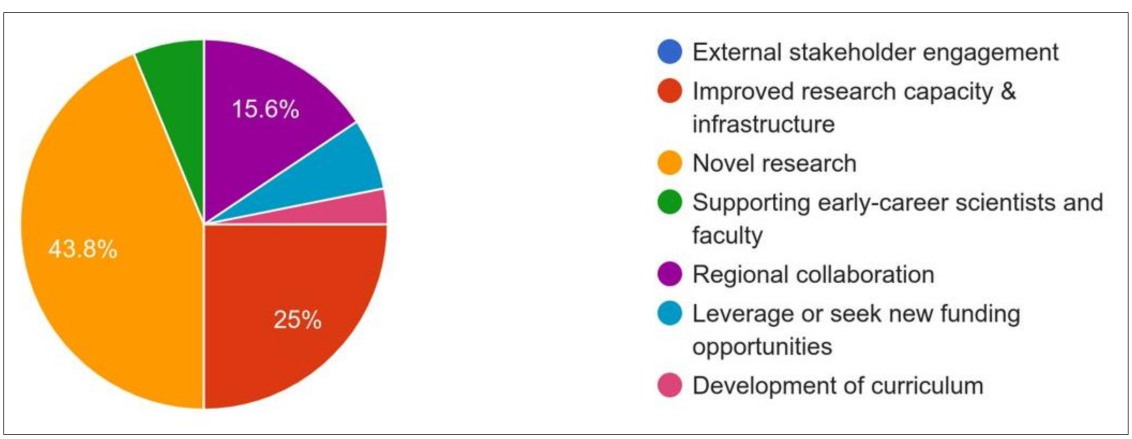


Figure 22. *Pie chart of INSPIRES team member's highest priorities for the effort.*

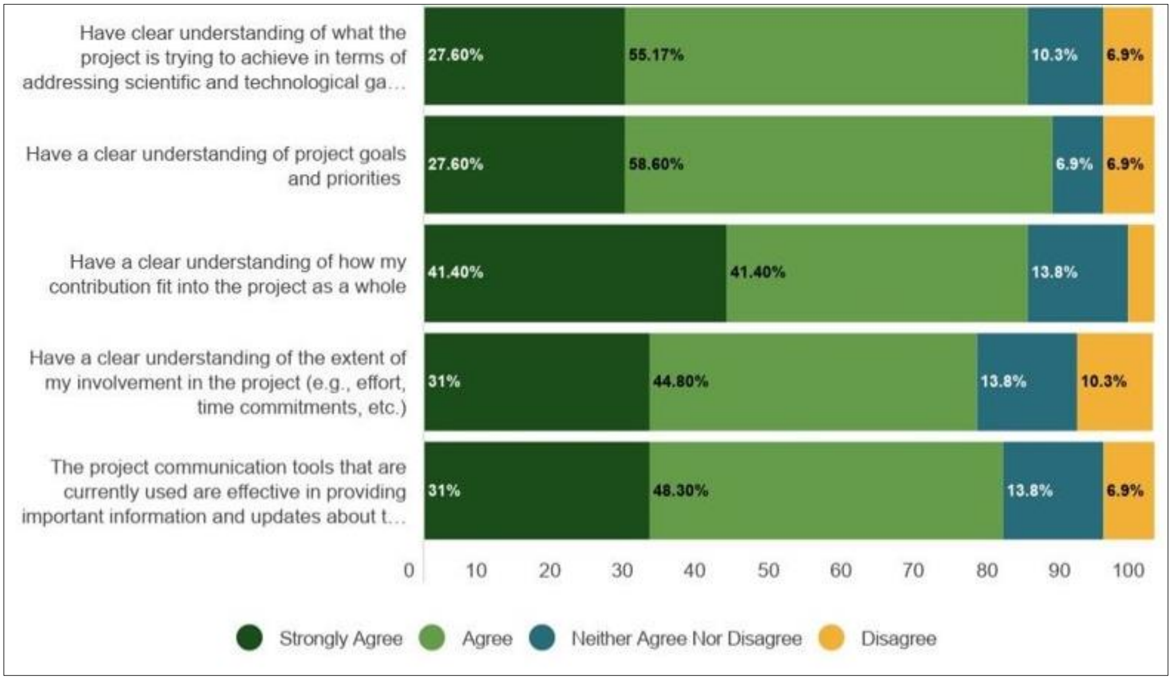


Figure 23. *Summary of 38 INSPIRES faculty from an external survey on project engagement and internal communication strategy.*

INTELLECTUAL MERIT

As highlighted in the project's Data Outcome Portal's snapshot, the INSPIRES effort has already resulted in a number of outcomes with high intellectual merit. This has included 9 submitted proposals (4 to NSF), 4 proposals funded (2 from NSF), 3 publications, and 15 presentations. The funded proposals have included a NSF Industry-University Collaborative Research Center Phase 3 proposal led by PI Weiskittel, which will help to connect INSPIRES research to key national forest industry stakeholders. In addition, early-career Senior Personnel Simons-Legaard (University of Maine) had a USDA AFRI grant funded, and has developed and submitted (pending) a NSF Dynamics of Integrated Socio-Environmental Systems (CNH2) proposal with early-career Senior Personnel Foster (University of Vermont). Both proposals directly relate to INSPIRES Theme 3 efforts as they support model refinement for simulating and forecasting forest response to disturbance, particularly defoliation by spruce budworm. University of Vermont Senior Personnel Classen and Adair received a Gund Institute Catalyst award to develop methods for low cost and high frequency quantification of soil nutrients in ecosystems undergoing rapid global change, which is directly related to INSPIRES Theme 1 and 2 activities. Future proposals are currently in development by several team members, including submissions to NSF's Platforms for Advanced Wireless Research (PAWR), Convergence Accelerator (C-Accel), and Signals in the Soil (SitS) as well as planned submissions to Wildlife Conservation Service's Climate Adaptation Fund, the Nature Conservancy's Natural Climate Solutions Accelerator Grant Program, and USDA AFRI. These efforts will help to leverage and strengthen current INSPIRES activities and collaborations.

In terms of publications and presentations, significant INSPIRES outcomes have been achieved in the first 9 months of the project. This has included three peer-reviewed publications from the University of New Hampshire with Co-PI Ollinger working with a graduate student and various early-career faculty to finalize several analyses related to key elements of INSPIRES such as remote sensing, carbon cycling monitoring, and ecosystem modeling. The publications were in top-tier peer-reviewed journals *Global Change Biology* (Impact Factor = 8.88), *Remote Sensing* (Impact Factor = 4.11), and *Ecosystems* (Impact Factor = 4.55). The University of Maine also published an article in *Remote Sensing* (Impact Factor = 4.11) with two early-career faculty as articles leads. Finally, the University of Vermont has a forthcoming publication in the *Canadian Journal of Forest Research* (Impact Factor = 1.81), which will help guide ongoing INSPIRES efforts. Future publications have been discussed at both INSPIRES theme and all-team meetings, which will be an important focus in Years 2 and 3 of the project. Presentations were given at a range of events including national conferences, invited seminars, and local meetings. A number of the presentations (11) were given by INSPIRES post-doctorate fellows and early-career faculty. These were at national conferences like the American Geophysical Union Fall Meeting and Information Theory and Application (ITA20) as well as local events like Maine's Forest Climate Change Initiative Forest Science meeting, Wabanaki Tribal Economic Conference, and the Forest Ecosystem Monitoring Cooperative Annual Meeting. As noted in the AAAS baseline assessment, INSPIRES CLT has prioritized aiding early-career faculty by encouraging and supporting their participation in national conferences, which is reflected in the number of presentations in Year 1 of the project. This support will remain a priority in future years of the project.

Overall, these early intellectual merit outcomes highlight the level and strength of current collaborations within INSPIRES. Like the submitted NSF CNH2 proposal, emphasis will continue to be placed on inter-jurisdictional outcomes, particularly publications. In addition, continued support and professional development of early-career faculty members will remain a high priority. Specifically, key synthesis products that assess current state of knowledge and outline strategies for future research will be prioritize in Years 2 and 3 of the project.

BROADER IMPACTS

As outlined in the project's implementation plan and the AAAS baseline survey (see Appendices 2-3), broader impacts and effective engagement with stakeholders is a high priority for INSPIRES.

In Year 1, particular focus was placed on connecting INSPIRES research with relevant regional stakeholders including forest managers from a variety of agencies (e.g., federal, state, non-profit, private), technological companies, and middle as well as high school teachers. These impacts are highlighted in the findings from the external INSPIRES faculty survey as the majority of respondents (69-76%) felt that INSPIRES would significantly influence both local and regional forest policies as well as benefit G6-12 students. In Year 1, many themes have already engaged with a broad array of local, regional, and national stakeholders (Figure 24). These interactions include input on sensor

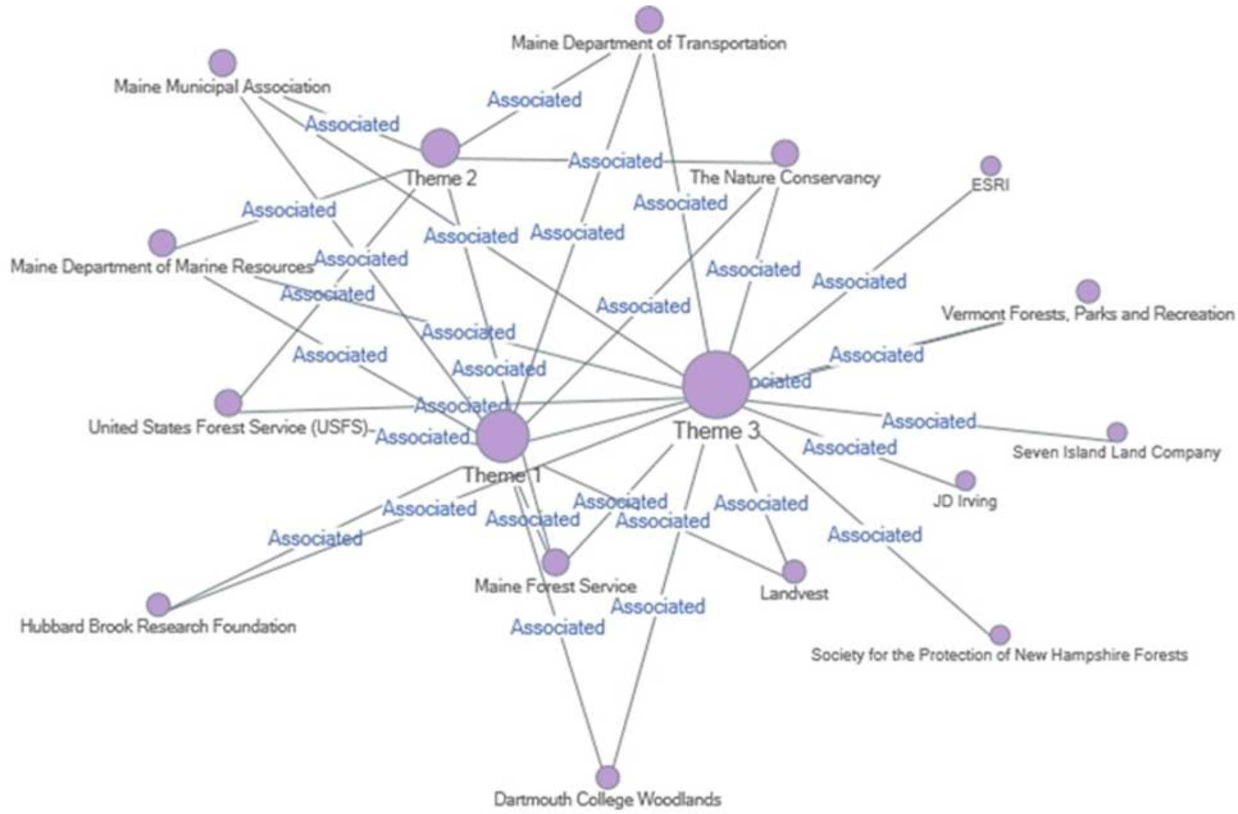


Figure 24. *Network analysis of INSPIRES research theme connections to external stakeholders based on 29 faculty respondents.*

monitoring needs and site selection, gaining access to key data or study locations, deploying key technology, and understanding current STEM curricular needs. Additionally, Theme 2's ontological representation and modeling impacts Theme 4, with initial discussions showing real promise of collaboration with the Wabanaki Youth Science Programs (WaYS). Early career researcher Sam Roy is building on pre-existing connections to The Nature Conservancy and The Maine Municipal Association, while also working directly on economic development opportunities provided by the Northern Borders Regional Commission.

Broader impacts related to INSPIRES have included a meeting of Themes 2 and 3 PIs from University of Vermont with collaborators from Appalachian Mountain Club (AMC), USDA Forest Service Northern Research Station, and Forest Ecosystem Monitoring Cooperative to discuss leveraging multi-temporal satellite, inventory, climate, and pollution data to document regional spruce-fir dynamics (December 17, 2019). This collaboration included extended partnerships and discussions with Vermont Forests, Parks and Recreation, the USDA Forest Service Northern Research Station, and Dartmouth College Woodlands to secure access to research sites for sensor deployment, generate input on key research questions, and develop collaborative relationships around the main INSPIRES themes to serve future years of the project. Collaboration with AMC has helped raise the profile of the Maine Woods Initiative (MWI), a relatively new, yet spatially extensive, land base that is partially a Maine Ecological Reserve and partly sustainably managed for timber harvest and restoration following earlier harvests. Finally, INSPIRES Co-PI D'Amato led a field tour for foresters from Vermont Forests, Parks and Recreation and managers from Dartmouth College Woodlands of an INSPIRES extensive sensor site at Dartmouth College's Second College Grant, NH on September 26, 2019. Foresters were introduced to the application of soil moisture and deadwood sensor arrays to document climate change impacts on fuel moisture dynamics and forest microenvironmental conditions (Photo 4).

As outlined in the INSPIRES evaluation plan, annual stakeholder surveys will assess the nature and outcomes of these partnerships (e.g., co-creation and/or utilization of research products) as well as the extent of alignment of project goals with external stakeholders' goals. Eventually, the goal is to assess which stakeholder partnerships are most successful in terms of producing strategic value that extends beyond the project. Given the importance of the forests to the region, this effective engagement of key stakeholders and focus on project broader impacts will remain a high priority for INSPIRES.

Photo 4. Field tour of an INSPIRES extensive sensor site at Dartmouth College's Second College Grant, NH led by INSPIRES Co-PI D'Amato and foresters from Vermont Forests, Parks and Recreation and managers from Dartmouth College Woodlands on September 26, 2019. (*Photo courtesy A. D'Amato*).

FUTURE PLANS

Although the current global pandemic has created significant unforeseen and difficult to manage challenges for the INSPIRES project, the team remains engaged and has continued to make significant strides as outlined in this Year 1 Progress Report. A quarterly all-team meeting held on April 17, 2019 was very well attended with lots of project updates and general discussion, which have been highlighted in this report. Despite some setbacks and significant challenges, the project remains largely on track and various next steps have been well identified by each of the research themes.

Year 2 will continue to build off of the current momentum from Year 1 and work to capitalize on the project's detailed implementation plan. Key Year 2 project plans and milestones will include:

- Continuation of regular CLT and research theme meetings with quarterly all-team meetings and an annual project retreat scheduled for December 2020
- Develop additional survey instruments to collect data from other project constituencies (e.g., undergraduate students and external stakeholders)
- Implement annual surveys of the INSPIRES team and assess project progress
- Conduct a formative strategic assessment site visit by a team of external experts organized by the project's external evaluator
- Form and implement the project's External Advisory Board (EAB), a Tri-Jurisdictional Institutional Advisory Board (IAB), and two project committees, namely Collaborative Research Committee (CRC) and Mentoring, Education, & Engagement (MEE) Committee
- Develop and regularly update project social media and communication materials such as a regular e-newsletter for project participants and external stakeholders
- Re-assess key project materials such as the governance agreement, project implementation plan, and project acronym/jargon dictionary
- Organize and conduct an INSPIRES field trip to visit a research site, build team relations, and continue refinement of research objectives
- Continue project team recruitment with focus on undergraduate and graduate students, post-doctorate fellows, and early-career faculty members
- Conduct key stakeholder outreach events such as teacher workshops, site visits, and technical sessions
- Organize and conduct a short graduate student training session on a key project focal area that helps to build collaborations across themes and jurisdictions
- Refine mentoring and student participation guidelines based on solicited feedback from project participants
- Develop a project mentoring strategy for early career faculty
- Determine and implement individual develop plans for project participants

SIGNIFICANT PROBLEMS

Since March 2020, a significant challenge and ongoing struggle for the INSPIRES team is the current global pandemic caused by COVID-19. This has caused numerous challenges for INSPIRES efforts, including heightened workloads resulting from the need to shift all university courses to an online format, imposed travel restrictions, rapid changes in university hiring as well as spending policies, significant challenges to faculty home-work equilibrium resulting from K-12 school closures, communication challenges among and across themes that have become more challenging under quarantine conditions, and high uncertainty for future planning given the rather dynamic nature of the situation. This has dramatically shifted planned priorities, particularly for the summer field season, and has reduced time available for research activities and reporting due to challenges with balancing professional (e.g., sudden transition to virtual teaching) and personal (e.g., care of ill family, school and daycare closures) requirements, as well as impacts related to stress from current economic and political fractures. For colleagues with children at home/out of school, COVID-19 has already had an effect on productivity in terms of publications and other metrics, particularly for women scientists (e.g., https://www.insidehighered.com/news/2020/04/21/early-journal-submission-data-suggest-covid-19-tanking-womens-research-productivity).

In addition, universities in Maine, New Hampshire, and Vermont have taken different policies to travel, spending, and campus (e.g., not allowed to work on campus or in labs) activities, but the constraining effects have nearly been the same across the three jurisdictions involved with INSPIRES. Overall, this situation has greatly limited access to university resources such as labs, computational resources, and other critical infrastructure needed for the INSPIRES project, which have significantly delayed planned research activities for the spring and summer. Also, spending and hiring restrictions imposed by the universities have limited project expenditures, particularly with respect to travel and necessary equipment purchases. It is still unclear when these policies will be lifted, which makes current contingency planning efforts quite challenging.

The current situation is highly unprecedented and a significant challenge for the project, yet progress continues to be made and INSPIRES team members have adapted. Virtual meetings continue to take the place of in-person ones, while recruitment efforts for INSPIRES undergraduate and graduate students are ongoing. Team members continue to make progress working at home. A variety of contingency plans are being developed and will help to be responsive to changing guidance for the planned summer field season. This has included modified travel plans, shifting focus of activities to the fall of 2020, and delaying planned activities for Year 1 to summer of 2021. This primarily affects Theme 1 where priority is shifting to sensor development rather than deployment, while Themes 2 and 3 will now work to inform sensor deployment opportunities. In addition, Theme 4 has shifted in-person teacher interviews planned for this spring to the fall. Efforts will continue to be made to increase project communication and coordination across teams as well as jurisdictions and maintain high flexibility for planned activities.

At the University of Maine, the computational infrastructure and support is currently being strategically assessed by an external review committee. This has created significant disruptions to the level of availability and support for the computational infrastructure that will be eventually needed by this project. The situation should be resolved by the early fall and may require using more of the computational infrastructure at University of New Hampshire and University of Vermont. Nevertheless, the existing and new collaborations established and the general governance and planning structure developed by INSPIRES over the first nine months have created a research culture and infrastructure that will ensure project success, despite these unprecedented changes in work and personal situations.

NOVEL OPPORTUNITIES

As noted in the external assessment survey, INSPIRES team members are have begun to explore novel outreach opportunities presented by the project, with average engagement of 1 to 5 key stakeholders currently. Of particular note being explored by the CLT is forming a partnership with Planetary Emissions Management Inc. (https://pemcarbon.com/), who are pursuing new and emerging technologies for high precision determination of 14CO2 in a portable analyzer. This high frequency and high precision data for $^{14}CO_2$ are required to track, analyze, manage, and monetize fossil fuel derived CO_2 in the biosphere. This potential partnership was explored after Planetary Emissions Management Inc.'s CEO, Founder and Chairman, Dr. Bruno Marino, contacted PI Weiskittel after seeing a press release on the project. PI Weiskittel and the CLT have had additional follow-up conversations with Planetary Emissions Management Inc.'s team. One possibility is to couple Planetary Emissions Management Inc.'s current technology with sensors being developed by INSPIRES Theme 1 at the intensive field sites. The Planetary Emissions Management Inc.'s iRIS-III sensor is a unique, high precision instrument that would leverage INSPIRES efforts and provide novel research opportunities as an in-kind contribution. The potential benefits of this partnership continue to be explored and assessed, particularly in light of the current uncertainty around the planned summer 2020 field season. Regardless, the ongoing discussions with Planetary Emissions Management Inc. have been productive, insightful, and highlight novel opportunities for INSPRIES despite the early stages of the project.

Another opportunity in development is leveraging INSPIRES' efforts to support the forest industry. PI Weiskittel currently oversees and directs NSF's Center for Advanced Forestry Systems (CAFS), which is an industry-university collaborative research center (IUCRC) that began its 5-year Phase 3 in December 2019. This IUCRC involves 6 other universities nationwide involving over 200 unique forest industry members, which provides an ideal window into forest industry research needs, particularly in New England with strong regional representation in CAFS. For example, current remote sensing research being conducted by INSPIRES Theme 2 will be presented at the annual CAF Industry Advisory Board meeting in June, which should help extend that research to other regions and build additional collaborations that will ultimately help benefit that effort.

Finally, a key INSPIRES Senior Personnel member, Sarah Nelson, has taken a new role as Science Director at the Appalachian Mountain Club (AMC), which is an important conservation NGO in New England that manages nearly 30,000 acres of forest in the region. This novel partnership has allowed INSPIRES to connect with other important conservation NGOs in the region as well as consider potential research strategies that leverage AMC's current ownership, which covers a rather unique ecological gradient in Maine. The multi-state team working on the Wildlife Conservation Society proposal are likely to continue working on the changing winters theme. There are opportunities in Maine and beyond to link with K-12 curricula, including connecting Theme 4 members with MWI's education team, which has an active climate change curriculum.

CHANGES IN STRATEGY

As outlined above, the ongoing global pandemic caused by COVID-19 has significantly disrupted planned activities and timelines for INSPIRES. Although the long-term impacts of this pandemic remain uncertain, the CLT and research themes continue to maintain open dialogs and have outlined a variety of contingency plans. This will likely remain the case for the foreseeable future as the pandemic continues evolve and alter the situation. The CLT has also maintained an open dialog with the external evaluator (AAAS) and modified timelines accordingly. This has led to the delay of the planned summer external site visit, which will now likely occur in the late fall or early winter of 2020 depending on future travel restrictions and policies.

At the April 17, 2020, INSPIRES all-team meeting COVID-19 was openly discussed and many team members shared their efforts to remain highly engaged with project activities, but also expressed uncertainty about actual implications on their role and potential contributions. The CLT along with research theme leads will continue to monitor the situation closely, stay available and responsive to team member concerns, and remain highly adaptable. Although the pandemic will not likely alter long-term intended project activity and desired outcomes, it will definitely delay and modify Year 1 and 2 timelines in an unplanned and difficult to predict manner.

EVALUATION

OVERVIEW

The American Association for the Advancement of Science (AAAS) Research Competitiveness Program (RCP) serves as the external evaluator for the INSPIRES project. The AAAS RCP uses a hybrid approach that combines data-driven evaluation with peer-to-peer strategic assessment and guidance to provide the project with information to monitor progress toward goals and objectives, assess the effectiveness of implementing project activities, and provide an external perspective and actionable guidance to maximize impacts.

In Year 1 of the project, AAAS RCP worked with the INSPIRES project leadership to design and launch a comprehensive evaluation plan and logic model, introduced the evaluation strategy to project participants in the first All-team Meeting held in December 2019, and collected and analyzed data to establish a baseline for measuring project progress and impacts (see pages 19-27 of the Project Implementation Plan). The formative strategic assessment site visit planned for May 2020 has been postponed due to the COVID-19 pandemic.

Informed by the project logic model, the evaluation plan outlined specific evaluation questions, the indicators to be tracked for each group of project participants, and approaches to data collection, analysis, reporting, and dissemination (Appendix 2). Two survey instruments were developed to collect baseline information about project participants (faculty and non-faculty researchers, as well as graduate students), which will be used as a reference against which to measure progress over the course of the project. The surveys were launched in January 2020. The data collected include demographics, prior and current collaborations, research productivity, and participant perceptions about project roles and implementation. The AAAS RCP evaluator’s analysis of the data and a summary of key findings was shared with the project leadership in March 2020 (Appendix 3).

OUTCOMES

The INSPIRES Faculty and Researchers Baseline Survey data show a diverse project team with balanced representation in terms of gender, career stage, disciplines, and institutions across the three participating jurisdictions. The data also illustrate that the project’s early engagement and internal communication strategies were effective in promoting a common understanding of project goals and priorities among participants and of how their contributions fit into the project. Among the concerns expressed by survey participants were that time constraints and funding limitations might affect the feasibility of project implementation. These data indicate that project participants may benefit from additional refinement of team goals, structured mentorship or training to support development of feasible milestones and sub-project timelines, and supporting early career faculty as they seek external funding related to INSPIRES. Using data from the survey, baseline reference levels were established for different indicators of research productivity, including the number and quality of publications, as well as for indicators of mentoring and professional development activities. These indicators supplement the data entered into the EPSCoR RII Track-2 Data Outcomes Portal (T-2 DOP). The baseline survey results also show that a collaboration network among project participants existed prior to INSPIRES.

Further, data from the baseline survey showed that a number of INSPIRES faculty and researchers have engaged in project-related collaborations or partnerships with several external stakeholder groups from federal and state government agencies, academia, industry, and non-profit organizations. The annual surveys will measure the benefits of leveraging existing networks, and monitor access to new collaborations, information, and resources to determine the extent to which the INSPIRES project has leveraged and expanded existing relationships to develop new capacity.

NEXT STEPS

During the remainder of Year 1 and into Year 2, additional survey instruments will be developed to collect data from other project constituencies (e.g., undergraduate students and external stakeholders). The evaluator will also implement the annual surveys, develop analytical reports to inform project implementation, and design a database that integrates annual survey data across different years for each project participant group. The formative strategic assessment site visit is tentatively rescheduled for December 2020. To prepare for the site visit, the AAAS RCP strategic assessment lead will collaborate with the project leadership to select and recruit three external experts to serve on the peer review panel, outline the specific assessment goals in a charge to the Panel, and draft a detailed site visit agenda, and orient the AAAS experts to the site visit and assessment process.

EXPENDITURES AND UNOBLIGATED FUNDS

YEAR 1 FINANCIAL PLAN

Although Year 1 of the project has been busy and has resulted in many successes, impacts of the COVID-19 epidemic caused us to shift effort in some places and reduce activities in others. As a result, spending of Year 1 funds was reduced to 78% of planned expenditures. Details and a plan for the future are outlined below.

Funding for the first two years of this award (8/1/2019-7/31/2021) was officially received and capable of being spent at the University of Maine in mid-September 2019, while the subawards with University of New Hampshire and University of Vermont were established by November and December 2019, respectively. Within two weeks of receiving the funds, the PI and co-PIs gathered for a planning meeting; key outcomes from that meeting include a shared management structure, development of cross-state and cross-discipline research teams (research themes), coordination of recruitment and hiring efforts, and drafting of core documents for team governance and communication. In addition, a strategic project implementation plan was developed and is a primary outcome from Year 1. Our Year 1 efforts primarily focused on recruitment of staff, graduate students and postdoctoral researchers, team building, defining core research objectives, and the selection of extensive as well as intensive research sites.

Total expenditures for Year 1 were $1,164,057.92 or 77.6% of the total allocation, which is below the 80% threshold (Table 9). Personnel costs and tuition comprised the majority of the proposal budget. Recruitment efforts that launched in the fall were not successful in some cases until late spring, and then delayed further by hiring freezes resulting from complications caused by the global coronavirus pandemic. Recruitment of graduate students was also complicated by the timing of the award start date, which occurred after the beginning of the academic year. However, as of August 2020, all planned hires are now complete.

In-person quarterly all-team meetings were held in 2019 (September & December), and were held virtually in 2020 (April & July), which significantly reduced travel expenditures in Year 1. Although the multi-disciplinary, cross-jurisdictional research theme working groups have been quite active, state and institutional restrictions related to the coronavirus forced us to curtail much of the field work planned for the 2020 summer season. We have been able to conduct some work at local field sites and existing personnel have been able to shift effort towards modeling and data-related activities, but the overall effect has caused an additional reduction in Year 1 expenditures. Furthermore, safety issues around the pandemic caused an all-team field tour planned for early June to be delayed indefinitely, and the Year 1 external evaluator team site visit originally scheduled for June 2020 has had to be postponed. We initially rescheduled the external site visit to occur concurrently with a planned December all-team in-person retreat, but at the time of this reporting it seems likely that any such meetings will need to be virtual due to the ongoing pandemic. Despite these challenges and high uncertainty caused by the pandemic, the Year 1 annual progress report to NSF was filed on May 5, 2020, which highlights the project's many accomplishments as well as its forward trajectory.

Several graduate students, post-docs, and professional staff assumed their positions during the summer of 2020. Consequently, we propose to distribute the Year 1 surplus to support additional research personnel (Table 10) in Year 2. The University of New Hampshire plans to add partial support for an additional PhD student and postdoctoral researcher who will focus on data assimilation, modeling, and tree physiology measurements. Other planned uses for the surplus include increased support for open-access peer-reviewed publications, support to develop data portals for this project, and website design. Additionally, adjustments are being made for travel, supplies, and other budget categories to complete the interrupted field work season. The University of Maine plans to use surplus funds to provide additional support for more research faculty members, an additional graduate student, and increased funding for field work, as well as for stakeholder meetings and workshops. Analogously, due to the lockdown of state and regional travel resulting from the pandemic, Year 1 funds planned for the external evaluator team site visit have been been reallocated to Year 2. The University of Vermont plans to distribute surplus to supplement faculty salary, add a post-doctoral associate, increase support for graduate students, and provide additional support for research supplies and communication.

Table 9. Total project spending and allocation in Year 1 by university and overall by specific NSF budget categories.

Item	Spent	Allocated	Variance	% Variance
University of Maine (Project Lead)				
Salary	$163,602.66	$185,083.00	$21,480.34	88.39%
Fringe Benefits	$46,799.12	$34,359.00	$12,440.12	136.21%
Travel	$15,813.54	$11,000.00	$4,813.54	143.76%
Materials and Supplies	$11,441.30	$12,502.00	$1,060.70	91.52%
Professional Services	$56,130.00	$70,498.00	$14,368.00	79.62%
Computer Services	$-	$5,000.00	$5,000.00	0.00%
Other costs	$9,140.00	$27,206.00	$18,066.00	33.60%
Indirect	$135,206.24	$175,006.00	$39,799.76	77.26%
Total	$438,132.86	$529,129.00	$90,996.14	82.80%
University of New Hampshire				
Salary	$156,920.09	$217,915.00	$60,994.91	72.01%
Fringe Benefits	$43,523.39	$50,807.00	$7,283.61	85.66%
Travel	$747.91	$13,050.00	$12,302.09	5.73%
Materials and Supplies	$7,215.54	$11,077.00	$3,861.46	65.14%
Professional Services	$-	$-	$-	0.00%

Item	Spent	Allocated	Variance	% Variance
Computer Services	$-	$2,200.00	$2,200.00	0.00%
Other costs	$6,381.00	$33,309.00	$26,928.00	19.16%
Indirect	$105,245.50	$149,000.00	$43,754.50	70.63%
Total	$320,033.43	$477,358.00	$157,324.57	67.04%
University of Vermont				
Salary	$182,116.91	$208,879.00	$26,762.09	87.00%
Fringe Benefits	$66,377.05	$71,829.00	$5,451.95	92.00%
Travel	$14,039.17	$16,000.00	$1,960.83	88.00%
Materials and Supplies	$7,808.16	$8,542.00	$733.84	91.00%
Professional Services	$-	$-	$-	0.00%
Computer Services	$-	$4,060.00	$4,060.00	0.00%
Other costs	$-	$33,280.00	$33,280.00	0.00%
Indirect	$135,550.34	$156,309.00	$20,758.66	87.00%
Total	$405,891.63	$493,426.00	$87,534.37	82.00%
Overall Project				
Salary	$502,639.66	$611,877.00	$109,237.34	82.15%
Fringe Benefits	$156,699.56	$156,995.00	$25,175.68	99.81%
Travel	$30,600.62	$40,050.00	$19,076.46	76.41%
Materials and Supplies	$26,465.00	$32,121.00	$5,656.00	82.39%
Professional Services	$56,130.00	$70,498.00	$14,368.00	79.62%
Computer Services	$-	$11,260.00	$11,260.00	0.00%
Other costs	$15,521.00	$93,795.00	$78,274.00	16.55%
Indirect	$376,002.08	$480,315.00	$104,312.92	78.28%
Total	$1,164,057.92	$1,499,913.00	$335,855.08	77.61%

Table 10. Proposed reallocation of Year 1 projects funds by university and the overall project.

Item	UM	UNH	UVM	Total
Salary	$33,978.76	$77,140.02	$39,275.23	$150,394.01
Fringe Benefits	$9,719.74	$21,395.57	$14,314.84	$45,430.16
Travel	$3,284.33	$367.66	$3,027.68	$6,679.67
Materials and Supplies	$2,376.25	$3,547.07	$1,683.90	$7,607.23
Professional Services	$11,657.68	$-	$-	$11,657.68
Computer Services	$-	$-	$-	$-
Other costs	$1,898.29	$3,136.82	$-	$5,035.12
Indirect	$28,081.08	$51,737.42	$29,232.71	$109,051.21
Total	$90,996.14	$157,324.57	$87,534.37	$335,855.08

APPENDICES

1. PRODUCTS

Journal or Juried Conference Papers (8; 4 published; 1 in press; and 3 under review)

Ganesh, M.V., Corso, J.J., and Sekeh, S.Y. (2020) MINT: Deep network compression via mutual information-based neuron trimming. https://arxiv.org/pdf/2003.08472.pdf. Submitted.

Hastings, J.H. and Ollinger, S.V., Ouimette, A.P., Sanders-DeMott, R.W., Palace, M.J., Ducey, M.B., Sullivan, F.A., Basler, D., & Orwig, D. (2020). Tree species traits determine the success of LiDAR-based crown mapping in a mixed temperate forest. Remote Sensing, 12: 309.

Legaard, K., E. Simons-Legaard & A. Weiskittel. (2020). Multi-objective optimization of support vector machines reduces systematic error in moderate resolution maps of tree species abundance. Remote Sensing 12: 1739.

Ouimette, A.P., Ollinger, S.V., Lepine, L.C., Stephens, R.B., Rowe, R.J., Vadeboncoeur, M.A., Tumber-Davila, S.J., & Hobbie, E.A. (2019). Accounting for carbon flux to mycorrhizal fungi may resolve discrepancies in forest carbon budgets. Ecosystems, 1432-9840. 10.1007/s10021-019-00440-3

Roy, S.G., Daignault, A., Zydlewski, J., Truhlar, A., Smith, S.M., Jain, S., & Hart, D. (2020). Coordinated river infrastructure decisions enhance social-ecological resilience. Environmental Research Letters. Under review.

Sanders-DeMott, R., Ouimette, A.P., Lepine, L.C., Fogarty, S.Z., Burakowski, E.A., Contosta, A.R., & Ollinger, S.V. (2019). Divergent carbon cycle response of forest and grass-dominated northern temperate ecosystems to record winter warming. Global Change Biology, 1354-1013. 10.1111/gcb.14850.

Simons-Legaard, E., Legaard, K., & Weiskittel, A. (2020). Landscape dynamics and the shifting state of the northern Acadian Forest. Landscape Ecology. Under Review

Woodall, C.W., Evans, D.M., Fraver, S., Green, M.B., Lutz, D.A., & D'Amato, A.W. (2020). Real-time monitoring of dead wood moisture in forests: Lessons learned from an intensive case study. Canadian Journal of Forest Research. In press.

Conference Presentation/Papers (17)

Byerssmall, E., Millay, L., Peterson, F., McKay, S.R., Pandiscio, E., Rockwell, H., Stetzer, M., Zoellick, B. (2019). Recruiting, preparing, and retaining STEM teachers in rural, high-need schools: Developing a model of support for new teachers through an NSF Fellowship Program. Association for Science Teacher Education Annual Conference. Burlington, VT.

D'Amato, A. (2019). Co-designing forestry studies to address adaptation science needs. Forest Ecosystem Monitoring Cooperative Annual Meeting. Burlington, VT.

D'Amato, A. (2020). New England adaptive silviculture for climate change: Dartmouth's Second College Grant. Society for the Protection of New Hampshire's Forests Meeting.

Foster, J. (2019). Monitoring trends in forest composition and productivity from space, field data, landscape models. Adaptive Silviculture for Climate Change Annual Meeting.

Foster, J. (2019). Unexpected expansion of montane tree species under climate change: The puzzling case of red spruce in the eastern US. Departmental Seminar: Department of Biology, Bryn Mawr College.

Foster, J. (2020). Unexpected expansion of montane tree species under climate change: The puzzling case of red spruce in the eastern US. Departmental Seminar: School of Environmental and Biological Sciences, Rutgers University

Hahmann, Torsten (2019). Integration of symbolic and statistical AI for environmental informatics. Department of Computer Science faculty seminar, University of Maine.

Millay, L., McKay, S.R., Peterson, F., Lindsay, S., Nickerson, L., Toolin, R. (2020). Connecting middle and high school teachers with big data and quantitative reasoning in the context of New England forests. Maine Environmental Education Association (MEEA) Annual Conference and Research Symposium. Belfast, Maine.

Ollinger, S. (2020). Understanding the role of forests in the Earth’s climate system. Climate and forest management workshop, Society for the Protection of New Hampshire Forests.

Ouimette, A. (2019). Does diversity in species specific leaf traits and resource use promote stability of forest ecosystem carbon and water fluxes? American Geophysical Union Fall Meeting.

Roy, S. (2020). Learning from dams: A multi-university case study on training the next generation of sustainability researchers. Maine Sustainability and Water Conference. Abstract accepted, meeting postponed due to COVID-19.

Roy, S. (2020). Partnerships for resilient river infrastructure and ecology: Watershed coordination of dam and culvert management decisions in Maine. Maine Sustainability and Water Conference. Abstract accepted, meeting postponed due to COVID-19.

Sanders-Demott, R. (2019). Asynchronous responses of carbon uptake and carbon loss to antecedent winter conditions in northern temperate ecosystems. American Geophysical Union Fall Meeting.

Simons-Legaard, E. (2019). Climate and Maine's changing forest. Maine Society of American Foresters.

Simons-Legaard, E. (2020). Climate and Maine's changing forest. Forest Climate Change Initiative's Forest Science Stakeholder Workshop. Orono, ME.

Simons-Legaard, E. (2020). Projecting Maine's future forest. Wabanaki Summit. Orono, ME.

Yasaei Sekeh, S. (2020). Efficient Memory-usage Techniques in Deep Neural Networks. Information theory and Application (ITA20).

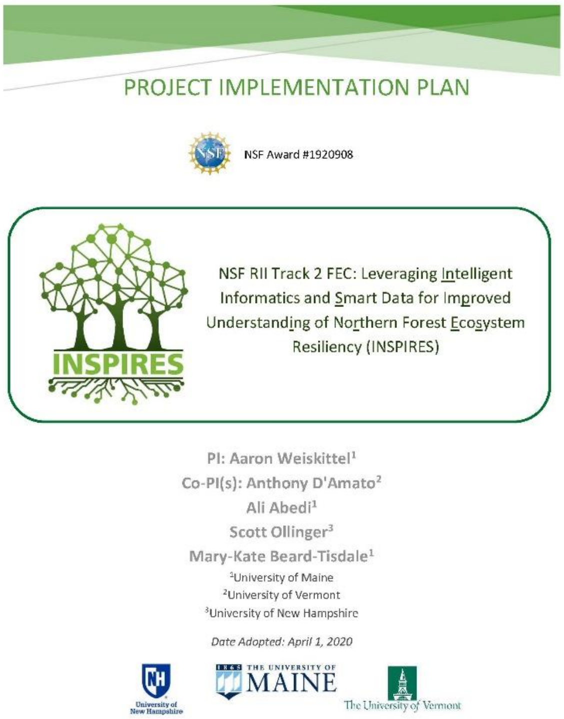
Other Publications (1)

McKay, S., McCormick, K., Nickerson, L., Pandiscio, E., Peterson, F., & Toolin, R. (2019). Northeast integrated mathematics partnership to benefit all preK-8 learners. Report to University of Maine Vice President of Research.

Website (1)

Maine ForEST (Forest Ecosystem Status and Trends) App. https://forestapp.acg.maine.edu/

2. PROJECT IMPLEMENTATION PLAN



PROJECT IMPLEMENTATION PLAN

NSF Award #1920908

NSF RII Track 2 FEC: Leveraging Intelligent Informatics and Smart Data for Improved Understanding of Northern Forest Ecosystem Resiliency (INSPIRES)

PI: Aaron Weiskittel[1]
Co-PI(s): Anthony D'Amato[2]
Ali Abedi[1]
Scott Ollinger[3]
Mary-Kate Beard-Tisdale[1]
[1]University of Maine
[2]University of Vermont
[3]University of New Hampshire

Date Adopted: April 1, 2020

EXECUTIVE SUMMARY

This document presents a comprehensive and strategic vision as well as outline for the National Science Foundation's RII Track 2 FEC: **Leveraging Intelligent Informatics and Smart Data for** Improved Understanding of Northern Forest Ecosystem Resiliency (INSPIRES). The document was collaboratively conceived, drafted, and refined by our research team. This will be a living document that will serve as a roadmap for project execution and management, but will also provide each INSPIRES team member with a comprehensive summary of important project information to help guide their work. This document will also serve as an overall orientation **package for our project's advisory boards and other key external stakeholders identified in this** document. In particular, our project implementation plan will be used by research theme leads, the INSPIRES Core Leadership Team, and our external evaluators to assess progress against our initial motivating project goals and objectives. Finally, we hope this will provide a baseline, structure, and overall framework for effective project reporting.

The organization and purpose of the document is to strategically assess our current conceptual framework for the project and map a path forward that leverages existing synergies, available **resources, and the team's expertise. We will regularly revisit this document and encourage** existing as well as new team members to do the same. Based on team input and consensus, we have structured the document to provide specific project items like purpose, organizational structure, evaluation, and key milestones, while allow the specific research themes to provide necessary details on logic maps, SWOT analyses, stakeholder matrices, and research objective maps.

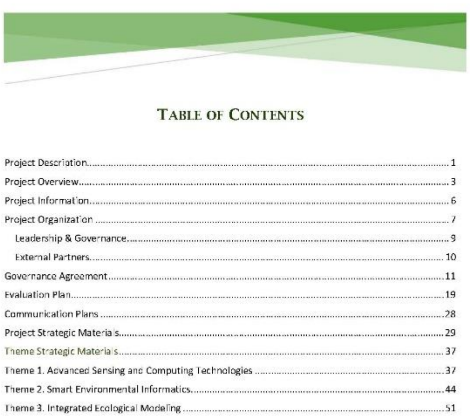
We look forward to implementing and refining this current plan to help ensure the success and future sustainability of this effort. As always, input and feedback on the plan are welcomed and encouraged.

Sincerely,
INSPIRES Core Leadership Team

Aaron Weiskittel, PI
University of Maine

Scott Ollinger, Co-PI
University of New Hampshire

Anthony D'Amato, Co-PI
University of Vermont



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PROJECT DESCRIPTION

NONTECHNICAL DESCRIPTION

Forests are an economically important and ecologically critical component of **New England's working landscape that provide numerous benefits to society. New England's forests are also highly** dynamic and diverse due to a wide variety of complex factors including changing conditions, management, and natural disturbances. This project will leverage unique expertise from the University of Maine, University of New Hampshire, and University of Vermont to construct a digital framework to better assess, understand, and forecast this complex forest at a resolution relevant to scientists, land managers, and policymakers. This will be accomplished by integrating emerging computational, monitoring, remote sensing, and visualization technologies that will provide a more holistic and near real-time quantification of the forest at broad spatial and temporal scales. In addition, increased educational and outreach on forests and the necessary data needed to effectively manage them will be a key focus of the **project's efforts. The project will include a broad array of disciplines including data science,** ecology, and engineering such as electrical, computer, and communications. The digital Big Data framework developed from this effort would be applicable to other forested regions and ecosystems. Most importantly, the effort will help support and sustain this unique forested landscape, which many rural communities rely on for their livelihoods.

TECHNICAL DESCRIPTION

Forests in New England represent the Northern Forest ecotone, which is a complex assemblage of transitional ecosystems that have a unique history of natural disturbance and human land use. In recent decades, societal demands on these forests and the ecosystem services they provide have continued to expand at a time when key stressors such as land use pressures, invasive pests, and extreme abiotic events are significantly on the rise. Maintaining the value and integrity of the Northern Forest for the communities that depend on them requires a better understanding of how these stressors affect this ecosystem and a new digital framework for harnessing Big Data to assess their influence under multiple scenarios of alternative future changes. To address these grand challenges, faculty from the state universities of Maine, New Hampshire, and Vermont are collaborating on the development of a regional Complex Systems Research Consortium that will conduct analyses of forest ecosystem integrity and resilience from multiple scientific perspectives.

Faculty and students will work across four integrated themes to develop a novel and flexible Digital Forest framework for effectively harnessing Big Data to enhance our fundamental understanding of Northern Forest ecosystems across multiple spatio-temporal scales.

Leveraging Intelligent Informatics and Smart Data for Improved Understanding of Northern Forest Ecosystem Resiliency (INSPIRES)

The four themes are:

(1) Advanced Sensing and Computing Technologies;

(2) Environmental Informatics and Analytics;

(3) Integrated Ecological Modeling; and

(4) Quantitative Reasoning in Context.

Project participants will explore how to integrate the traditional ecological knowledge (TEK) of Wabanaki tribes and other available qualitative data with the primarily quantitative data typically employed to analyze and model ecosystems. Importantly, the effort will link with ongoing regional efforts to improve K-20 data literacy skills, while generating valuable new approaches for supporting the natural resources–based economies and associated industries. The formation of a regional forest ecosystems research consortium will incorporate, extend, and sustain the strengths of all three EPSCoR jurisdictions that leverages prior and ongoing efforts.

Project Overview

Maine (ME), New Hampshire (NH), and Vermont (VT) encompass major parts of the complex and highly interconnected Northern Forest Region (NFR), which has a long history of ecological integrity and service to rural communities. The economies and identities of local communities strongly depend on the health of these forests (>$15 billion in annual economic contributions and over 140,000 direct employees), but the forest is increasingly threatened by complex and dynamically interacting stressors.

For example, NFR has some of the highest densities of non-native forest pests in the US, linked to changes in both climate and human behavior. In addition, NFR is a transitional ecotone; changing climatic conditions create significant stress as most species are at either their northern or southern limit. This stress has become even more evident as precipitation events have become more extreme and snowpack has become less continuous as well as more variable, which has significant implications for trees as well as the larger ecosystem. Currently, temperatures in NFR are warming much faster than other areas in the contiguous US, and should increase by 3°C by 2030 (alongside the 2°C rise globally). Consequently, our ability to understand and predict the stressors and NFR response is challenged by this complex socio-ecological landscape and highly dynamic regional variability.

One key dimension of NFR variability stems from the historical and current contrasting management patterns across Federal, state, and private land ownership, which spans large industrial forests to small, single-owner woodlots, along with tribal and conservation lands. Heterogeneous, uncoordinated ownerships and mixed-management patterns have resulted in an inconsistent availability of critical forest data.

A second dimension of variability relates to the highly varied collection of forest-related information that ranges from national-scale coverages, including remote sensing satellite images and derived outputs (e.g., Landsat, Sentinel, MODIS), inventory plots, and other available products like soils, topography, and land use/cover data to finer-scale regional and local information, such as experimental forest, research woodlot, and citizen science data collections. This patchy availability of ecological data is known to confound systematic assessment of other ecosystems, particularly when elevation gradients are involved.

A third dimension of variability is the NFR's position as a transitional ecosystem; for instance, the region ranges from 43-47° latitude and 68-73° longitude, with an elevation gradient from sea-level to elevations over 2500 m. In this project, we **aim to harness the region's complex landscape** and digital information diversity through the creation of a Digital Forest resource, which is our

Big Data Science approach to integrating contrasting forest information, ownership, management units, and underl**ying ecology into a "natural laboratory" that can be used to** support hypothesis formulation and testing across the various social-ecological dimensions that comprise the highly complex NFR. Our Digital Forest framework and approach extends beyond current methods for assessing and projecting forest conditions, which are generally hindered by inefficient linkages between ecological models and driving data, limited flexibility to work across spatial-temporal scales, gaps in spatial and temporal data coverage, and poor capacity for quantifying and managing uncertainty, particularly with respect to belowground processes. Our efforts address the following overarching science questions:

1. How are spatio-temporal variation and uncertainty in NFR forest extent, composition, health, and productivity driven by: (a) climate; (b) land use; (c) forest management; (d) regulatory policies; (e) invasive insects; (f) other biotic stressors like invasive plants; and (g) natural disturbances?
2. How will these changes affect ecosystem integrity and key services related to: (a) carbon storage/fiber production; (b) habitat/biodiversity; and (c) water quality/surface energy regulation?

Our overarching hypothesis is that novel Big Data acquisition, integration, and analysis will allow us to address these questions in a way that informs how we approach challenges and opportunities related to the current and future integrity of forest ecosystems. To address these goals, the University of Maine System (UMS; [UM, USM, UMFK, UMPI]) has partnered with the University of New Hampshire (UNH) and the University of Vermont (UVM) to advance our fundamental knowledge regarding forest ecosystem resilience and productivity by taking a new convergent approach to analyzing contrasting current and future ecosystem integrity values (fiber/carbon, biodiversity/habitat, and water/energy). Collaboration across the three jurisdictions will also build quantitative reasoning in context skills (QRC) for G6-12 students who will contribute to and use the project**'s research.**

Our interdisciplinary effort is organized across four integrated themes that will contribute to an innovative and flexible framework for harnessing Big Data across multiple spatio-temporal scales. Early career faculty will lead each theme, supported by senior mentors. Each theme will include researchers and/or students from all three jurisdictions, as well as personnel cross-over to ensure **sustainability and convergent approaches to problem solving. INSPIRES' four integrated themes** are: (1) Advanced Sensing and Computing; (2) Environmental Informatics and Analytics; (3) Integrated Ecological Modeling; and (4) QRC (Figure 1).

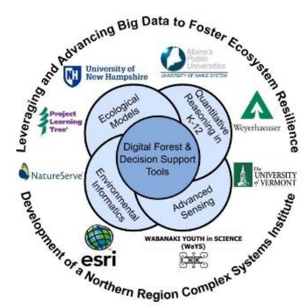


Figure 1. INSPIRES Digital Forest Research and Workforce Development Framework

The traditional ecological knowledge (TEK) of the Wabanaki tribes will support each theme and advance our ability to use Big Data to analyze and model ecosystems. In addition, machine learning (ML) will help us to integrate and analyze Big Data across all themes of our Digital Forest framework. For example, we will use multi-objective ML algorithms to identify alternative wireless sensor network designs with efficient spatial coverage that minimize material use and cost. Sensor data also inform our definition of the spatio-temporal semantics of different forest places and events. Consequently, we will develop these semantics using the proven classification and regression capacities of supervised ML algorithms. Semantic classifications and abstraction trees are the basis for spatio-temporally explicit inverse parameterizations used to initialize the integrated ecological models that estimate forest health and productivity. Further, these models provide uncertainty estimates to help ensure future wireless sensor network designs will provide suitable coverage and improved semantic classifications. These models of productivity and quality can then be used in multi-objective ML algorithms to help decision makers identify management practices that lead to efficient and desirable outcomes for the various ecosystem integration metrics. Each theme relies on high-performance, cloud-based data processing and storage.

PROJECT INFORMATION

Project #: 1920908

Project Duration: 4 years

Project Dates: 8/1/19 to 7/31/23

Program Manager: Ann Stapleton

Project Citation: Weiskittel, A., Abedi, A., Beard-**Tisdale, K., D'Amato, A., Ollinger, S., Adair**, E., Bagrow, J., Burakowski, E., Classen, A., Contosta, A., Ducey, M., Foster, J., Gunn, J., Hahmann, T., Hayes, D., Simons-Legaard, E., Legaard, K., Lindsay, S., Martin, M., McGill, B., McKay, S., Millay, L., Nelson, P., Nelson, S., Nittel, S., Nickerson, L., Peterson, F., Petrik, M., Rizzo, D., Ranco, D., Roy, S., Segee, B., Shulman, D., and Toolin, R. 2019. RII Track-2 FEC: Leveraging Intelligent Informatics and Smart Data for Improved Understanding of Northern Forest Ecosystem Resiliency (INSPIRES). NSF EPSCoR Track 2. $6,000,000.

Project Logo:

Project Website: https://crsf.umaine.edu/inspires

Project Shared Communications: Slack Channel (to add new members use this link)

Collaborative Document/File Sharing: Project Box Folder

Resource Links for Team Members

- Project Calendar
- Project Team Roster
- Project Governance Document
- Project Annual Report Form
- Project Outcome Reporting Portal
- Anonymous Feedback Form

PROJECT ORGANIZATION

The proposed research projects, which extend across the four integrated themes, will be convergent in nature, engaging senior and early career faculty from diverse fields (including education, electrical/computer engineering, forestry, computer science, ecology, ecological modeling, statistics, remote sensing, data science, and anthropology; Table 1). Each theme will be cross-jurisdictional with early career faculty leads, senior faculty mentors, and supporting members that include postdoctoral researchers, graduate and undergraduate students, and staff. In addition to collaborations with UNH and UVM, this project involves 4 of the 6 campuses that comprise UMS. **The inclusion of these smaller campuses is important to Maine's research infrastructure, and will** help to mitigate the isolation that can impact early career faculty in rural areas and/or institutions that primarily serve undergraduates. These smaller campuses also often function as a conduit to remote areas and rural communities where faculty and citizens can interact with the results of this project.

INSPIRES is structured to encourage the three jurisdictions to share best practices and address potential deficiencies in a way that strengthens complex systems work in all three states and creates greater strength overall in terms of research and education that is relevant for the region. **All jurisdictions have strengths that can be linked to the region's natural resource base and rural** nature, while each jurisdiction brings key strengths to the project that will benefit the other jurisdictions. UMS strengths include deep and historic relationships with the forest industry and related organizations through an existing NSF I/UCRC led by PI Weiskittel, long-term forest research sites, state-wide relationships with teachers through the Maine Center for Research in STEM Education (RiSE), work with underrepresented in STEM students and teachers through two INCLUDES projects and other endeavors like the recent NRT in conservation science, expertise in TEK and working with Native American communities, deep spatial informatics expertise (National Center for Geographic Information and Analysis), and strong collaborations between scientists and 4-H personnel for STEM outreach. UNH strengths include both undergraduate and graduate-level Analytics and Data Science programs as well as an existing Earth Systems Research Center (ESRC) and a recently developed statewide terrestrial and aquatic sensor network (EPS-1101245). UVM strengths include a Complex Systems Center with associated undergraduate- and graduate-level degrees in Complex Systems and Data Science, as well as expertise in developing sensor networks and managing Big Data over time to examine complex socio-ecological questions, such as the interactive effects of climate change and land use on the Lake Champlain basin, as a result of past EPSCoR funding (OIA-1556770).

The complementary areas of strength across ME, NH, and VT, results of past EPSCoR investments, and the proposed efforts in INSPIRES create an ideal foundation for a regional Complex Systems

Research Institute. As outlined in the letter co-signed by university leaders from the three jurisdictions, this institute will promote the sharing of expertise and best practices, facilitate co-advising of graduate students, encourage collaborative proposals, and continuously identify emergent long-term research topics of interest to the region.

Table 1. Key Faculty by INSPIRES Project Theme

Research Theme	Personnel
1. Advanced Sensing & Computing	**Theme Leads**: Bundy* (UMA), Contosta* (UNH, F), Adair* (UVM, F); **Senior Mentors**: Abedi (UM), Segee (UM), Classen (UVM, F); **Team Members**: Lutz* (DC)
2. Smart Environmental Informatics	**Theme Leads**: P. Nelson* (UMFK), Hahmann* (UM), Petrik* (UNH); **Senior Mentors**: Beard (UM, F), Rizzo (UVM, F), Nittel (UM, F); **Team Members**: Ranco (UM), Legaard* (UM), McGill (UM), Roy* (UM) Martin (UNH, F), Sekeh* (UM, F)
3. Integrated Ecological Modeling	**Theme Leads**: Hayes* (UM), Foster* (UVM, F), Burakowski* (UNH, F); **Senior Mentors**: Weiskittel (UM) Ollinger (UNH), D'Amato (UVM) ; **Team Members**: Simons-Legaard* (UM, F), Gunn* (UNH), Zhou (UNH)
4. Quantitative Reasoning Skills in Context	**Theme Leads**: Peterson* (UM, F), Shulman* (UM,F); **Senior Mentors**: McKay (UM, F) ; Toolin (UVM, F); **Team Members**: S. Nelson (UM, F), Lindsay (UM, F), Nickerson (UNH,F), Millay (UM, F)
*= Junior Faculty; F = Female; UM = University of Maine; UMA = University of Maine at Augusta; UMFK = University of Maine at Fort Kent; UNH = University of New Hampshire; UVM = University of Vermont. **In addition to faculty, each theme will include a joint post-doc, as well as graduate and undergraduate students.**	

LEADERSHIP & GOVERNANCE

INSPIRES will benefit from a management structure that promotes effective leadership and governance, intentional learning and evaluation, and research integration. Complex organizations working across multiple disciplinary and institutional boundaries require a management structure that allows for clear and diverse forms of leadership and builds learning, evaluation, and information processes so the organization has a way to track its own progress and adjust when needed. A multi-tiered organization will be developed with a Core Leadership Team (CLT) consisting of EPSCoR representatives, Co-PIs, and at least one leader from each theme, which will encourage the senior faculty to mentor a number of the junior faculty who are the theme leads. The CLT will meet bi-weekly to evaluate progress, discuss barriers/ opportunities, and implement changes. The CLT also will steward policies and procedures across the three jurisdictions, oversee funding allocations, and revise plans across the teams as needed to meet the research objectives, approaches, and outcomes. Although the CLT has a greater share of oversight responsibility, this team will encourage diverse and shared leadership, with a focus on enhancing the experiences of the early career faculty.

Studies of organizations as complex systems have demonstrated the need to create an organizational culture where people feel invested in taking on leadership roles and advancing project goals together. A key element of this approach will be the development of an adaptive governance agreement that everyone will contribute to and sign. This guidance document will describe the shared principles and commitments of the project and set the expectations for important norms related to codes of conduct, team decision making, collaborative writing, **conflict resolution, data sharing, and other important "co**-productive capacit**ies". Theme Leaders,** supported by their Senior Mentors, will coordinate research teams, organize regular team **meetings, and communicate the CLT's recommendations. Every Theme team will include** representation from each jurisdiction and will have at least two members from each of the other themes to promote broader integration. Quarterly all-team meetings and one multi-day yearly retreat will reinforce cross-theme and project team collaboration. Regular research seminars and workshops will encourage interacti**ons among all project participants. PI Weiskittel's research** center (Center for Research on Sustainable Forests; CRSF) will provide technical assistance, including support for travel planning/booking, grant writing, data sharing, video conferencing, collaborative space, and online hosting.

INSPIRES CLT will work closely with an external evaluator (AAAS Research Competitiveness Service (RCS)), an External Advisory Board (EAB), and a Tri-Jurisdictional Institutional Advisory Board (IAB) to ensure high quality program delivery. The EAB will include expertise from a range of disciplines and institutional contexts across jurisdictions and will: (1) help INSPIRES achieve its research and education goals and outcomes; (2) assist INSPIRES in preparing for and responding to NSF and AAAS reviews; (3) identify potential jurisdictional barriers to minimize their potential impact on the project; (4) promote the relevance of INSPIRES to industry, NGOs, and other sectors; and (5) assist with sustainability by helping to identify related research opportunities. The EAB will meet bi-annually with the CLT to provide support and to help the organization update and advance research objectives. The IAB will consist of Provosts, Vice-Presidents of Research, and Deans across the three jurisdictions and will address potential institutional barriers to collaboration and align resources to help sustain as well as broaden the impacts of INSPIRES.

Two additional standing committees will foster intentional learning and evaluation and research integration, namely: (1) Mentoring, Education, and Engagement (MEE) Committee and (2) Collaborative Research Committee (CRC). The MEE Committee (led by Co-PI **D'Amato) will foster** a culture of shared mentorship and effective advising across the project and lead educational and professional development activities, including offering courses, writing retreats, and field trips to promote cross-project learning and research advancement, and will work closely with the CRC (led by Co-PI Ollinger) to plan monthly all-team meetings and annual retreats. Using a Science of Team Science approach, the CRC will establish an ongoing research program to study and inform the development of the organization, promote interdisciplinary research efforts, and strengthen relationships with stakeholders. These committees will meet regularly and present important activities/findings to the CLT quarterly. In addition to this tiered organizational structure, we will create a communication system for internal and external communications with various audiences that will include the extensive and tailored use of cyber data infrastructure and campus-based public relations resources working closely with the EPSCoR offices at each jurisdiction.

External Partners

INSPIRES will build valuable synergies across a variety of institutions as well as industry/community partners (see Supplemental Documents). This will include forest landowners (e.g., US Forest Service, Weyerhaeuser), geospatial technology companies (e.g., ESRI), and state agencies and nonprofit organizations (e.g., NatureServe). PI Weiskittel is ideally prepared to foster these relationships as a result of his experience with an existing NSF-funded IUCRC (CAFS) **as well as his leadership of UM's CRSF. Other project personnel hav**e complementary experience fostering relationships with K-12 educators and students, government agencies (the National Park Service), private forest landowners, and other sectors. This includes strong linkages with regional efforts focused on developing actionable science for addressing climate change impacts on forests through Co-PI **D'Amato's leadership roles with the Northeast Climate Adaptation** Science Center and Northeast Silviculture Institute for Foresters.

Governance Agreement

Opening Statement

This governance agreement sets out shared principles to guide the work and relationships of faculty, staff, and students participating in the INSPIRES program. This is a living document intended to evolve as the program grows. This governance agreement serves as guidance to team members, as individuals and as a **collective whole, and to prompt conversations about the program's structure, code of conduct,** roles and responsibilities, conflict resolution, data sharing, authorship of publications, and mentoring.

Code of Conduct

By signing on and contributing to this shared enterprise, we have made a commitment to each other and to the dynamic and interdisciplinary work we have proposed. Team members agree to help create an inclusive, multi-disciplinary, and student-focused organization that intends to build capacity for applied forest science at the Universities of Maine, New Hampshire, and Vermont.

From the outset we agree to treat each other, students, colleagues, and community stakeholders with respect; to respect the diverse contributions we will make toward this joint enterprise; to **respect each other's time, including keeping meetings on time and on task, delivering on** deadlines, quickly responding to requests, and sharing the administrative and logistical workload **of the program; and to respect each other's capacity for leadership by offering opportunities for** all team members to take on important roles in the program.

Because of the complexity and interdependence of our proposed research, we commit to regularly communicating with each other and striving to include all team members in our events and activities, as well as working to be as transparent as possible in our communication and governance. As part of that commitment, we agree to make use of our shared communication technologies, including the team folders on Box and e-communications with Slack, to coordinate with each other and keep track of our progress.

We agree to civilly raise concerns and issues with each other before they grow, and to approach members of the Core Leadership Team for assistance as appropriate, while keeping in mind that differences of discipline and opinion are an important and productive facet of interdisciplinary research.

When the need or opportunity arises, we will communicate about our experiences on the program to support and improve our collective work together over time. We remember our stated intention to connect with our partners in state agencies and civic organizations and will

continue to include them in the development of the program as it evolves as well as seek their advice about how to tailor to the program to meet their needs.

Governance Structure

The INSPIRES governance structure is intended to encourage openness and efficiency in the day to day operations of the program. The policies that govern the program are primarily developed **and maintained by the program's Core Leadership Team (CLT) and a Graduate Student** Representative (GSR). The program also includes an External Advisory Board, External Evaluator, and Tri-Jurisdictional Board that have no formal input into the governance structure (Fig 2). The CLT of the project will be those designated as co-PIs and the Program Coordinator. The GSR will be formally appointed by their peers. CLT meetings are to be held on at least a monthly basis, with Co-PIs and the GSR expected to attend. (Note that GSRs may be asked to excuse themselves in cases where sensitive information is being discussed.) Other committees such as the Collaborative Research Committee (CRC) and Mentoring, Education, and Engagement (MEE) are expected to meet on an as-needed basis and provide updates to the CLT. These committees should include at least one faculty PI but can also consist of Cooperating Faculty who have formally committed to participating in the INSPIRES program. All participants are expected to follow the processes presented in this agreement. CRC would serve to ensure cross-theme

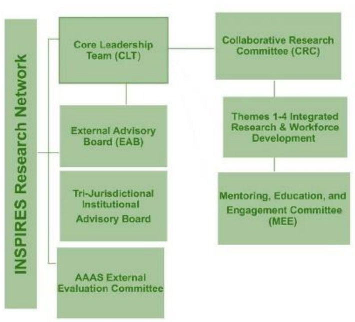


Figure 2. NSF INSPIRES Governance Structure

research collaboration, while MEE would ensure proper practices for mentoring, education, and engagement of students, faculty, and stakeholders are being implemented in INSPIRES.

Team Member Expectations

The INSPIRES program strives to produce a highly collaborative and multi-disciplinary research team. The program values a cordial, professional, and communicative group of faculty and students. We are focused on developing an inclusive and integrated cohort of graduate students collectively working in a variety of disciplines. As a result, all INSPIRES participants (i.e., faculty, students, and staff) are expected to:

- Communicate openly and professionally with internal and external partners.
- Contribute to various sources of communication (e.g., papers, reports, websites, etc.) in a timely manner.
- Attend and participate in all relevant meetings and retreats.
- Attend and participate in program seminars, student defenses, and related research and engagement activities.
- Actively contribute to the teaching, mentoring, and advising components of the program. This includes serving on student committees and adhering to formal mentoring plans developed by the Mentoring, Retention and Engagement Committee.
- Actively seek research funding associated with the transdisciplinary research programs specific to the INSPIRES program.
- Assist with graduate student recruitment.
- Complete all relevant IRB and IACUC training requirements and obtain necessary approvals for research programs (e.g., with human subjects)
- Provide timely information for annual NSF reports and program evaluation.
- Participate in program assessment and reflection exercises.
- Acknowledge funding support: All research products, including papers, presentations, posters, websites and other intellectual materials produced under the grant, must include this statement:
    - ***"Support was provided by a National Science Foundation award (#1920908)."***
    - Logos for INSPIRES and NSF can be found on the program Box Folder.

All faculty who are members of the CLT are also expected to actively participate in program design and implementation, including mentoring faculty and other personnel related to the program. The program PI and Co-PIs are also expected to chair individual committees and take a lead on NSF reporting and other faculty administrative tasks. All students are also expected to **follow the "Commitments of Graduate Students" guide**lines developed by the Mentoring, Education, and Engagement Committee.

INSPIRES is committed to including other faculty and staff to participate in various aspects of the program. Those designated as Cooperating Faculty are expected to co-mentor students and/or teach a class that has some coursework specifically aligned with the INSPIRES program curriculum.

To achieve affiliation as "Cooperating Faculty," the individual is expected to:

- Submit a CV and 1-page Statement of Interest when formally applying to the program to the CLT that outlines why and how they want to be involved in INSPIRES.
- Contribute to co-mentoring INSPIRES students, if applicable.
- Seek funding and submit grant proposals to fund programs/opportunities related to INSPIRES, if applicable.
- Incorporate an INSPIRES-specific component into a course they teach, if applicable. Volunteer to participate in a program committee that is most relevant to their contribution to the program.
- Attend annual INSPIRES All-Team meeting.
- Contribute to annual reporting.

Conflict and Conflict Resolution

1. Defining Conflict

With a large, evolving project composed of individuals representing diverse disciplines, and at different stages in their academic careers, we recognize that conflicts and/or grievances may arise. Such areas of conflict may relate to, for instance:

- Allocation of project resources among project faculty and students (e.g., graduate student stipends, travel allowances, or other research funding)
- Prioritization and/or selection of certain research projects over others
- Development of courses
- Selection of graduate students
- **Failure to meet one's responsibilities (e.g., regular committee meeting attendance, timely** completion of tasks)
- Allocation of research or teaching responsibilities among project faculty

In pointing to these examples, we recognize that conflict need not be malicious in intent, but rather be related to the confluence of various understandings and perspectives, as well as demanding schedules.

2. Conflict Resolution Process

We encourage individuals who have experienced a conflict and/or have a grievance related to **the project to adhere to the following steps (adapted from the UMaine Graduate School's** process):

- (*For students only*): Communicate with your faculty advisor and the INSPIRES Program Coordinator to try to reach a resolution.
- Bring the issue to the attention of the Mentoring, Education and Engagement Committee, where the issue will be considered confidentially (to the extent possible) and with respect for the individual(s) involved.
- Given a situation in which a CLT member is involved in a conflict, and/or a team member seeks an alternative resolution venue, we will utilize the resources freely available to the INSPIRES community, including the mediation services of:
  - Chair/Director of **advisor's unit.**
  - Graduate School
  - University Ombudsperson
  - Employee Assistance Program

In considering a reported conflict, the CLT will gather pertinent information from all parties involved while attending to issues of status/rank (e.g., MS vs. PhD student; untenured vs. tenured faculty) that may affect a fair (and/or equitable) resolution. That is, the CLT acknowledges that power may influence the conflict resolution process, with possible adverse **implications for the team's most vulnerable members.**

3. Reporting of Discrimination and/or Harassment

If a conflict and/or grievance qualifies as discrimination and/or harassment, we strongly encourage team members to follow the INSPIRES protocol for reporting:

- If the person discriminating against the team member is an employee or other non-student, contact the Office of Equal Opportunity and follow their guidance
- If the person discriminating against the team member is a student, contact Title IX Student Services.

Additional, general information on discrimination and harassment in the workplace can be found at:

- Maine Human Rights Commission: www.maine.gov/mhrc

- Equal Employment Opportunity Commission: www.eeoc.gov
- **U.S. Department of Education's Office of Civil Rights**: www.ed.gov/ocr

Data Sharing

The INSPIRES program is intended to operate in the spirit of collaboration and openness. This effort includes the sharing of data and information among project personnel and beyond with the larger scientific community. While there may be good reasons to not immediately release data (e.g., check data quality; confirm confidentiality for sensitive information, etc.), we will strive is to share data as openly, swiftly, and efficiently as possible. All participants in the program are expected to follow the formal Data Management Plan, which is accessible on INSPIRES Box Folder, and are required to log details about who and when they are sharing data and materials with. This is not only good practice, but it also assists with NSF reporting requirements. In addition, researchers must adhere to all University Institutional Review Board (IRB) and Institutional Animal Care and Use Committee (IACUC) protocols, where relevant. Note that some project partners (e.g., Federal Agencies) have strict data release policies, and it is the responsibility of all INSPIRES participants to adhere to these protocols, where relevant.

Authorship and Publication

Principles governing authorship should embody a spirit of inclusiveness and respect the traditions and reward structure associated with **each collaborator's discipline (i.e., communication,** psychology, forestry, ecology, etc.). Wherever appropriate, we strongly encourage including participating students as co-authors, and especially in the development of posters, articles, and chapters that promote cross-project and transdisciplinary learning.

We offer a template and the following as general guidelines for working through authorship decisions:

- Discuss authorship and author order early and often. Miscommunications can best be managed by open, clear communication and keeping track of writing contributions and authorship decisions over time can help avoid and work miscommunications through when they arise.
- Confirm author order and define contributions of each author before submitting a manuscript before publication. A simple email reminder will confirm the agreed upon order.
- The lead author should keep all co-**authors informed of a manuscript's status and include** them in conversations about revisions. The lead author should also communicate the

most current version of a manuscript title and author order once the manuscript has been submitted. This will help to refine reporting practices so that the same manuscript does not appear with different titles.

- **When confusion or conflicts arise, please utilize the INSPIRES' conflict management** processes to help facilitate an open, clear resolution. Authorship disputes can arise easily, and open communication can help to ensure a respectful, productive environment for collaboration.
- Our understanding of the needs for shared authorship will evolve as the project develops. We will reserve time at annual retreats and monthly meetings as needed to continually discuss our authorship needs and experiences and adjust this section as needed.

Mentoring

Graduate Students

INSPIRES graduate students and mentors will follow the guidelines developed by the Mentoring, Education, and Engagement (MEE) Committee. Both are available in the MEE **Committee's folder** on Box. For graduate students, the direct link is here, while the direct link for faculty mentors is here. Regular review and discussion of these documents is expected for both INSPIRES graduate students and mentors. In cases where the MEE guidelines conflict with guidelines provided by a **student's home institution, the home institution's guid**elines should be followed, but differences between the two should be acknowledged and discussed by the student, advisor and advising committee.

Post-Doctoral Researchers

Mentoring of post-doctoral researchers would follow the plan outlined in the original INSPIRES proposal. This included the creation of an Individual Development Plan (IDP), which had both short- and long-term goals that reflects their background and career aspiration. The IDP would be reviewed at least annually, and updated accordingly.

Early Career Faculty

A primary intention of INSPIRES is the support and development of early-career faculty. To ensure this, each early-career faculty would be paired with an INSPIRES senior faculty member on the same research theme. The mentor and mentee would meet regularly to discuss project progress, potential issues encountered, and desired outcomes. To protect from over-commitment on the project, early-career faculty service on INSPIRES committees would be limited both in time and scope. The MEE Committee is currently working on a more detailed mentoring plan for early-career faculty

External Evaluation

External evaluation is a component of the INSPIRES program that is mandated by NSF, and the continuation of our funding will be partly based on the results of this process. All project participants should respond to requests for information or participation regarding evaluation and assessment, including AAAS site visits and Advisory Board meetings.

Progress Reports

NSF has a data portal that all researchers will have to use. This will likely take a few hours per year. Team members should recognize this and be willing to input their data in accordance with the required timelines. Team members will be asked to identify annual milestones for their work, indicating progress against objectives, and may be asked to contribute narrative on their work for the annual report to NSF. Timely submission of annual reports to NSF is a requirement for receiving funding for the next year.

Update of this Document

This governance document is intended to be a living document that will be reviewed and possibly revised on at least an annual basis. In the event that a major update to the governance document is proposed, it must be discussed and agreed to by the CLT before any formal changes are made. All participants in the INSPIRES program are expected to read and sign this document.

ACKNOWLEDGEMENT OF AGREEMENT

Please print and sign your name to indicate that you have read and agree with the following statement:

I have read the INSPIRES Governance Agreement and agree to abide by the guidelines.

[Signatories can be found on living governance document.]

Evaluation Plan

Background

The National Science Foundation (NSF) EPSCoR Research Infrastructure Improvement (RII) Program—Track-2 Focused EPSCoR Collaborations (FEC) funds projects that seek to build interjurisdictional collaboration among researchers from eligible jurisdictions with complementary expertise and resources to tackle a significant research problem and build sustainable STEM capacity.

The University of Maine (UMaine) is leading a multi-jurisdictional research collaboration involving the University of New Hampshire (UNH) and University of Vermont (UVM) that is focused on leveraging big data to inform research and enhance understanding of challenges and opportunities related to the current and future integrity of forest ecosystem. The project, titled **"Leveraging Intelligent Informatics and Smart Data for Improved** Understanding of Northern Forest Ecosystem Resiliency (INSPIRES)," **will draw upon relevant expertise from participating** institutions to advance regional capacity to address complex systems issues. The project is designed to address key requirements of the EPSCoR program including:

1. Broadening the participation through the strategic inclusion and integration of different types of individuals, institutions, and sectors
2. Building sustainable STEM capacity in participating jurisdictions
3. Supporting the development of early-career faculty

The evaluation plan described in this document provides a framework for collecting, analyzing, and reporting data related to the implementation and outcomes of different project elements. The plan is based on the project objectives as outlined in the funded proposal and provide an approach to assess if these objectives are being met. This plan is intended to be dynamic to accommodate ongoing learning and feedback throughout the project's life cycle.

The plan will include process and outcomes evaluation measures. Process measures will focus on quality of implementing project activities, while outcome measures will focus on assessing the achievement of expected outcomes and impacts.

Research Themes

1. ***Advanced Sensing and Computing Technologies.*** Aims to provide big data to advance existing ecological models and knowledge of the Northern Forest Region (NFR) ecosystem. The theme has three objectives:
   - Improve power and wireless spectrum efficiency for a large-scale network to enable a novel in-situ forest data collection and processing system

   - Quantify the spatial-temporal variability of key forest ecosystem integrity metrics
   - Use machine learning to link quality improvement and efficient resource utilization in addition to data mining
2. ***Environmental Informatics and Analytics.*** Aims to integrate remote sensing data, sensor data, and qualitative information (e.g., TEK) to better understand spatial-temporal variability of stressors, while semantically enriching data to help identify future measurements to predict stress. The theme has four objectives:
   - Develop and test how a theoretical model can (1) quantify spatial & temporal variability and uncertainty and (2) incorporate qualitative and other nontraditional sources of ecological knowledge
   - Identify where additional sensing leads to greatest increases in data quality and model accuracy to improve the efficacy of sparse sensor networks
   - Build a smart data framework that leverages semantic knowledge to extract and characterize high-level places/events
   - Gain knowledge about how forest stressors vary across places and inform modeling by identifying where more granular models are beneficial
3. ***Integrated Ecological Modeling.*** Aims to quantify the impact of various stressors on ecosystem integrity indicators and predict change across NFR. The theme has four objectives:
   - Integrate sensor data, remote sensing streams, and semantically enriched information from Themes 1 and 2
   - Enhance and complete an inverse parameterization of regional ecological models
   - Project forest ecosystem integrity and its uncertainty under an array of alternative futures that include variation in climate, land use, regulatory policies, and natural disturbance scenarios
4. ***Quantitative Reasoning in Context.*** Aims to connect teachers and students to locally relevant research and datasets and broaden and deepen their STEM engagement. The theme has three objectives:
   - Develop/adapt materials for G6-12 that build QRC with opportunities to learn through data collection using sensors, asking and answering research questions about forests and the local environment and ecology using big data sets, and engaging in data visualization activities
   - Investigate the knowledge teachers need to support students in developing quantitative reasoning skills
   - Evaluate how students benefit from these opportunities

FOCUS OF THE EVALUATION

Evaluation Goals

The evaluation will assess the implementation of project activities overtime (formative evaluation) and the extent to which the intended goals of the project are achieved (summative evaluation). The data gathered from the formative evaluation phase will be shared with the project leadership annually to provide the feedback needed to guide project adjustments during its implementation.

Logic Model

A project logic model was developed in consultation with the project leadership. The model informed the development of specific evaluation questions and identification of relevant performance measures and will guide the evaluation activities throughout project implementation.

Evaluation Questions

The evaluation will seek to answer questions related to the development of research capacity, interjurisdictional collaborations and partnerships, and education and workforce development.

Research Capacity

- What progress has been made in achieving the key benchmarks and milestones in each **of the project's four research themes?**
- How has the project contributed to enhancing the ability of researchers to monitor key forest properties and processes?
- How has the project contributed to enhancing the ability of researchers to predict future conditions of the forest ecosystem?
- In what ways has the project expanded the science and technology knowledge base in the field of forest ecology?

Interjurisdictional Collaborations and Partnerships

- To what extent has the project enabled researchers in the participating institutions to establish interdisciplinary collaborations?
- To what extent has the project enabled researchers in the participating institutions to establish partnerships with external stakeholders in industry, government, and non-profit sectors?
- What value has the project generated for stakeholders?

- How has the project contributed to connecting science education communities within the three jurisdictions to share and disseminate best practices in quantitative reasoning instruction?

Education and Workforce Development

- **What progress has been made in achieving the project's education and workforce** development benchmarks and milestones?
- Has the project contributed to enhanced ability of middle and high school teachers to develop curricular material and tools to support the integration of quantitative reasoning in context into classroom instruction?
- What value has the project generated for middle and high school students?
- Has the project contributed to broadening the participation of undergraduate students and students from groups underrepresented in STEM through project activities?
- To what extent has the project enabled graduate students to expand their disciplinary and interdisciplinary knowledge and skills?
- In what ways has the project contributed to the career development and advancement of early career researchers?

EVALUATION DESIGN

A longitudinal evaluation design will be used in which quantitative and qualitative data will be collected annually from project participants. Baseline data collected in year one will be used as a reference point or benchmark to assess progress achieved over time. Survey instruments will be developed and used to collect evaluation data from the following project constituencies:

1. Project leadership (PI, Co-PIs)
2. Faculty and researchers (including postdoctoral trainees)
3. Undergraduate and graduate students
4. External stakeholders

INDICATORS

1. Research Capacity

Benchmarks and milestones for individual objectives under each research theme will be tracked over time. The benchmarks and milestones are currently being developed by the project leadership team (Research Objectives Maps) and will be tracked by the evaluator through surveys sent to the project leadership annually. An example of how the information will be presented in the evaluation report is provide in Table 2.

Table 2. Example of Chart Developed to Show Progress Achieved in Each Research Theme

Theme	Objective	Benchmarks	Number of Benchmarks Met in Year x	Number of Benchmarks Met to date
1	A. Improve power and wireless spectrum efficiency for a large-scale network to enable a novel in-situ forest data collection and processing system			

In terms of research impacts and practical implications, project **participants'** surveys will include questions to facilitate data collection on ways in which the participants think their research has contributed to advancing the field of forest ecology. Data will also be collected on key products and outputs resulting from the INSPIRES project including:

- Publications (submitted/published)
- Proposals (submitted/funded)
- Patents (submitted/awarded)
- Presentations
- Other (e.g., software, database, etc.)

Survey information on research products and outputs will facilitate NSF-required reporting through the EPSCoR RII Track-2 Data Outcomes Portal (T-2 DOP) and provide additional insight into implementation success indicators and project outcomes and impacts that are not captured by T-2 DOP. Research impact will also be assessed through the quality of journals where project articles are published using bibliometrics including journal impact factor and citation impact.

2. Interjurisdictional Collaborations and Partnerships

Network analysis will be used to examine the linkages established over time among project participants. The analysis will illustrate growth in research collaborations among researcher, students, and partners across institutions, departments, disciplines, and sectors overtime and the resulting benefits in terms of flow of knowledge and resources. The following research collaborations and partnerships indicators will be tracked annually through faculty/researcher, student, and stakeholder surveys:

- Number of project participants by category (e.g., title, institution, department, discipline, etc.)
- Number and type of connections among project participants (e.g., within and among groups of participants, purpose of interaction such as research collaboration or mentoring, etc.)

- Benefits of collaborations and partnerships, e.g., shared knowledge/expertise, leveraged resources, application of research to address technology challenges or develop/refine policies and management strategies

3. Education and Workforce Development

Benchmarks and milestone for the project's education and workforce development component will be tracked over time (e.g., number of graduate students recruited and enrolled, number of undergraduate students involved in project activities, number of k-12 teachers trained, etc.). The benchmarks and milestones will be tracked by the evaluator through surveys sent to the project leadership annually.

K-12 teachers: information on the benefits received by teachers in terms of knowledge and skills as a result of the training and support offered by INSPIRES will be captured by project activities under Theme four. As an external stakeholder group, trained K-12 teachers will be asked to complete an annual survey to collect information about the benefits of training in terms of development and integration of curricular material and tools into classroom instructions to enhance students' quantitative reasoning skills. Information will also be collected about ways in which teachers have disseminated and shared any knowledge gained and lessons learned with their peers and the wider science education community in the region.

K-12 students: the evaluator will work with theme four researchers and staff to develop relevant indicators and data collection instrument in year two to assess project benefits to K-12 students.

Undergraduate and graduate students: a survey instrument for undergraduate students and **another for graduate students will be used to collect information about the project's educ**ation and training benefits to students in terms of knowledge and research skills gained, mentoring received, professional development and networking opportunities, and education and career plans/outcomes.

Early career researchers: researchers participating in the project will be asked to complete an annual survey to collect information about their participation in the project and their level of engagement in different project research, education, and training activities, mentoring received/offered, professional development, networking, and leadership opportunities, and career plans/outcomes.

Details about the type of evaluation data that will be collected from each group of project participants are provided in Table 3.

Table 3. Evaluation Data Matrix

Domains	Project Leadership	Faculty and Researchers	Graduate and Undergraduate Students	Stakeholders/ Partners
Project implementation (e.g., strategic planning, management, communication)	√	√	√	√
Research benchmarks and milestones	√			
Education and workforce development benchmarks and milestones	√			
Research outputs	√	√	√	
Research outcomes/impacts	√	√	√	
Research collaborations and partnerships	√	√	√	√
Professional development opportunities	√	√	√	√
Networking opportunities	√	√	√	
Mentoring	√	√	√	
Knowledge transfer	√	√	√	√
Education and career plans/outcomes		√	√	

DATA COLLECTION

Survey instruments to collect evaluation data from different groups of project participants will be developed in consultation with the project leadership team. The instruments will then be converted into web-based surveys (using Survey Monkey). A link for each of the survey instruments will be forwarded to the project manager. The evaluation data will be collected

according to the timeline provided in Table 4 which aligns with NSF's annual reporting cycle. The project manager will send an invitation letter via email to project participants to complete the evaluation surveys. The letter will be drafted by the evaluator to provide a brief description of the surveys, an estimate of the time it would take to respond to the survey questions, and the URL for the survey web site. The participants will receive two reminders, one will be sent a week after sending the initial invitation and another reminder after an additional week. Following the completion of a 4-week data collection period, the surveys will be closed, and data will be exported into Excel and prepared for analysis. The evaluation data will be stored in a secure database accessible only by AAAS RCP evaluators and will be maintained for at least five years after the project has ended.

ANALYSIS

For quantitative data, descriptive statistics (e.g., averages, percentages, measures of dispersion) will be used to present findings from the evaluation. Cross-tabulation will be used when appropriate to illustrate differences in distribution of indicators overtime across subgroups. The statistical software Stata (v 16.0) will be used in the analysis of quantitative data. For qualitative data from open-ended survey responses will be analyzed using qualitative coding and analysis software (NVivo). Survey data on interdisciplinary and interjurisdictional research collaborations and partnerships will be analyzed using UCINET to assess collaboration network overall structure, density, and centrality.

DISSEMINATION

The primary audience for the evaluation findings is the project leadership team. Annual evaluation reports will be prepared and shared with the project leadership after each data collection wave has been completed. A virtual meeting will be scheduled shortly thereafter to discuss key findings from the evaluation and implications for project implementation. The reporting timeline allows the project leadership to utilize the evaluation data for NSF reporting purposes. A final evaluation report presenting result from the longitudinal analysis of project evaluation data will be prepared and submitted to the project leadership.

The reports will only include aggregate summaries of data and will not identify individual participants by name. An exception will be made for data that can be used for NSF reporting purposes (i.e., products and outputs resulting from the INSPIRES project such as publications, grants, patents, etc.).

Table 4. Timeline for Evaluation Activities

Evaluation Activities	2020			
	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Baseline survey	√			
Data analysis and reporting		√		
Annual survey				√
	2021			
	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Data analysis and reporting	√			
Annual survey				√
	2022			
	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Data analysis and reporting	√			
Annual survey				√
	2023			
	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Data analysis and reporting	√			
Annual Survey			√	
Data analysis and final report development				√

Communication Plans

INTERNAL

A multi-media approach to internal team communications will be used for this research project. This will include the use of traditional formats like in-person meetings and conference calls as well as emerging team communication technologies like Zoom and Slack. Monthly all-team emails will be sent from the Core Leadership Team to provide updates, priorities, and deadlines. Regular in-person institutional meetings would help between-theme discussions and enhance collaboration opportunities within each jurisdiction. Online quarterly all-team meetings would be conducted on Zoom that would provide key project updates and broaden collaboration opportunities between jurisdictions. Annual in-person meetings and summer field tours would provide opportunities for personal interactions, networking, team building and in-depth project discussions. Themes will be encouraged to maintain active dialogs using Slack and regular in-person and remote (using Zoom) meetings. As part of the annual evaluation process, project members would surveyed about project communications and improvements sought.

EXTERNAL

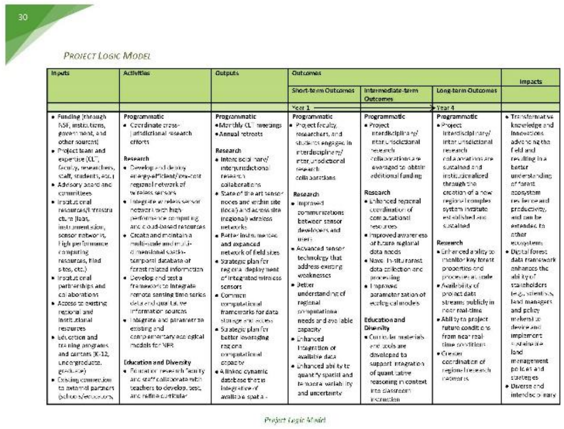
Similar to the internal team communications, a multi-media approach to external project **communications will be employed. Key external communications would include the project's** advisory board, identified stakeholders, and the general public. The project advisory board would receive semi-annual project emails and meet in-person or virtually once per year to provide input. They would be provided with key project materials like the implementation plan, evaluation reports, and annual progress reports. Based on the theme stakeholder matrices presented below, a project stakeholder list would be compiled and a targeted communications strategy formed. The theme stakeholders would receive regular theme updates, while the broader stakeholder list including key university administrators, state agency personal, and other scientists would receive a regular project e-newsletter that would feature project updates, student profiles, and any relevant project outcomes or events. For the general public, an open-access website for the project will be made available, which will link to ongoing research, current/past team members, and project outputs. Project links to social media would be made **using the University of Maine's Center for Research on Sustainable Forest's Facebook and Twitter** accounts.

Project Strategic Materials

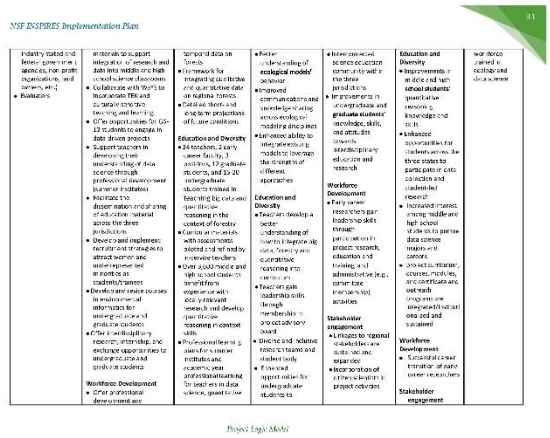
The project is divided into four research themes that have specific focal areas, research approaches, and goals as outlined below. More details on each research theme are given in the sections specific to the individual research theme.

INSPIRES RESEARCH APPROACH AND GOALS BY THEME

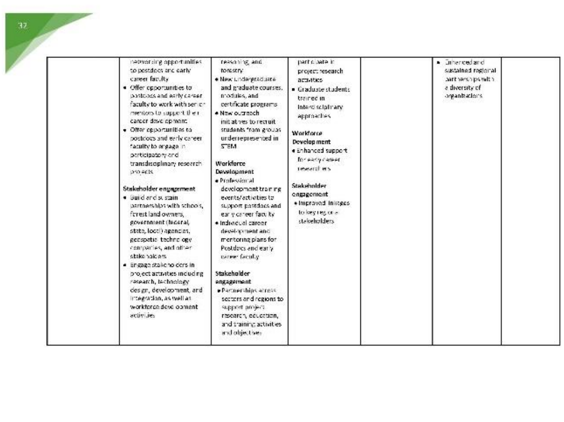
Research Approach	Research Goals
Theme 1. Advanced Sensing and Computing Technologies can contribute valuable Big Data that, when combined with smart environmental informatics, advances ecological models & our knowledge of the NFR ecosystem.	Improve power and wireless spectrum efficiency for a large-scale network to enable a novel in-situ forest data collection and processing system that furthers our fundamental knowledge of advanced sensing and computing technologies, while reliably quantifying the spatial-temporal variability of key forest ecosystem integrity metrics. Use ML for link quality improvement and efficient resource utilization in addition to data mining.
Theme 2. Smart Environmental Informatics can help integrate remote sensing data, sensor data, and qualitative information (e.g., TEK) to better understand spatial-temporal variability of stressors. Semantically enriching data helps to identify future measurements to predict stress.	Develop and test how a theoretical model can (1) quantify spatial & temporal variability & uncertainty and (2) incorporate qualitative & other nontraditional sources of ecological knowledge. Identify where additional sensing leads to greatest increases in data quality and model accuracy to improve the efficacy of sparse sensor networks. Build a smart data framework that leverages semantic knowledge to extract and characterize high-level places/events. Gain knowledge about how forest stressors vary across places and inform modeling by identifying where more granular models are beneficial.
Theme 3. Integrated Ecological Models can quantify the impact of stressors on ecosystem integrity indicators & predict change across NFR when refined and driven by links to Themes 1 and 2.	Integrating sensor data, remote sensing streams, and semantically enriched information from Themes 1 and 2 to better enhance as well as complete an inverse parameterization of regional ecological models for projecting forest ecosystem integrity and its uncertainty under an array of alternative futures that include variation in climate, land use, regulatory policies, and natural disturbance scenarios.
Theme 4. Improving Quantitative Reasoning in Context will connect teachers and students to locally relevant research and datasets, broadening and deepening STEM engagement.	(1) Develop/adapt materials for G6-12 that build QRC with opportunities to learn through data collection using sensors, asking & answering research questions about forests and the local environment & ecology using big data sets, and engaging in data visualization activities; (2) investigate the knowledge teachers need to support students in developing quantitative reasoning skills; (3) evaluate how students benefit from these opportunities.



Project Logic Model



Project Logic Model



Project Logic Model

		[illegible] research project	
Strong connections with key stakeholders throughout the region	High	Varied available data and infrastructure across the region	High
Existing long-term data	High	Highly varied forest with key regional differences	Medium
Diverse set of expertise on team	High	Limited and mixed institutional support for project	Medium
Unique and non-overlapping strengths of each institutions	High	Ambitious research objectives	Medium
Input from prior Track 2 projects	Medium	Limited institutional collaboration in the past	Medium
Limited geographic barriers	High	Involved faculty on multiple large research projects	High
Equal involvement of early-career and senior faculty members	High	Highly diverse research themes with varying needs and relatively limited funding	High
PI and Co-PI have experience managing large, inter-disciplinary research projects	High		
Available staff support with extensive experience in project management and reporting	Medium		
Clear regional need and interest in research	Low		
Related ongoing research projects	High		
External Factors			
OPPORTUNITIES (+)	IMPORTANCE	THREATS (–)	IMPORTANCE
Engaged and supportive stakeholders	High	Varied perspectives on project success	Medium
Emerging and prominent discussions on forests	High	Declining university budgets	High
Growing institutional awareness of strength in project expertise	High	Continuity of research vision beyond PI and Co-PIs	High

Project SWOT Analysis

PROJECT SWOT ANALYSIS

Resurgence in Northern Forest's forest-based economy	High	Drift of project scope	Medium
Greater availability of new technologies to better monitor forests	High	Undefined research plan	Medium
Growing interest in and support for forest carbon markets	High	High reporting requirements and expectations	High
Strategic alignment on emerging opportunities like Maine Climate Council	High	Limited engagement of institutional leadership	High
Common research interests and needs	High	Balancing research production with long-term sustainability	Medium
Linkages to other ongoing projects	High	Key geographic and institutional differences	Medium
		Different motivators for project involvement	Medium
		Numerous soft-money, early career faculty	High

PROJECT MILESTONES

PROJECT OUTCOME METRICS

Program Area	Output/Outcome/Impact Indicators	Annual Project Benchmarks
Research Capacity	Interdisciplinary and convergent research collaborations; post-docs recruited; graduate students enrolled; new regional Complex Systems Research Institute	3 post-docs and 8 graduate students, 3 research assistants, strategic plan presented to internal/external advisory boards
Research Productivity	Peer-reviewed publications; submitted (awarded) grants (by funding source); patents, licenses and commercialization opportunities; amount and resolution of data generated	6 publications (50% multi-institution), 10 presentations, 4 proposals submitted (50% multi-institution), 1 cross-jurisdictional grant funded, 5 data products publically available (24% being integrated)
Education and Diversity	Student participation in project research activities; student participation in project professional and career development training vents; student research and career development outcomes; diversity (participation of students from populations underrepresented in STEM; i.e., WaYS)	10 undergraduates involved, 5 undergraduate and graduate students enrolled in certificate programs, 3 training events, 35% of project participants from underrepresented backgrounds, 1 inter-institutional graduate course
Workforce Development	Undergraduate/graduate student education and career outcomes (next steps); early career faculty development outcomes (progress toward research independence, tenure, teaching, mentoring, and leadership skills development); integration of Big Data modules into K-12 curricula	5 early career faculty involved, curricular materials for grades 6-12 created/improved (Yrs 2-4), **annual teacher's workshop held (Yrs 204)**, 1000 students impacted (Yrs 2-4). 20 involved (Yrs 2-4), post-docs/graduate/undergraduate students gain experience in K-12 education, perspectives from WaYS reflected in curricular materials
Stakeholder Engagement	Collaborations and partnerships with local organizations, industry, and other academic institutions; benefits to participants in collaborative networks	5 involved partnerships, 3 outreach events, 5 media features, 25 event participants

PROJECT WORKFORCE DEVELOPMENT

Digital Forest Tri-Jurisdiction Workforce Development Pipeline			
G6-12	**Undergraduate**	**Graduate**	**Early Career**
• New Earth and life sciences curricular materials with Big Data emphasis • Local problem solving with Big Data • Professional development and networking for teachers • Hands-on, relevant data science with PLT and other partners • Collaboration with WaYS to incorporate TEK and culturally sensitive teaching and learning • Support of ongoing initiatives led by ESRI • Interactions with STEM-based faculty and students	• New certificate with revised and new courses in environmental informatics • Hands-on collaboration with INSPIRES research faculty and graduate students • WaYS recruitment of Native American undergraduate students to broaden participation in STEM careers • Recruitment of women, first generation and other underrepresented in STEM populations to enhance Big Data workforce • Big Data research opportunities	• Mentoring by faculty and post-docs • Leadership opportunities with undergraduates • Participation in convergent research across themes • Innovative, interdisciplinary theses • Certificate in environmental informatics • Learning and networking across jurisdictions • WaYS recruitment of Native American graduate students to broaden participation in STEM careers • Big Data research opportunities	• Mentoring by senior faculty • Participation in convergent research approaches • Leadership experiences within research themes and collaborative governance structure • Networking opportunities across three jurisdictions • Postdoctoral mentoring to enhance career development • Support for summer salary, travel, undergraduate, and graduate students, and research infrastructure

THEME STRATEGIC MATERIALS

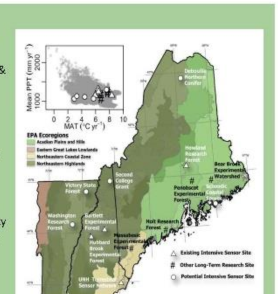
THEME 1. ADVANCED SENSING AND COMPUTING TECHNOLOGIES

GOAL

Contribute valuable Big Data that when combined with smart environmental informatics, advances ecological models & our knowledge of the Northern Forest Region ecosystem.

OBJECTIVES

1. Improve power and wireless spectrum efficiency for a large-scale network to enable a novel in-situ forest data collection and processing system
2. Quantify the spatial-temporal variability of key forest ecosystem integrity metrics
3. Use machine learning to link quality improvement and efficient resource utilization in addition to data mining



38 *Project Strategic Materials*

THEME 1 LOGIC MODEL

Inputs	Activities	Outputs	Outcomes			Broader Impacts
			Short-term Outcomes	Intermediate-term Outcomes	Long-term Outcomes	
			Year 1 →		Year 4	
• **UMO's Wireless Sensor Lab & Advanced Computing Group** • Prior experience with wireless sensor development & application • Highly instrumented fields sites with prior records • Connections with NEON and existing flux tower sites • Example networks like weather stations or SnoTel • Faculty with expertise in both wireless sensors, wireless networks, and field monitoring sites • Wide availability of environmental sensors • An improving infrastructure for rural wireless signals • Varied computational infrastructure for storing and accessing data	• Coordinate cross-jurisdictional research efforts and field sites • Determine current research needs for wireless sensor and networks • Develop common protocols for key measurement attributes • Synthesize available data and current sensors • Identify potential field sites and sensor needs • Develop and deploy prototype sensors at selected sites • Strategically expand network of sensors using appropriate methods • Test alternative network configuration to maximize data collection • Define consistent cloud based computational frameworks for storing and accessing environmental data	• Developing state of the art sensor nodes and within site (local) and across site (regional) wireless networks • More cost effective and power-efficient wireless sensors • More cost-effective and power efficient local wireless sensor networks • Better instrumented and expanded network of field sites • Greater regional coordination of available data and sensors • Common computational frameworks for data storage and access • Strategic plan for better leveraging regional computational capacity	• Improved communications between wireless sensor developers and users • Documentation of available data and potential data gaps • Understanding of advantages and disadvantages of currently available wireless sensors • Prototype sensor nodes that adress identified weaknesses of existing sensor nodes • Strategic plan for regional deployment of integrated wireless sensors • Outline of regional computational needs and available capacity	• Custom environmental sensor node development at scale • Greater number of sensor options and networked sites • More regional coordination of computational resources • Growing awareness of future regional data needs • Novel in situ forest data collection and processing	• Improved ability to monitor key forest properties and processes at scale • Core regional spatial temporal trends in forest ecosystem attributes captured • Data streams publicly available in near real-time • Greater development and utilization of open-source data repositories • Regionally consistent protocols for acquiring, storing, and summarizing available data	• Better availability of regionally consistent environmental data streams • Increased utilization of available data to address both short- and long term questions about forests • Improved monitoring of the forest that publicly recognized • Greater coordination of regional research networks • Improved capacity to understand regional forest conditions at scale and near real-time

Strategic Materials: Theme 1 Logic Model

NSF INSPIRES Implementation Plan 39

Strategic Materials: Theme 1 Logic Model

Frequent meetings and increasing collaboration	
Capacity to create hardware and software	
Team expertise	
Past experience and projects (Water Quality, NH sites, etc)	
External Factors	
OPPORTUNITIES (+)	THREATS (–)
Need for creation of low cost wireless dendrometers to measure tree growth	COVID-19 pandemic and the associated disruptions
Need for sensors to better monitor foliage and woody litterfall	
Need for sensors to better monitor stem respiration	
Availability of drones for data collection	
Existing research sites, sensors, and data	
External collaborators (AMC, etc.)	
Availability of drones for data collection	

Strategic Materials: Theme 1 SWOT Analysis

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THEME 1 RESEARCH OBJECTIVES MAP

Objective	Objective leads	Projects	Project responsible parties	Milestones			
				Y1	Y2	Y3	Y4
1.1 Develop and deploy a regional network of cost- and energy-efficient wireless sensors for measuring critical ecosystem attributes like soil moisture, canopy cover, phenology, and water quality	Contosta, Adair	1.1a Wireless sensor research and development	Abedi, Contosta, Adair, Naden	Identify existing and new field sites and sensor needs at these sites; Assess state of the art for ecological sensors	Deploy prototype sensors at selected field sites	Strategically expand network of sensors using appropriate methods	Continue strategic expansion of regional sensor network based on available data
1.2 Evaluate alternative wireless sensor network designs informed by ML that maximize power and wireless spectrum efficiency for large scale applications	Contosta, Adair	1.2a Wireless sensor network design	Abedi, Contosta, Adair	Determine research needs for wireless sensor networks; Synthesize available data from current sensor networks	Test alternative network configuration to maximize data collection	Field test alternative network designs at selected field locations	Regionally implement sensor networks
1.3 Integrate the wireless sensor network with a cloud-based processing system that serves as a digital library for storing, documenting, and linking the data across research themes	Abedi, Bundy	1.3a Cyber-based big data harmonization, ML & interface	Abedi, Bundy	Develop common protocols for key measurement attributes; Test alternative machine learning algorithms	Define consistent cloud based computational frameworks for storing and accessing environmental data	Implement machine learning approaches to ecological sensor collection, storage, and processing	Process, summarize, and synthesize available regional ecological sensor data collected by this project and develop online interface

Strategic Materials: Theme 1 Research Objectives

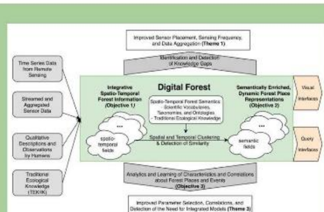
THEME 1 STAKEHOLDER MATRIX

Stakeholder Name	Contact person	Field of activity	Purpose of engagement	Strategy for engaging	Stakeholder engagement	How would the stakeholder contribute	How would the stakeholder benefit
Old Town High School	Ed Lindsey	Education	Co-production of knowledge around changing winters and the winter-to-spring transition	In person	Monthly	Ed Lindsey and his students manage an ecological observatory in the UMaine Research Forest adjacent to their school. The data they collect is in hourly to daily increments and could be used to support both the empirical research of Theme 1 and the process based modeling work of Theme 3	The students in Mr. Lindsey's classes are from rural Maine and do not have many opportunities to interact with scientists. We have seen from prior engagement that they feel empowered to pursue higher education in science (sometimes as first generation attendees at a four-year college) when working besides scientists and "getting their hands dirty."
Appalachian Mountain Club	Georgia Murray	Citizen Science	Raise awareness about climate change in the Northern Forest by training people to monitor environmental variables that herald this change	In person, conference calls	Annually	Data collected through citizen science initiatives might contribute to the empirical research of Theme 1 and the process-based modelling research of Theme 3	New sensor technologies that INSPIRES develops will enhance AMC's ongoing research and monitoring efforts

OpenTEAM	Dorn Cox	Tools for data collection in agroecosystems	Share lessons learned in the development and deployment of low-cost, open source wireless sensor networks	In person, conference calls	Annually	Cox has been visionary in developing an interdisciplinary cohort of developers, researchers, and end-users of open source sensors in agricultural systems, and could share hard-learned lessons	New wireless sensing capabilities might be transferable from forested to agricultural system and might enhance the work of OpenTEAM
Smart Forests for the 21st Century	Chris Woodall	Forest Inventory	Identify regional forest inventory needs	In person, conference calls	Monthly	Chris works on national inventory design and methods. New sensor technologies may help provide new insights	New sensor technologies that INSPIRES develops may improve national inventory efforts
Hise Scientific Instrumentation	Jeremy Hise	Sensor Development	Provide insights on new sensor technology and methods	In person, conference calls	Annually	Jeremy owns and runs a business centered on ecological sensor development and deployment	Learn about ongoing research and collaboration opportunities in the region
PEM Carbon	Bruno Merino	Sensor Development	Provide insights on new sensor technology and methods	In person, conference calls	Annually	Provide input and potential sensors for comparison	Identify collaboration opportunities and be more engaged with ongoing research

GOAL

Integrate remote sensing data, sensor data, and qualitative information (e.g., TEK) to better understand spatial-temporal variability of stressors, while semantically enriching data to help identify future measurements to predict stress.



OBJECTIVES

1. Develop and test how a theoretical model can (1) quantify spatial & temporal variability & uncertainty and (2) incorporate qualitative & other nontraditional sources of ecological knowledge

2. Identify where additional sensing leads to greatest increases in data quality and model accuracy to improve the efficacy of sparse sensor networks

3. Build a smart data framework that leverages semantic knowledge to extract and characterize high-level places/events

4. Gain knowledge about how forest stressors vary across places and inform modeling by identifying where more granular models are beneficial

THEME 2 LOGIC MODEL

Inputs	Activities	Outputs	Outcomes			Broader Impacts
			Short-term Outcomes	Intermediate-term Outcomes	Long-term Outcomes	
			Year 1 →		→ Year 4	
• Ongoing research on environmental semantics • Existing theoretical models (e.g. fields model) for quantifying spatial and temporal uncertainty • Available expertise on Traditional Ecological Knowledge • Existing connections to key regional stakeholders including state agencies and tribal communities • Prior experience on integrating spatial-temporal data • Cross-jurisdictional informatics expertise	• Develop scientific vocabularies, taxonomies, and ontologies • Conduct interviews and focus groups with tribal leaders to understand TEK • Integrate available data streams from remote sensing, sensor data, qualitative observations, and TEK • Build a smart data framework that leverages semantic knowledge to extract and characterize high-level places/events • Conduct advanced analytics and learning on the characteristics and correlations about forest places and events	• A linked dynamic database that is integrative of available spatial-temporal data on forests • Spatial-temporal clustering of data to detect similarities and potential trends • Framework for integrating qualitative and quantitative data on regional forests • Incorporation of nontraditional sources of ecological knowledge like TEK	• Better integration of available data and identification of current knowledge gaps • Improved linkages to key regional stakeholders • Quantification of spatial & temporal variability & uncertainty	• More informed ecological modeling by identifying where more granular models are beneficial • Ability to both visual and query data • Identification of where additional sensing leads to greatest increases in data quality and model accuracy to improve the efficacy of sparse sensor networks • Better incorporation of available citizen scientists	• Ability to extract and characterize high-level places/events • Improved capacity for efficiently developing sensor networks and aggregating available data • Greater parameterization of ecological models • Increased recognition and ability to use nontraditional sources of information	• Knowledge about how forest stressors vary across places • Digital frameworks extensible to other ecosystems • More efficient and informed monitoring of the forests • Enhanced regional partnerships with a diversity of organizations

THEME 2 SWOT ANALYSIS

INTERNAL FACTORS	
STRENGTHS (+)	**WEAKNESSES (–)**
Prior research on spatial mapping of key forest attributes like LAI or leaf N	Extent/ quality of field/training data are lacking for LAI
Available ground-based or sensor datasets	Lack of clarity on key objectives and needs from other themes
Existing expertise on AI/ML, remote sensing, informatics, and spatial analysis	Potential mismatch spatial and temporal
Available algorithms and tools in need of a specific application	Potential lack of representative data for key attributes
Available G-LiHT and UAV high-resolution data	Perpetually cloudy region that can make traditional remote sensing methods difficult
Existing regional network of sensor data for soils and climate	Potential breakdown of core relationships like foliar N
Need for improved segmentation algorithms	Difficultly of measuring wood productivity
	Can Theme 2 members realistically fulfill needs for Theme 3 and still meet the internal objectives of Theme 2?
EXTERNAL FACTORS	
OPPORTUNITIES (+)	**THREATS (–)**
Database for ingesting various data layers	Lack of Landsat or FIA data in the future
Better AI/ML for cloud masking and data ingestion	Products do not align with stakeholder modeling/decision support needs
Collaboration with Theme 3: need for foliar nitrogen maps, species composition	Stakeholder fatigue
Need for better classification of remote sensing pixels, particularly disturbance	Availability of cloud-based resources
Collaboration with Theme 1: identify optimal sensor network sites	
Integration of Alternative, higher-resolution datasets (SfM, ICESat, JEDI) with feature selection ML algorithm to support fine-scale forest changes (ex: individual tree scale or features below Landsat resolution)	

THEME 2 RESEARCH OBJECTIVES MAP

Objective	Objective leads	Projects	Project responsible parties	Milestones	
				Y1	Y2
2.1 Extend the field model of Liang to integrate remote sensing time-series data and qualitative information sources in addition to streamed in-situ sensor data. Determine and quantify uncertainty for both quantitative/qualitative data and combine them to decrease overall uncertainty.	Nitie, Petrik, Ranco	2.1a Extension of field model beyond in situ sensors	Nitie, Petrik, Ranco	Summarize current data availability and location of regional ecological sensor networks, identify potential gaps in sensor data and geographical representation	Develop methods to scale ecological sensor data and its uncertainty at test locations to the broader landscape
2.2 Generate temporal, spatial, and spatio-temporal profiles of forest types and ecologically important events. Cluster and learn about highly influential forest places (e.g., distributed across NH, ME, and VT) according to their spatio-temporal profiles and correlated ecological event types using ML, supervised learning and semantic-based abstractions trees	Hahmann, Beard, Martin	2.2a Hybrid Semantic statistical representation of forest places	Hahmann, Beard, Legaard, Bagrow, & Martin	Obtain requirements for inputs or outputs from Theme 3; Identify pre-existing models/resources to work from	Develop a framework for extending ontologies with statistical representations of spatio-temporal information

	Hahmann, Beard, Martin	2.2b Provide spatial datasets for theme 3 objectives (LAI, tree height/stature, foliar nitrogen, tree/forest age, historic disturbances)	Hahmann, Beard, Martin	Obtain specific requirements for outputs from Theme 3 (e.g. LAI, tree height/stature, soil nitrogen, foliar nitrogen, tree/forest age, tree species/assemblages present, disturbance history, land use history datasets, historical aerial photography, insect outbreak cycles);	Outline conceptual framework for Digital Forest using select spatio-temporal datasets
	Legaard, Roy, Yasar	2.2c. Develop and evaluate alternative ML algorithms for analyzing spatio-temporal datasets	Legaard, Roy, Yasar	Evaluate current state of art for use of ML algorithms in environmental sciences and potential limitations	Adopt and implement memory-efficient deep learning architectures or a cloud-based platform

2.3 Examine whether stress responses in forest places can be detected from remote sensing. Develop methods to identify spatial or temporal gaps in data to inform where improved in-situ sensing will yield the greatest reduction uncertainty, thus improving understanding and modeling of unique places with minimally denser sensing.	Beard, Legaard, Petrik, Hahmann, Ranco	2.3a Analysis of forest place correlations and similarities	Beard, Legaard, Petrik, Hahmann, McGill, Roy, Ranco	Obtain requirements for outputs from Theme 3; Identify pre-existing models/resources to work from	Develop new layers of regional climatic, forest type, disturbance, and potential productivity based on forecasted changes from available data sources

THEME 2 STAKEHOLDER MATRIX

Stakeholder Name	Contact person	Field of activity	Purpose of engagement	Strategy for engaging	When will the stakeholder be/was engaged	How would the stakeholder contribute	How would the stakeholder benefit
ESRI	Peter Frederics/Dawn Wright	Geospatial science & technology	Learn about new emerging topics & focus areas	E-mail and conference calls	Annually	Provide input on current project focus and link to ongoing software development	Learn about and help guide research outcomes
NatureServe	Don Faber-Langendoen	Scientist	Understand current use of geospatial databases for ecological analyses	Email and in-person discussions	Annually	Provide input on current project focus and link to ongoing software development	Learn about research and help guide outcomes
JD Irving	Jason Killam	Chief Forester	Better understand stakeholder needs in terms of complex geospatial databases	Email and in-person discussions	Annually	Provide context for geospatial technologies and landscape spatiotemporal analyses	Learn about research and help guide outcomes
Weyerhaeuser	Greg Johnson	Director	Better understand stakeholder needs in terms of complex geospatial databases	Email and in-person discussions	Annually	Provide context for geospatial technologies and landscape spatiotemporal analyses	Learn about research and help guide outcomes

Strategic Materials: Theme 2 Stakeholder Matrix

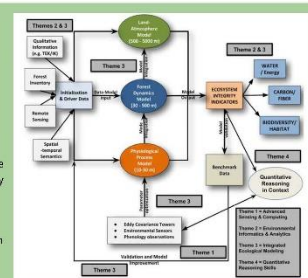
GOAL

Quantify the impact of various stressors on ecosystem integrity indicators & predict change across Northern Forest Region when refined and driven by links to Themes 1 and 2.

OBJECTIVES

1. Integrating sensor data, remote sensing streams, and semantically enriched information from Themes 1 and 2

2. Enhance as well as complete an inverse parameterization of regional ecological models



3. Project forest ecosystem integrity and its uncertainty under an array of alternative futures that include variation in climate, land use, regulatory policies, and natural disturbance scenarios.

Strategic Materials: Theme 3

THEME 3 LOGIC MODEL

Inputs	Activities	Outputs	Outcomes			Broader Impacts
			Short-term Outcomes	Intermediate-term Outcomes	Long-term Outcomes	
			Year 1 →		→ Year 4	
• Prior experience using a range of ecological models (e.g. FVS, LANDIS, PnET) • Existing regional calibration of certain ecological models • Availability of field and remote sensing across the region • Good linkages to other research themes • Existing partnerships with key stakeholders	• Conduct surveys or focus groups with stakeholders to understand potential alternative futures for the region • Explore model sensitivities and uncertainties to better understand data needs for improved parameterization • Complete baseline simulations to quantify current model behavior • Attempt regional inverse model parameterization using past and current data • Do a model comparison for selected field sites to better understand strength and weaknesses	• Improved localization of model parameterization • Documentation of alternative future scenarios that cover the range of possibilities throughout the region • Detailed short- and long-term projections of future conditions	• Improved understanding of model behavior • Better integration of existing models to leverage strengths of contrasting approaches • Increased communications and knowledge across ecological modeling disciplines	• Strategy for incorporating uncertainty in model projections and improving future projections • Novel framework for integrating available data streams to improve model predictions • Better understanding of data needs to ensure proper model parameterization	• Quantify the impact of various stressors on ecosystem integrity indicators & predict change across Northern Forest Region • Future vulnerability of certain locations through the region due to changes in condition • Certainty of future conditions and primary drivers of uncertainty • Greater knowledge of future variability of forests across the region • Ability to project future conditions from near real-time conditions	▪ Better forest management ▪ More informed forest policies that can guide long-term management ▪ Investment in infrastructure needed to improve future predictions ▪ Greater availability of model output to engage a range of key stakeholders ▪

Strategic Materials: Theme 3 Logic Model

	model calibration
Regional parametrization of existing models	Lack of funding for field campaign to map key variables
Long-term field sites and data for model evaluation	Limited high-resolution soils or ecological land classification for the region
Prior model sensitivity analyses	Mixed resolution of species and forest type mapping
Existing relationships with key stakeholders	No comprehensive map of stand age or time since last disturbance
Good linkages with other research themes	Lack of long-term historical disturbance data
Prior model scenarios for the region	
Complementary strengths from each institution	
Inclusion of early career faculty within the theme	
Experienced team members for managing significant research efforts	
Available graduate students and post-doc for conducting theme research	
Related ongoing and potential projects/proposals	
Existing regional data layers such as foliar N, LAI, and species composition	
New emerging technologies that would allow better parameterization	
Available computational infrastructure such as Google Earth or cluster network	
Ongoing effort to better map ecological land classification for GNF and WNF	
Current downscaling of climate data happening in UVM	
Current regional species mapping happening at UM	

Strategic Materials: Theme 3 SWOT Analysis

54 *Project Strategic Materials*

EXTERNAL FACTORS	
OPPORTUNITIES (+)	**THREATS (–)**
Unmixing MODIS LAI with higher-resolution remote sensing products	Lack of existing MOU with FIA for regional collaboration
Ability to incorporate TEM/CLM-FATES into regional projections	Model inter-compatibility
Extensive LiDAR coverage for better topographic mapping and ecological land classification	Stakeholder scenario fatigue
Intensification vs. extensification of forest management with linkages to climate	Spatial and temporal mismatch for model needs
Potential point simulation using intensive field sites	Changing ownerships/stakeholders
PnET/LANDIS simulations for potential scenarios including wind/ice damage or invasive insects	Model/version provenance
Expand ongoing climate downscaling to NH and ME	Loss of key personnel
Update existing regional EFI maps using recent LiDAR data	Reporting requirements
Update existing LandTrendr maps for region and derive stand age/height	
Mapping of stone wall boundaries	
Mapping of foliage N	
Availability of historical/NAIP aerial images	

Strategic Materials: Theme 3 SWOT Analysis

NSF INSPIRES Implementation Plan

THEME 3 RESEARCH OBJECTIVES MAP

Objective	Objective leads	Projects	Project responsible parties	Milestones Y1	Y2	Y3
3.1 Use advanced Informatics from Theme 2 to provide key data that allows for more effective model integration and parameterization. Conduct a Big Data–driven inverse parameterization, which creates a distribution of parameters by matching model outputs and observation, for two existing mechanistic forest projection models.	Foster, Simons-Legaard	3.1a Inverse parameterization of ecological models	Foster, Simons-Legaard	Identify necessary inputs for model development and refinement; Prioritizing information needs and sites for model evaluation;	Use FIA and long-term locations plots (e.g. Howland, Hubbard Brook) to complete an initial inverse parameterization of Landis II and PnET; Identify model parameter uncertainty	Complete model in parameterization ... small test landscap across the region; Identify model uncertainty at cert landscape features types of disturbanc
3.2 Leverage additional data across identified spatio-temporal gaps from Advanced Sensing and Computing of Theme 1 for improved model integration and decision making	Hayes, Burakowski, Ollinger	3.2a Model integration and application	Hayes, Burakowski, Ollinger	Assess model strengths and weakness; Initiate model sensitivity analyses; Outline a potential multi-model comparison	Complete model sensitivity analyses and model evaluation; Continue to refine model representation of disturbance and species response to climate	Initiate model integ and evaluate performance on se sites; Complete refinement of mod representation of disturbance and sp response to climat

Strategic Materials: Theme 3 Research Objectives

56 *Proj*

3.3. Perform broad-scale and contrasting simulations over a range of alternative futures. Visualize and analyze key outputs as well as uncertainty at the regional scale.	Weiskittel, D'Amato, Ducey, Gunn	3.3a Scenario assessment & trend analysis	Weiskittel, D'Amato, Ducey, Gunn	Synthesize prior regional research and needs; Outline potential research questions and necessary scenarios; identify key stakeholders	Complete regional baseline projections and assess outcomes; Present to stakeholders for input and feedback	Complete regional scenarios projectio assess outcomes; I to stakeholders for and feedback

Strategic Materials: Theme 3 Research Objectives

NSF INSPIRES Implementation Plan

THEME STAKEHOLDER MATRIX

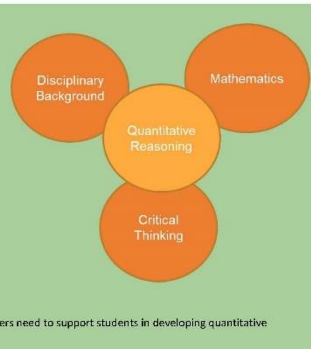
Stakeholder Name	Contact person	Field of activity	Purpose of engagement	Strategy for engaging	When will the stakeholder be/was engaged	How would the stakeholder contribute
Seven Islands Land Company	Ian Prior	Forest Analyst	To seek input on scenarios and inform about management implications	Email and in person discussions	Annually	Provide input on scenarios and outcomes
Maine Forest Service	Patty Cormier	State Forester	To seek input on scenarios and inform about management implications	Email and in person discussions	Annually	Provide input on scenarios and outcomes
Vermont Forests, Parks and Recreation	Mike Snyder	Commissioner	To seek input on scenarios and inform about management implications	Email and in-person discussions	Annually	Provide input on scenarios and outcomes
Northern Forest Center	Rob Riley	Director	To seek input on scenarios and inform about management implications	Email and in-person discussions	Annually	Provide input on scenarios and outcomes
The Nature Conservancy	Peter Ellis	Scientist	To seek input on scenarios and inform about management implications	Email and in-person discussions	Annually	Provide input on scenarios and outcomes

Strategic Materials: Theme 3 Stakeholder Matrix

THEME 4. QUANTITATIVE REASONING SKILLS IN CONTEXT

GOAL

Connect teachers and students to locally relevant research and datasets, broadening and deepening STEM engagement



OBJECTIVES

1. Develop/adapt materials for G6-12 that build QRC with opportunities to learn through data collection using sensors, asking & answering research questions about forests and the local environment & ecology using big data sets, and engaging in data visualization activities
2. Investigate the knowledge teachers need to support students in developing quantitative reasoning skills
3. Evaluate how students benefit from these opportunities

Strategic Materials: Theme 4

THEME 4 LOGIC MODEL

Inputs	Activities	Outputs	Outcomes: Short-term Outcomes	Intermediate-term Outcomes	Long-term Outcomes
			Year 1 →	→	Year 4
• Maine Center for Research in STEM Education (RISE Center) at UMaine (Education research faculty & professional staff including 2 early career faculty) • Maine Project Learning Tree • Leitzel Center, UNH (Professional staff) • Create a network of 12 middle school teachers & 12 high school teachers and their students • College of Education & Social Services, UVM (Education research faculty)	• Regular conversations with researchers on other themes to understand what data they are gathering and how • Summer Institutes • Teachers (Ts) collaborate with education research faculty and staff to develop curricular materials to support integration of research and data into middle and high school science classrooms • Ts collaborate with education research faculty and staff to refine curricular	• 24 Ts, 2 early career faculty, 3 postdocs, 12 graduate students, and 15-20 undergraduate students experience growth in their knowledge and ability to teach big data and quantitative reasoning in the context of forestry and are supported by project members • Curricular materials with assessments piloted and	• Activities serve as a pilot, developing collaborative relationships between participants across and within 3 states • Ts begin to develop an understanding of the integration big data, forestry, and quantitative reasoning • Ts have an understanding of the research being conducted by the project	• Education research contributes to understanding of the knowledge and supports teachers need to support quantitative reasoning in context in their classrooms • Curricular materials are developed to support integration of quantitative reasoning in context into classroom instruction	• **Curricular materials** and lessons learned are disseminated across the education networks of ME, NH and VT • Ts, early career faculty, postdocs, graduate students, and undergraduate students gain knowledge about Big Data and ways to integrate data and student-led research into classroom instruction while supporting quantitative reasoning in context (Increased capacity to teach about big data • **Middle and high** school students of

Strategic Materials: Theme 4 Logic Model

• Wabanaki Youth in Science (WaYS) • INSPIRES Postdocs, Graduate and Undergraduate Students	materials guided by data collection and community feedback • Final meeting in Year 4 for teachers across 3 states to share and disseminate education materials • Ts help lead the work of INSPIRES through participation on **project's external** advisory board • Research into supports needed for teachers to support quantitative reasoning and impacts for students	refined by in-service teachers • Two high school teachers gain leadership skills by being a part **of project's** external advisory board • Over 3,600 middle and high school students benefit from experience with locally relevant research and **develop** quantitative reasoning in context skills • Professional learning plans for summer institutes and academic year professional learning for teachers	• Ts participate in interviews focused on their use of quantitative reasoning in the classroom • Theme 4 researchers will have an understanding of the research being conducted by the project		the teachers trained by this project indicate an increased relevance of STEM fields to their daily lives/increased awareness of the relevance of forests to their lives/increased awareness of the relevance of Big Data to their daily lives • **Increased capacity to** provide professional learning for other teachers in Big Data, quantitative reasoning, and forestry and increased capacity to bring this knowledge and these tools to new students

Strategic Materials: Theme 4 Logic Model

THEME 4 SWOT ANALYSIS

INTERNAL FACTORS	
STRENGTHS (+)	**WEAKNESSES (–)**
Current relationships with teachers across the state through the Maine STEM Partnership	Working through research-practice partnerships requires excellent communication and is time-consuming
Experience conducting research focused on quantitative reasoning with Maine teachers	There is currently a lack of curriculum materials to support development of students' quantitative reasoning in context skills
Experience providing professional learning to Maine teachers focused on quantitative reasoning in context	There is currently a lack of data analysis and quantitative reasoning in context skills among students; these can also be challenging for teachers
Opportunity for three-state collaboration including collaboration with colleagues who have complementary skills, experiences, and infrastructure	Technology and computing resources are not uniform across school districts; some districts may be limited by lack of internet access
A strong, interdisciplinary, three-state team	There are differences across school districts in the level of freedom and opportunities allowed to teachers for carrying out project-based or outdoor activities
Opportunities to collaborate with Maine Tree Foundation and their statewide network of teachers	
Opportunities to collaborate with and learn from the other three INSPIRES themes	
The project team is already experienced in collaborating via electronic methods (which is important given the current situation with Coronavirus)	
EXTERNAL FACTORS	
OPPORTUNITIES (+)	**THREATS (–)**
Common Core and Next Generation Science Standards intersect on quantitative reasoning in context skills	Coronavirus and school closures have eliminated opportunities for classroom observation in Spring 2020
Current changes due to coronavirus and school closures are creating new interest in and support for out-of-classroom and project-based learning	Coronavirus and school closures have also raised uncertainty about school attendance for next year
There is an existing pool of teachers who would welcome supports for doing more project-based and outdoor learning with students	Coronavirus has also created challenges for many teachers, potentially limiting their time and ability to participate in research
There is a strong need for students to develop skills in quantitative reasoning in context and working with Big Data	Coronavirus has also limited our ability to hold group events for the near future, limiting or requiring changes in professional learning models
Maine, New Hampshire, and Vermont all have forest resources that are accessible for teachers and students in most school districts	Current standardized testing models emphasize teaching for accountability and sometimes limit project-based or inquiry-based opportunities
INSPIRES will expand the available data and data collection sites, providing increased opportunities for teachers and students to gather and work with locally-relevant forest data	

Strategic Materials: Theme 4 SWOT Analysis

Theme 4 Research Objectives Map

Objective	Objective leads	Projects	Project responsible parties	Milestones			
				Y1	Y2	Y3	Y4
4.1 Identify the types of knowledge and supports needed by secondary earth/physical science teachers to successfully involve students in scientific, data intensive explorations, in partnership with university faculty	Peterson, Shulman, Millay	4.1a Design and implementation of Big Data modules integrated into G6-12 curricular materials	Peterson, Toolin, Millay, Lindsay, McKay, Shulman, Nickerson	Ts have an understanding of the research being conducted by the project	Curricular materials are developed to support integration of quantitative reasoning in context into classroom instruction	Curricular materials are iterated to support integration of quantitative reasoning in context into classroom instruction	Curricular materials and lessons learned are disseminated across the education networks of ME, NH, and VT
		4.1b Use local Big Data to answer student- and community-relevant science questions	Peterson, Toolin, Millay, Lindsay, McKay, Shulman, Nickerson	Theme 4 researchers will have an understanding of the research being conducted by the project	Project research investigates student learning as curricular materials are piloted	Project research documents student learning through curricular materials	**Region's workforce** continues to benefit from the educational skills developed by project personnel, as well as from the enhanced skills of students impacted through middle and high school instruction
4.2 Identify the ways that students benefit from instruction focused on QRC of ecology, ecosystems, and community-relevant investigations	Peterson, Shulman, Millay	4.2a Investigate teacher needs to build **students' QRC**	Peterson, Toolin, Millay, Lindsay, McKay, Shulman, Nickerson	Ts participate in interviews focused on their use of context-driven quantitative reasoning in the classroom	Ts begin to develop an understanding of the integration big data, forestry, and quantitative reasoning in context; interviews provide evidence of learning for project research	Ts begin to develop an understanding of the integration big data, forestry, and quantitative reasoning in context; interviews provide evidence of learning for project research	Education research contributes to understanding of the knowledge and supports teachers need to support quantitative reasoning in context in their classrooms

Theme4 Stakeholder Matrix

Stakeholder Name	Contact person	Field of activity	Purpose of engagement	Strategy for engaging	When will the stakeholder be/was engaged	How would the stakeholder contribute	How would the stakeholder benefit
Maine TREE Foundation - Project Learning Tree	Logan Johnson	Citizen Science and Education	Support professional learning opportunities for teachers and student engagement around big data and forestry topics.	Ongoing conversation/meetings	We've met with MTF and Project Learning Tree personnel once in the past year to discuss collaboration. We'll have another conversation this spring and summer to determine what level of collaboration makes sense going forward.	Project Learning Tree may help identify teachers interested in participating in project activities and may be able to share some of their educational materials or models.	Project Learning Tree/Maine Tree Foundation will benefit by gaining connection with the RISE Center and a more evidence-based, research-based, standards-aligned model for offering professional learning to teachers.
Maine STEM Partnership	Marina Van der Eb	Teacher Professional Learning	Connect INSPIRES work to teachers and classrooms statewide	Present at Maine STEM Partnership Leadership Team meetings, the coordinator for the Maine STEM Partnership will work part-time on this project.	Currently engaged and will engage for the duration of the project.	Maine STEM Partnership provides connections to teachers and classrooms across the state.	Teachers and classrooms will benefit from the resources and strategies developed through INSPIRES.
Teachers in Maine, New Hampshire, and Vermont	Laura Millay	Teacher Professional Learning	Professional learning for teachers and engaging students in learning about big data through forestry contexts	Teachers will be recruited to participate in the project	Maine teachers will be recruited this spring, New Hampshire and Vermont teachers will be recruited next year	Teachers will help develop materials to use in classrooms	Teachers will gain professional learning about big data and forestry contexts and will have opportunities to collaborate with colleagues

3. AAAS DETAILED PROJECT BASELINE REPORT

AAAS | Research Competitiveness Program

REPORT
INSPIRES Baseline Survey: Faculty & Non-Faculty Researchers

The American Association for the Advancement of Science
Research Competitiveness Program
March 2020

Prepared by:
Maysaa Alobaidi, Ph.D.

Introduction

Leveraging Intelligent Informatics and Smart Data for Improved Understanding of Northern Forest Ecosystem Resiliency (INSPIRES) is an NSF EPSCoR RII: Track-2 collaborative project among investigators from the University of Maine, University of New Hampshire, and University of Vermont. The project aims to establish a regional Complex Systems Research Consortium that focuses on examining forest ecosystem integrity and resilience. To accomplish this aim, investigators from the three participating jurisdictions are working across four integrated themes to develop a "novel and flexible Digital Forest framework for effectively harnessing Big Data to enhance our fundamental understanding of Northern Forest ecosystems across multiple spatio-temporal scales."[1]

The project started in August 2019 and is scheduled to end in July 2023. In September 2019, the AAAS evaluator worked with the INSPIRES project leadership to develop a logic model and evaluation plan to help guide evaluation activities. As a first step to establish a baseline, two surveys were conducted - one targeting faculty and non-faculty researchers and the other targeting graduate students. At the time the baseline surveys were launched in January 2020, the project had enrolled only two graduate students. The Baseline Graduate Student Survey did not receive any responses; thus, this report focuses on findings from the INSPIRES Faculty and Non-Faculty Researcher Baseline Survey only.

The goal of the INSPIRES Faculty and Non-Faculty Researcher Baseline Survey was to collect baseline information about project participants, including demographics, professional backgrounds, and individual roles in the project. Information was also collected about prior and current collaborations, level of research productivity, and participants' perception about different aspects of project implementation. Data from the baseline survey will be used as a reference against which to measure progress over the course of the project. Annual surveys targeting different project constituencies, including faculty, researchers, graduate students, undergraduate students, and external stakeholders/partners are planned for years 1 through 4 to track annual progress made toward the achievement of project goals.

[1] INSPIRES Project Summary:
https://www.nsf.gov/awardsearch/showAward?AWD_ID=1920908&HistoricalAwards=false

Approach

After meeting with the project leadership and participants at the all-team meeting in December 2019, the AAAS Evaluator developed draft two survey instruments. The draft instruments were sent to INSPIRES Principle Investigator (PI) and Co-Investigators (Co-PIs) for review and input. The draft instruments were updated based on the feedback received from the project leadership and finalized.

The updated survey instruments were then converted into web-based surveys (using SurveyMonkey™ software (SurveyMonkey, San Mateo, CA, USA). A link for each of the survey instruments was forwarded to the INSPIRES project manager. The link was sent to INSPIRES project participants via email on January 24, 2020. The participants subsequently received two reminders to respond to the survey - one sent a week after sending the initial invitation and a second reminder after an additional week. Following the 3-week data collection period, the surveys were closed on February 14, 2020.

Survey Instrument

The development of the INSPIRES Faculty and Non-Faculty Researcher Baseline Survey instrument was informed by a review of project documents, discussions with the project leadership and participants, and a review of existing literature and instruments[1–6].

The final version of the survey instrument had 42 questions/items, which included a participant background section and seven domains:

Participants Background (12 items): name, institution, department, discipline, academic rank, project role, membership in project committees, affiliation with project themes and related research projects, gender, and race/ethnicity

Project Implementations (4 items): attendance to project kick-off and all-team meetings, understanding of different aspects of the project, and concerns about project implementation feasibility

Collaborations (6 items): prior and current collaborations, perceived benefits of collaborations, and perceived barriers to collaborations

Research Productivity (7 items): number of articles, books, presentations, patents, software, and other research outputs produced, as well as number of grant applications submitted and awarded in the previous year

Mentoring (4 items): number of students mentored, number of faculty mentored/mentees, and mentoring process

Professional Development (2 items): professional development opportunities pursued and barriers to pursuing professional development in the previous year

External Stakeholder Engagement (2 items): current and planned engagements with external stakeholder groups

Anticipated Project Impacts (5 items): anticipated impact of the project on opportunities to apply for future funding, knowledge creation, addressing the region's computational needs, building G6-12 students' data literacy, and future forest policy and management strategies

Survey Findings

Based on the INSPIRES project team roster in January 2020, the project involves the participation of a total of 38 faculty and non-faculty researchers from three different jurisdictions (Maine, New Hampshire, and Vermont). The INSPIRES Faculty and Non-Faculty Researcher Baseline Survey received 29 responses, which constitutes a response rate of 76.3%. The respondents had the option to skip any question(s) they did not wish to answer.

INSPIRES Faculty and Researchers

Of those who participated in the survey, 15 (51.7%) identified as female, and the majority of respondents (89.9%) identified as white (Table 1). The number of project participants in each category will be tracked from year to year, over the next four years to report on changes in project participants' demographics.

Table 1: Survey Respondent Characteristics

Characteristic	Number of Responses	Percentage
Gender		
Female	15	51.7%
Male	13	44.8%
Race/Ethnicity		
Asian	2	6.9%
White	26	89.7%

The NSF EPSCoR RII Track 2 Program places a significant emphasis on the development of diverse early-career faculty as a critical component of building a sustainable STEM capacity.[7] The INSPIRES faculty composition leans towards early-career investigators as shown in Table 2 which illustrates the distribution of survey responses by academic rank/title (based on career stage designation in team roster, 16 (55.2%) survey participants were early career). Among survey respondents, 8 (53.3%) early career faculty or researcher identified as female.

Table 2: INSPIRES Participants by Academic Rank/Title

Academic Rank/Title	Number	Percentage
Professor	8	27.6%
Associate Professor	3	10.3%
Assistant Professor	4	13.8%
Research Assistant Professor	6	20.7%
Research Scientist	2	6.9%
Professional Staff	3	10.3%
Postdoctoral Researcher	2	6.9%
Other	1	3.4%

Also, among the primary goals of the NSF EPSCoR RII Track-2 Program is to promote multi-institutional, multi-jurisdictional research collaborations. Table 3 illustrates the number of INSPIRES faculty and researchers from each jurisdiction and institution who participated in the survey. The number of project participants from each jurisdiction and institution will be tracked from year to year to assess the project's commitment to multi-institutional and multi-jurisdictional representation in its research, education, and training activities.

Table 3: INSPIRES Participants by Jurisdiction/Institution

Jurisdiction/Institution	Number	Percentage
Maine		
University of Maine	13	44.8%
New Hampshire		
University of New Hampshire	9	31%
Dartmouth	1	3.5%
Appalachian Mountain Club	1	3.5%
Vermont		
University of Vermont	5	17.2%

Multidisciplinarity is a key driver of the NSF EPSCoR RII Track-2 Program. The survey asked participants to identify their primary discipline. Based on responses from the baseline survey, the INSPIRES project involves faculty and researchers representing 15 disciplines (Table 4).

Table 4: INSPIRES Participants by Discipline

Discipline	Number of Participants
Ecosystem Ecology/Ecosystem Science	4
STEM Education/Research	4
Biogeochemistry	4
Forest Ecology/Forestry/ Forest Ecology and Silviculture	3
Ecology	2
Remote Sensing	2
Data Science	2
Forest Biometrics	1
Computer Engineering	1
Earth Science	1
Wildlife Ecology	1
Geographic Information Science (GIS)	1
Cyberinfrastructure	1
Computer Science	1
Physics	1

Project Implementation

Engagement of Project Participants

A critical component of the evaluation plan is to assess how the INSPIRES project is implemented, with a focus on describing activities and processes undertaken to achieve project goals. The goal of this component of the evaluation is to provide feedback to the project leadership to help improve the effectiveness of project implementation.

Project implementation started with the leadership organizing a *kick-off meeting* and inviting all members of the project team to participate. The meeting was held virtually in early September 2019. The goal of the meeting was to introduce the project, ensure the participants understand the project's vision and objectives, bring participants from different institutions and departments together, and begin the project team-building process. Of the 29 survey participants, 21 (72.4%) indicated that they participated in the kick-off meeting.

An *all-team meeting* was held mid-December 2019 to provide an opportunity for project participants to get to know each other, share their ideas and collective expertise to inform the development of specific objectives and implementation plans for each of the project's four themes, and to set expectations across the entire project team in terms of roles and responsibilities and key milestones. A total of *25* survey respondents *(86.2%)* indicated that they participated in the all-team meeting.

Project Internal Communication

In conjunction with the kick-off and all-team meetings, the project leadership put in place an infrastructure to facilitate internal communication and collaborations among members of the project team. To facilitate online collaboration, access, and sharing of project documents, INSPIRES leadership deployed *Box*, a cloud content storage and management service. The project leadership also encouraged team members to use *Slack* as a communication platform among participants of the project.

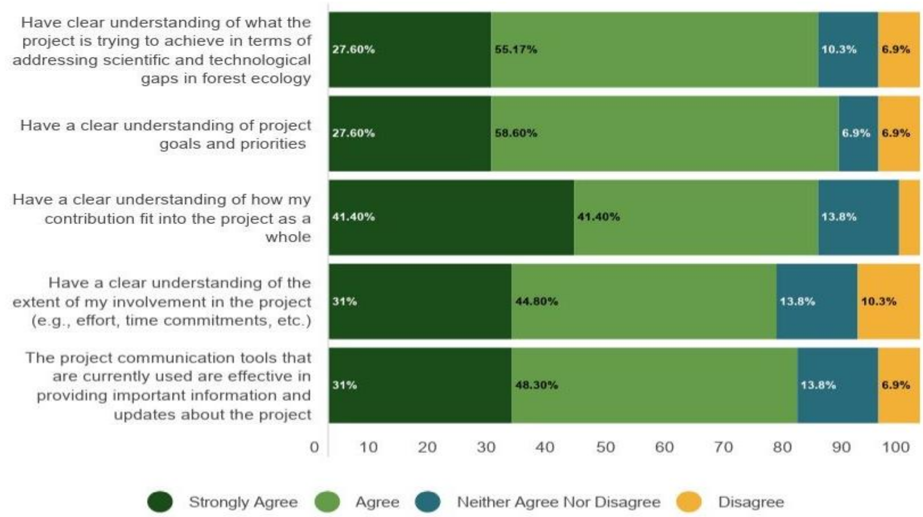


Figure 1. Participant Understanding of Project Goals and Priorities and their Role and Expected Contribution.

A *governance agreement* was created that outlines the responsibilities of project leadership and participants, as well as the decision-making structure and process for the project. The leadership promoted inclusive development of the agreement by asking all members of the team to review and provide input on the agreement during the all-team meeting in December. An implementation plan was also developed for the project to serve as a reference document for participants as they implement different aspects of the project.

The INSPIRES Faculty and Non-Faculty Researcher Baseline Survey included questions that asked participants to indicate the extent of their agreement with several statements that describe their understanding of the project's goals and priorities as well as their role and expected contributions to the project. On average, more than 75% of respondents indicated agreement (either agreed or strongly agreed) with the statements as shown in Figure 1. Participants who either disagreed or were neutral (neither agreed or disagreed) represent different career stages and were affiliated with different institutions.

A few participants provided comments in response to the communication statement, for example, one participant indicated that project members do not use Box and Slack for communication in their other projects. As such, having to login to use these tools exclusively for INSPIRES is perceived as a hassle and may contribute to lack of utilization of these communication and collaboration tools. A recommendation was made to bring the project team together for a 'communication-focused session' or focusing on this issue in group meetings as a potential solution to this challenge. Another participant highlighted communication challenges attributed to the lack of activity in some Slack channels. This is perceived as a barrier for participants who are trying to develop and sustain a collaborative relationship with

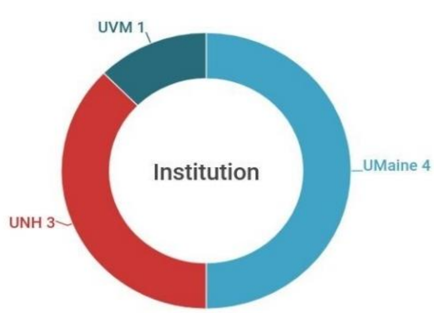


Figure 2a: CRC Membership, by Institution

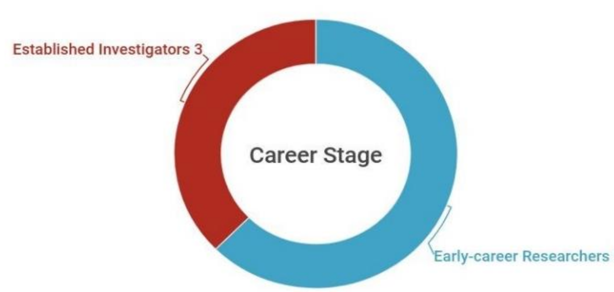


Figure 2b: CRC Membership, by Career State

other project members working in the same theme area. Finally, a suggestion was made by one of the participants to clarify to project members who the theme leads are in order to facilitate communication within and across themes.

The survey also included questions that asked participants to indicate whether they are currently involved in one or more INSPIRES project committees. A total of eight survey participants indicated their involvement with the Collaborative Research Committee (CRC). The breakdown of committee members by institutional affiliation and career stage is provided in Figures 2a and 2b.

A total of five survey participants indicated their involvement with the Mentoring, Education, and Engagement (MEE) Committee. The breakdown of committee members by institutional affiliation and career stage is provided in Figures 3a and 3b.

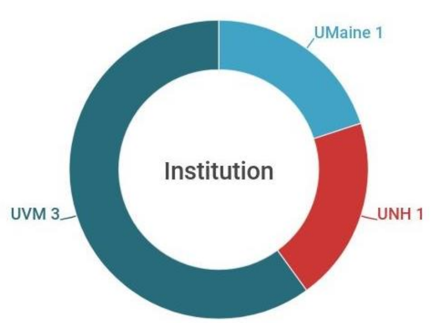


Figure 3a: MEE Committee Membership

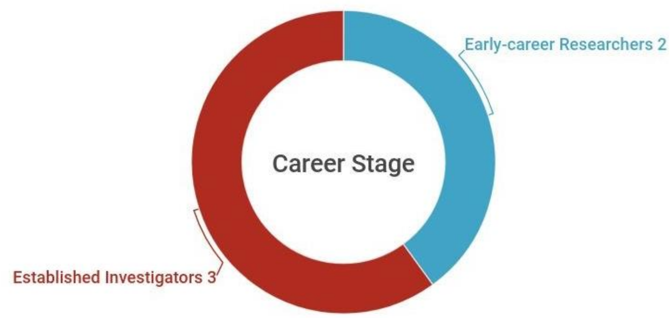


Figure 3b: MEE Committee Membership

The involvement of early-career faculty and researchers in INSPIRES project committees demonstrates alignment with the NSF EPSCoR RII Track-2 focus on the development and preparation of diverse early-career faculty for future leadership roles[7]. The annual surveys will collect more detailed information on the benefits to early-career researchers form involvement in project committees.

Implementation Barriers

Participants were asked about possible concerns with the project implementation feasibility. As shown in Figure 4, time constraints and funding limitation were identified as key concerns.

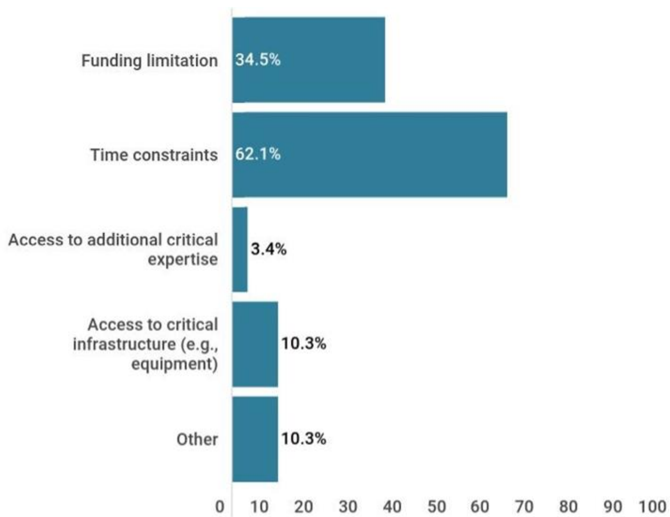


Figure 4: Concerns about Project Implementation Feasibility

Among the other concerns identified were needs for:

- Communication with the other teams in the project
- A clear set of research questions for the project
- Integration among project themes
- Access to the right big data collection
- Opportunities for face time with project teams

The project leadership may want to consider ways to address the barriers reported by the participants, especially in the area of time constraints. For example, project participants may benefit from additional refinement of team goals, and structured mentorship or training to support development of feasible milestones and sub-project timelines.

Table 5: Representation on INSPIRES Project Themes

Theme	Number of Jurisdictions (Institutions)	Number of Disciplines	Number of Investigators	Number of Early-Career Faculty and Researchers (%)
Theme 1: Advanced Sensing and Computing Technologies	3 (5)	9	10	6 (60%)
Theme 2: Smart Environmental Informatics	3 (3)	7	9	7 (77.8%)
Theme 3: Integrated Ecological Modeling	3 (4)	12	16	11 (68.8%)
Theme 4: Quantitative Reasoning Skills in Context	3 (4)	7	7	1 (14.3%)

Collaborations

Inter-jurisdictional and multi-institutional collaborations is a key focus of the NSF EPSCoR RII Track-2 program. The INSPIRES project aims to promote such collaborations by enabling its participants to work across four integrated research themes. Responses from the baseline survey clearly demonstrate the multi-jurisdictional, multi-institutional,

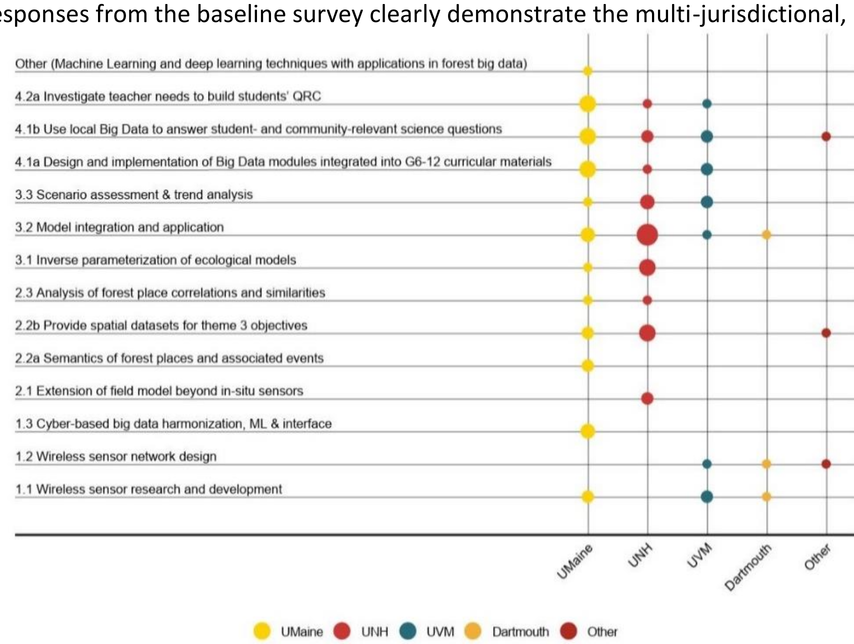


Figure 5: Cross-Institutional Representation on INSPIRES Research Projects

and multidisciplinary natures of the project (Table 5). They also illustrate alignment with the focus to involve early-career faculty across project activities. Project participants may work on more than one theme or research project.

Each of the four project themes include multiple research projects. As shown in Figure 5, most of the research projects include participants from at least three institutions. The sizes of the bubbles in the figure represent the relative number of participants from each institution. Figure 6 shows the specific disciplines represented in each project theme.

Enhancing research competitiveness and developing research capacity are among the primary goals of the NSF EPSCoR RII Track-2 program.[7] One aspect of growth in research capacity at the project and individual researcher levels is the enhanced access to knowledge, expertise, equipment, and collaborators through the participation in collaborative research networks.[2]

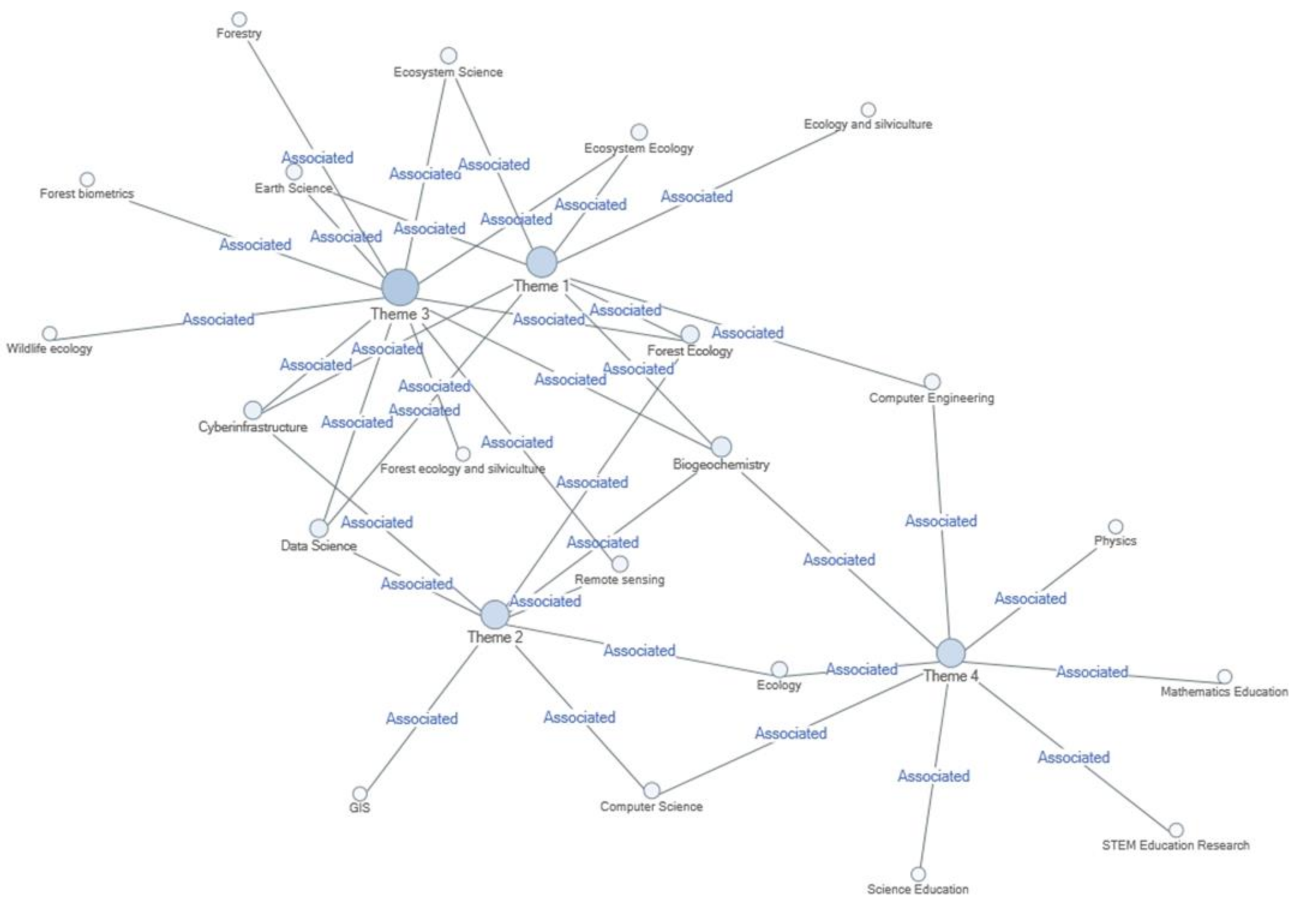


Figure 6: Cross-disciplinary Collaborations within Each Theme

The INSPIRES Faculty and Non-faculty Researcher Baseline Survey included a set of questions to examine the collaboration networks developed to achieve project goals. The first question asked participants to indicate if they are currently working with other members of the project team on INSPIRES-related activities and to specify the nature of that collaboration (e.g., working on research projects, grant proposals, publications, presentations, mentoring or training, and/or committees/work groups). Figure 7 shows current relationships among INSPIRES faculty and researchers. The node (circle) size represents the centrality of the participant to the network and the line thickness represents the number of connections they have with other INSPIRES participants.

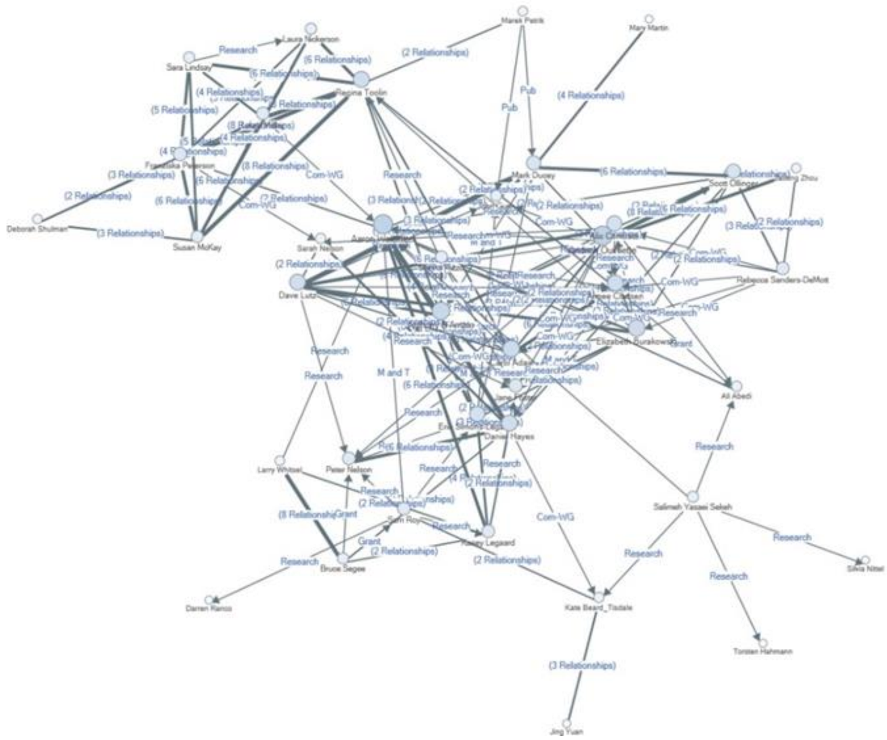


Figure 7: Current Collaborations on INSPIRES-Related Activities

Overall Inspires-related Network Metrics: Density = 0.104; Reciprocity = 0.514; Centrality = 6.33; Betweenness = 49; Closeness = 0.011

The density of a network reflects the extent to which members of the project know each other, and consequently, the extent to which information and resources are available in the network.[8,2] The density of the current collaboration network on INSPIRES- related activities is 0.104 (10% of *all possible connections or relationships* in this network are actualized). The average number of connections reported by survey participants to other members of the project is six, and only 50% of these connections are reciprocated (connections reported in the opposite direction between the

[2] ***Reciprocity:*** the proportion of relationships in the network that are reciprocated.

Centrality: the number of participants in the network to which a given participant is directly connected.

Betweenness: how often the participant lies on the shortest path between two other participants (i.e., which person is most likely to have the most information flowing through them).

Closeness: a measure of reach and indicates who has the easiest and quickest access to information in the network (how close a participant is to all other participants in the network).

same people). In Figure 7, lines without arrowheads represent bidirectional relationships (reciprocal), while arrowed lines represent unidirectional relationships.

Another survey question asked participants to indicate if they are currently working with other members of the project team on non-INSPIRES-related activities and to specify the nature of those collaborations. Figure 8 shows current collaborations among INSPIRES faculty and researchers on such activities.

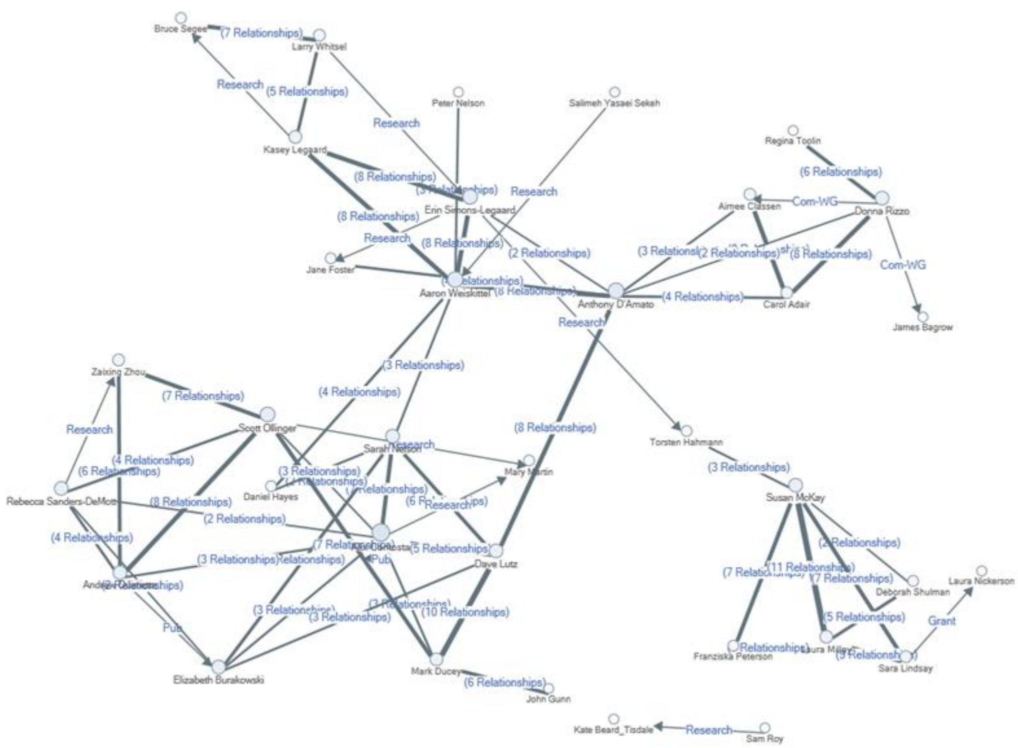


Figure 8: Collaborations on Non-INSPIRES-Related Projects

Overall Non-INSPIRES-related Network Metrics:
Density = 0.049; Reciprocity = 0.612; Centrality = 2.83; Betweenness = 66.5; Closeness = 0.055

As the overall network metrics indicate, the non-INSPIRES activities network has less density in comparison to the network in Figure 7 (5% of all possible relationships in this network are actualized). Participants also reported lower number of relationships on average (approximately three).

Finally, participants were asked to indicate if they have collaborated with other members of the project team prior to INSPIRES and to specify the nature of those collaborations. Figure 9 shows that the prior collaboration network is slightly less dense in comparison to the current collaboration network on INSPIRES-related activities depicted in Figure 7 (9% of all possible relationships in this network are actualized). On average, participants also reported slightly lower numbers of relationships (approximately five) compared to the network in Figure 7.

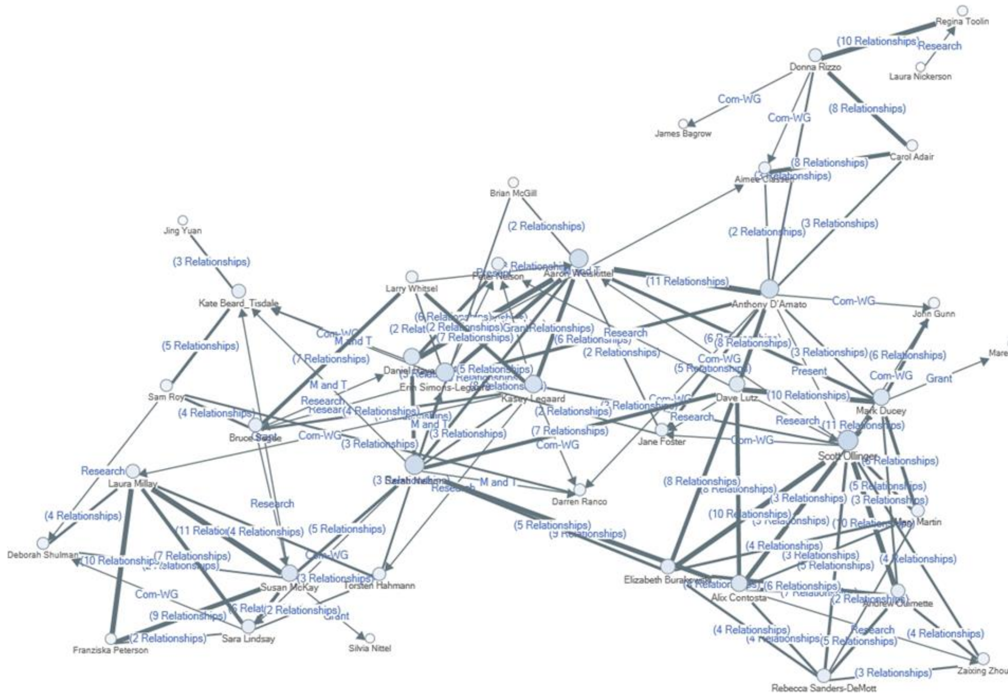


Figure 9: Collaborations Prior to INSPIRES

Overall Network Metrics: Density = 0.090; Reciprocity = 0.568; Centrality = 5.29; Betweenness = 58.2; Closeness = 0.010

Findings from the survey indicate that a research collaboration network among members of the project team already existed prior to INSPIRES. The positive implication of these findings is that project members have worked with each other previously, and thus, they may be better able to coordinate their efforts and achieve the goals of the INSPIRES project. The annual surveys will measure the benefits of leveraging existing networks, and monitor access to new collaborations, information, and resources to determine the extent to which the INSPIRES project has leveraged and expanded existing relationships to develop new capacity. As the relationships among project participants continue to develop over the course of the project life cycle, and as researchers become more familiar with each other's role on the project as well as the sequence and dependency of project tasks/activities, there will be more opportunities to optimize linkages among participants from different institutions, disciplines, themes, and research projects.

Examination of network metrics based on the type of collaboration shows differences in network density for each type of collaboration among the three networks (Table 6). Collaborations in the network for current INSPIRES-related activities seem to focus more on research projects compared to other activities, which makes sense given that the project only started three months prior to the survey launch. The level of collaboration on grant proposals and publications in this network is lower than the collaboration levels in the 'Prior Network'. This is expected to change as the project progresses and participants start publishing and presenting their research results and leveraging these results to apply for future funding. When comparing the three networks, the density of collaborations on research projects in the current INSPIRES-related network is higher than that of the other two networks.

Table 6: Network Metrics, Based on Type of Collaboration

Network Metrics	Research Projects	Grant Proposals	Publications	Presentations	Mentoring/ Training	Committees/ Work Groups
Current INSPIRES-Related Collaborations						
Network Density	0.082	0.028	0.024	0.015	0.023	0.037
Average Number of Collaborations	4.81	1.86	1.62	1.14	1.76	2.86
Reciprocity	0.567	0.408	0.341	0.154	0.103	0.095
Current Non-INSPIRES-Related Collaborations						
Network Density	0.042	0.023	0.033	0.02	0.017	0.016
Average Number of Collaborations	2.52	1.48	1.83	1.29	1.2	1.04
Reciprocity	0.548	0.450	0.643	0.457	0.276	0.429
Prior Collaborations						
Network Density	0.062	0.053	0.041	0.041	0.031	0.035
Average Number of Collaborations	3.57	3.19	2.33	2.48	2.19	2.28
Reciprocity	0.598	0.543	0.620	0.535	0.264	0.4

Network metrics were also analyzed by participant career stage and role in the project (Table 7). In the current INSPIRES-related collaborations network, the PI has higher proportion of connections compared to others indicating a more central position in the network. The INSPIRES project seems to enable early-career researchers to establish connections (higher average number of connections compared to prior and current non-INSPIRES networks and compared to established investigators).

In the current network for INSPIRES-related collaborations, early-career researchers have lower numbers of incoming ties (In-degree Centrality) on average, compared to established investigators but higher numbers of outgoing ties (Out-degree Centrality).[3] A higher number of outgoing ties indicates higher levels of engagement, as participants initiate connections with other members of the project team. This pattern is reversed for established investigators, who have higher numbers of incoming ties on average, indicating they are more likely to be sought after for guidance, information, and resources.

[3] **Out-degree Centrality:** the number of relationships or ties a participant has initiated with others on the project; **In-degree Centrality:** the number of relationships or ties directed towards a participant.

Table 7: Network Metrics[4], Based on Project Role and Seniority

Participant Characteristics	Degree Centralization	In-degree Centrality	Out-degree Centrality	Betweenness Centrality	Closeness Centrality
Current INSPIRES-Related Collaborations					
PI	15	13	6	442.9	0.016
Co-PIs	7.5	7	3.5	56	0.012
Senior Personnel	6.1	4	4.1	24.6	0.011
Early Career (Yes)	6.6	3.8	4.5	42.1	0.011
Early Career (No)	6	4.8	3.9	58.2	0.011
Current Non-INSPIRES-Related Collaborations					
PI	7	5	5	294.59	0.013
Co-PIs	3.5	2.8	2.5	113.93	0.256
Senior Personnel	2.4	1.8	1.6	60.29	0.041
Early Career (Yes)	2.71	2.08	1.71	54.8	0.05
Early Career (No)	3	2	2.5	81.9	0.06
Prior Collaborations					
PI	12	9	8	264.3	0.013
Co-PIs	8	6	5.3	175.6	0.011
Senior Personnel	5.3	3.7	3.7	56.2	0.009
Early Career (Yes)	5.1	3.7	3.3	32.4	0.009
Early Career (No)	6.2	4.2	4.7	108.3	0.010

Examination of the structure of the three networks also indicates that investigators with a more senior role on the project (e.g., PI and Co-PIs) have higher betweenness centrality compared to others signifying their role as 'bridges' (i.e., facilitate the flow of information and resources) between participants in the networks.

[4] **Degree Centralization*:*** the number of participants in the network to which a given participant is directly connected; **Betweenness Centrality*:*** how often the participant lies on the shortest path between two other participants (i.e., which person is most likely to have the most information flowing through them); **Closeness Centrality*:*** a measure of reach and indicates who has the easiest and quickest access to information in the network (how close a participant is to all other participants in the network).

Perceived Benefits of Collaborations

The INSPIRES Faculty and Non-Faculty Researcher Baseline Survey asked participants to indicate their level of agreement with several statements describing potential benefits of collaborations established as part of the INSPIRES project.

As shown in Figure 10, participants tended to report a higher level of agreement with statements describing benefits from collaborations at the individual level:

- Facilitating knowledge generation and transfer
- Facilitating resources sharing
- Contributing to career development of early career faculty
- Providing opportunities to work on new topics
- Providing opportunities to extend expertise in new directions
- Providing opportunities to work with investigators in other jurisdictions

Participants reported a lower level of agreement with statements describing benefits from collaborations at the collective/project level:

- Developing innovative solutions to research and technology problems
- Improving commercial application of research
- Contributing to student training
- Providing opportunities to publish in journals outside primary discipline

Since the project is still at an early stage, these findings are not surprising. Benefits from collaborations at the individual level are realized earlier than at the collective or project levels and are considered a critical aspect of research capacity building (e.g., through contribution to enhanced research productivity, lower research costs due to resource sharing, etc.). Annual surveys will be used to track changes in the perception of the benefits of project collaborations over the course of the project life cycle.

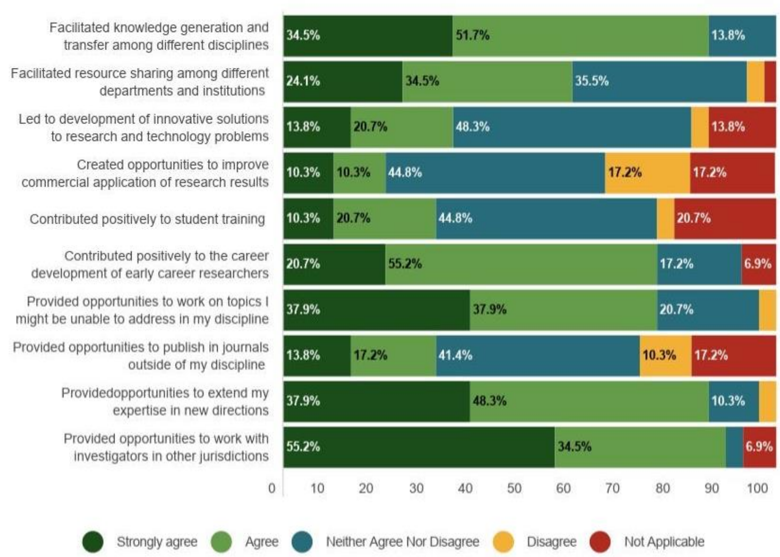


Figure 10: Perceived Benefits of INSPIRES Collaborations

Barriers to Collaborations

The survey asked participants to identify barriers to successful project collaborations. Familiarity with each other's disciplines and research approaches as well as communication among different disciplines were identified as barriers by many respondents (Figure 11). Researchers trained in a specific discipline learn to speak a certain language and adopt methodological approaches that may not be shared by those who are trained in other disciplines, which represent a challenge to interdisciplinary collaborations.[9] While it is normal to expect that it will take time and effort on the part of participants to become familiar with each other's disciplinary languages and approaches, it might be beneficial for the project leadership to explore mechanisms to accelerate the familiarization process.

Additional barriers identified by survey participants include:

- The need for more clarity on the science goals of the project (define what question(s) the project wants to answer or what specific problem it is trying to solve).
- Time constraints
- Differences in training and focus
- Lack of communication
- The need to implement team building approaches
- The need to Identify project theme leads

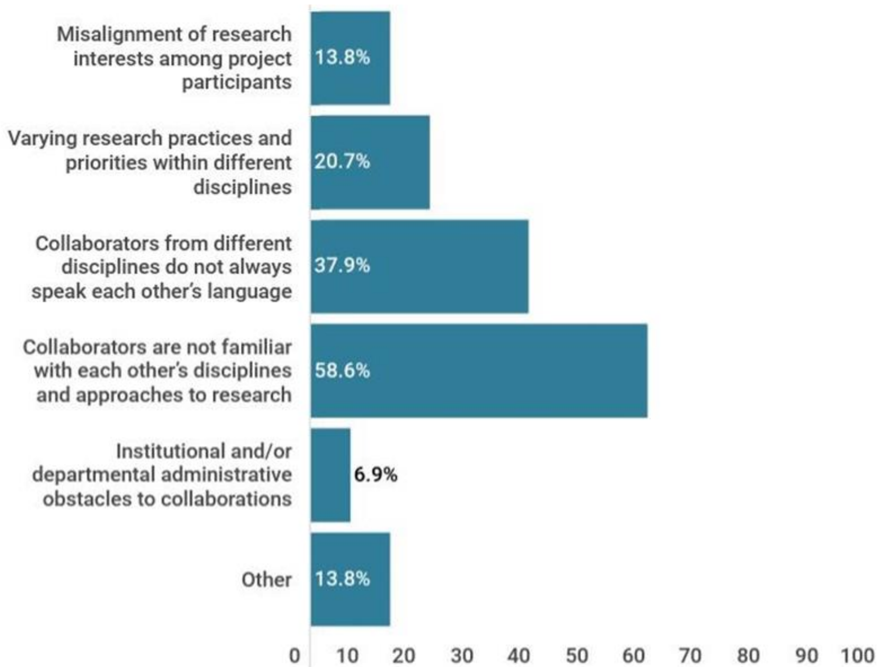


Figure 11: Perceived Barriers to INSPIRES Collaborations

Research Productivity

Survey participants were asked to indicate the number of various types of research outputs they produced in 2019 (Table 8).

Table 8: Research Products by Project Participants in 2019

Number of Products	Articles	Books	Presentations	Patents	Software
	Number of Respondents				
1-3	8	8	6	3	4
4-6	5	1	9	-	-
7-10	4	-	7	-	-
>10	3	-	-	-	-

In addition to the research products outlined in table 9, participants listed the following outputs:

- Protocols and education/outreach products
- Published data sets and educational materials
- Conference abstracts

Changes in the level of research productivity will be tracked through the annual surveys from year to year, across different career stages, disciplines, and project themes.

The impact level of the project members' publications at baseline was assessed by examining the profile of the journals to which survey participants submitted articles in 2019. Journal profile was examined using two bibliometric measures[5]:

Eigenfactor Score: calculated based on the number of articles published in a journal and its citation, compared to all scientific articles published. It considers which journals have contributed to these citations so that highly cited journals will influence the network more than lesser cited journals. References from one article in a journal to another article from the same journal are removed, so that Eigenfactor Scores are not influenced by journal self-citation.

Impact Factor: defined as all citations to the journal in the current Journal Citation Reports (JCR) year to items published in the previous two years, divided by the total number of scholarly items (these comprise articles, reviews, and proceedings papers) published in the journal in the previous two years.

The total number of published articles in 2019 reported by survey participants was 75 (conference proceedings were not counted, and the same article reported by more than one researcher was counted once). An additional five articles were submitted and accepted, but not published within that calendar year. The profile of the 56 journals listed by survey participants is provided in Table 10. The average Eigenfactor Score for journals was 0.077 (median=0.015) and the average Impact Factor was 4.72 (Median=3.95).

Bibliometric measures for the following journals were not available through *the 2018 Journal Citation Reports (JCR)*[6]:

- Environmental Research Communications (1 – published)
- Earth's Future (1 – submitted (accepted))
- Conservation Science and Practice (1 – published)
- Ecological Processes (1 – published)
- Mathematical and Computational Forestry & Natural-Resource Sciences (1 – published)

Annual surveys will be used to track numbers of publications and quality of journals from year to year to see if involvement in the project contributed to enhanced visibility of the participants' research.

Table 9: Journal in Which Project Participants Published in 2019

Full Journal Title	Journal Impact Factor	Eigenfactor Score	Number Submitted (Accepted)	Number Published
PLoSOne	2.776	1.706450		1
Proceedings of The National Academy of Sciences of The United States of America	9.580	1.021890		2
Geophysical Research Letters	4.578	0.185350		1

[5] InCites Journal Citation Reports: http://help.incites.clarivate.com/incitesLiveJCR/overviewGroup/overviewJCR.html
[6] Journal Citation Reports (Clarivate Analytics): http://clarivate.libguides.com/jcr

Science of The Total Environment	5.589	0.131290		1
New Phytologist	7.299	0.082470		1
Global Change Biology	8.880	0.075640		3
Nature Reviews Microbiology	34.648	0.054580		1
Environmental Research Letters	6.192	0.053450	1	3
Remote Sensing	4.118	0.048660		2
Biogeosciences	3.951	0.046690		1
Ecology	4.285	0.041450		1
Journal of Environmental Management	4.865	0.038380		1
Soil Biology & Biochemistry	5.290	0.031750		1
Forest Ecology and Management	3.126	0.031550		11
Ecological Indicators	4.490	0.030590		1
Cryosphere	4.790	0.024050		1
Journal of Ecology	5.687	0.023130		1
Global Ecology and Biogeography	5.667	0.021920		1
Geoderma	4.336	0.021880		1
Nature Plants	13.297	0.020090		1
Ecosphere	2.746	0.019500		4
Full Journal Title	Journal Impact Factor	Eigenfactor Score	Number Submitted (Accepted)	Number Published
Ecological Applications	4.378	0.018960		1
Global Biogeochemical Cycles	5.733	0.018100	1	
Nature Ecology & Evolution	10.965	0.016660		1
Ecological Modelling	2.634	0.015220		1
Ecology and Society	4.136	0.015060		1
Landscape and Urban Planning	5.144	0.014880	1	1
American Journal of Botany	2.858	0.013240		1
Biological Invasions	2.897	0.013050		1
Theoretical and Applied Climatology	2.720	0.012790		1
Ecosystems	4.555	0.011170		4
Biogeochemistry	3.406	0.010080		1
Forests	2.116	0.009070		2
Soil Science Society of America Journal	1.997	0.007280		3
Canadian Journal of Forest Research	1.703	0.006240		2
Earth System Dynamics	4.351	0.005950	1	
Ecohydrology	2.564	0.005880		1

IEEE Geoscience and Remote Sensing Magazine	9.659	0.003270		1
Journal of Environmental Planning and Management	1.855	0.003090	1	
Forestry	2.876	0.002640		2
Agroforestry Systems	1.792	0.002390		1
Arctic Antarctic And Alpine Research	1.708	0.002370		1
BMC Ecology	2.381	0.002270		1
Scandinavian Journal of Forest Research	1.667	0.002240		1
Canadian Journal of Remote Sensing	2.553	0.001890		1
Journal of Forestry	1.980	0.001720		1
Carbon Management	1.463	0.001550		1
Natural Areas Journal	1.032	0.000950		1
Northeastern Naturalist	0.488	0.000910		1
Forestry Chronicle	0.800	0.000850		1
Forest Ecosystems	1.852	0.000820		1

A few participants suggested "automating" the process of collecting information about research products or outputs as it was perceived as time consuming (for example, if project participants did not have a typed list of publications, presentation, and grants available, they had to create that list when responding to the survey). One way to address this issue is to ask project participants to create an ORCID ID and to use this ID when submitting abstracts, manuscripts, and/or grants. This will facilitate the longitudinal tracking of research outputs without having to ask project participants to provide a typed list of publications, presentations, and grants at the end of each year.

The number of participants who applied for funding in 2019, number of awarded investigators, number of grant proposals submitted, and number of awards by type of funding source are provided in Figure 12. The Federal Government was the primary target and source of funding for project members who participated in the survey followed by home institutions. The annual surveys will track changes in grant application success rate from different sources by career stage.

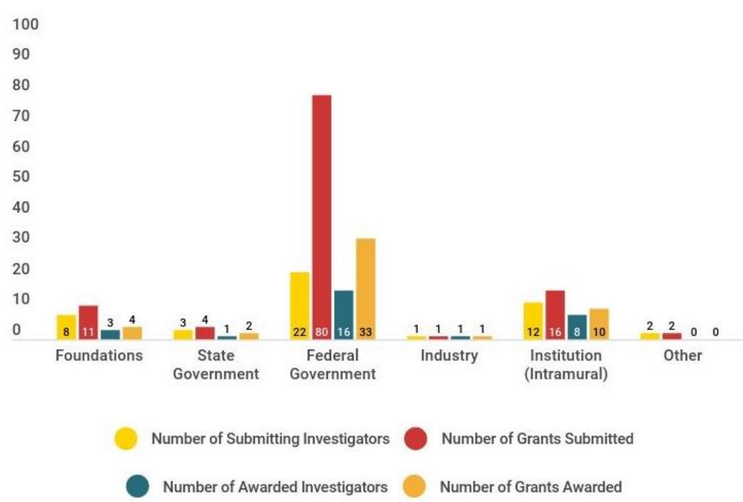


Figure 12: Funding Applications and Awards of Project Participants, by Funding Source in 2019

Mentoring

Survey participants reported involvement in mentoring relationships as mentors, mentees, or both. As shown in Figure 13, four faculty members reported mentoring early-career researchers affiliated with INSPIRES. Seven early-career researchers and faculty reported being mentored by senior INSPIRES faculty.

Of the four participants who reported mentoring INSPIRES-affiliated early-career faculty and researchers, three respondents specified the areas in which they work with their mentees:

- Review/tenure/promotion (2 – to some extent, 1 – not applicable)
- Teaching (1 – to some extent, 1 – to a small extent, 1 – not applicable)
- Research (3 – to a large extent)

Of the 29 survey participants, 19 (65.5%) indicated that they mentored graduate students in 2019 and 9 (31%) said they mentored postdoctoral fellows. Two participants reported mentoring INSPIRES-affiliated students (all graduate students), but only one specified the areas in which they work with their mentees:

- Professional development and networking (to a large extent)
- Career interest (to a very large extent)
- Research projects and interests (to a very large extent)
- Educational choices and strategies (to a large extent)

Participants were asked if they use Individual Development Plans (IDPs) or Mentoring Compacts (MCs) when working with mentors and/or mentees. Only three respondents reported using IDPs and two reported using MCs.

More detailed information on the nature and benefits of mentoring will be collected through the faculty, non-faculty researcher, and student annual surveys. Meanwhile, the project leadership may want to consider using more formal or structured approaches to mentoring (both, for students and early-career researchers).

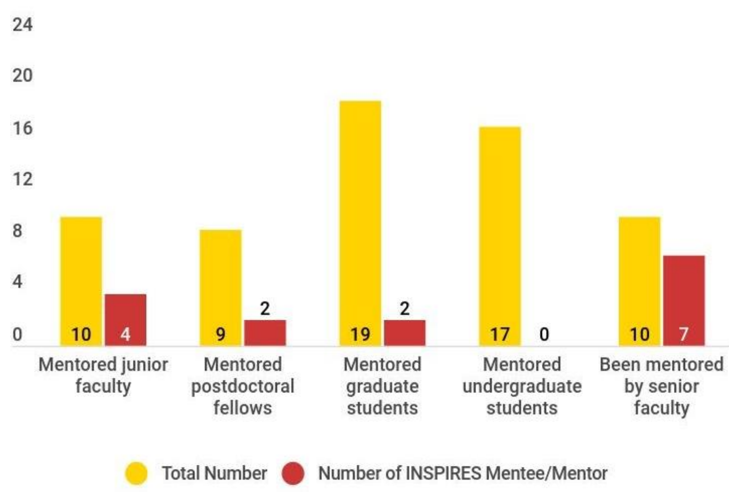


Figure 13: Mentoring Relationships Reported by Survey Participants

Professional Development

The INSPIRES Faculty and Non-Faculty Researcher Baseline Survey included two questions about professional development opportunities pursued in 2019. As illustrated in Figure 14, conferences and professional meeting constituted most of these professional development activities, followed by grant writing training and training to improve teaching skills.

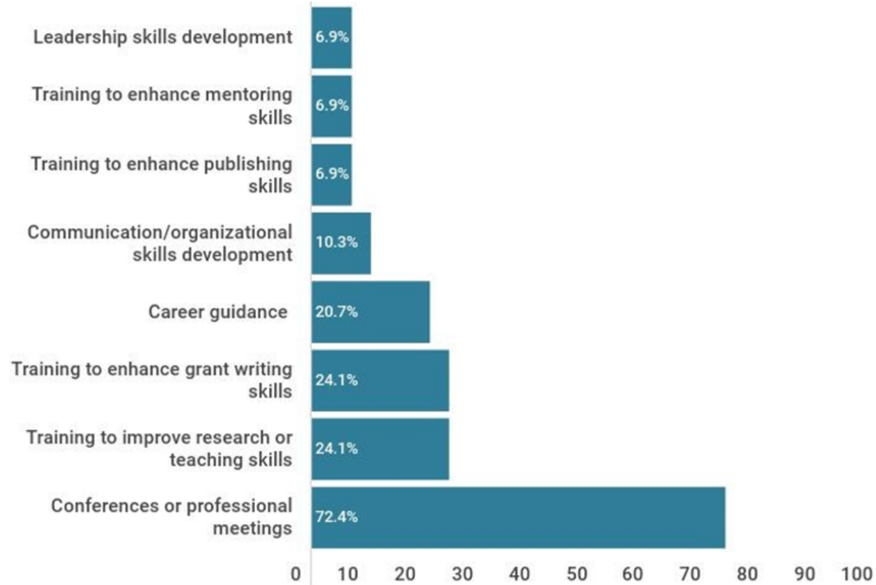


Figure 14: Professional Development Activities in 2019

Participants were asked about key barriers that prevented them from pursuing professional development opportunities in 2019. Their responses are summarized in Figure 15. Insufficient time and high workload were cited by approximately two thirds of the participants as the main reason they did not pursue professional development opportunities in the previous year.

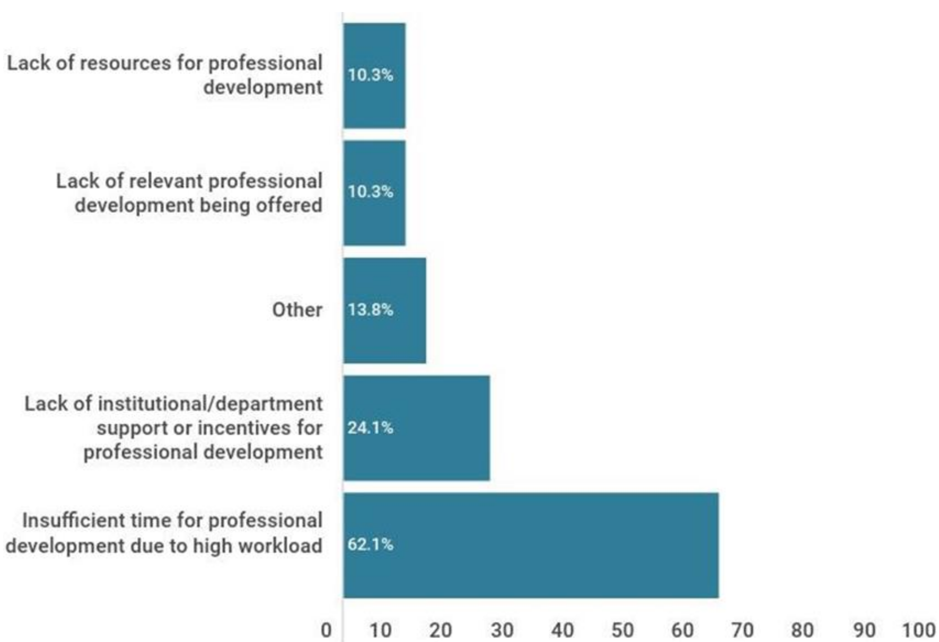


Figure 15: Barriers to Professional Development

Project leadership may want to consider conducting needs assessments of professional development needs, especially for early-career faculty and researchers, and to explore ways to support their project team members in identifying relevant professional development opportunities and addressing barriers to pursuing these opportunities.

External Stakeholder Engagement

Seven (24.1%) of the 29 respondents reported current engagement with external stakeholders. The number of stakeholder groups reported/listed by each of these participants ranged from 1 to 5. Most of those who reported current engagement with external stakeholders were affiliated with project Theme 1 (4 respondents) and Theme 3 (7 respondents). The different stakeholder groups currently engaged by each project theme are depicted in Figure 16.

Three (10.3%) survey participants reported planned future engagement with external stakeholders. The number of stakeholder groups reported/listed by each of these participants also ranged from 1 to 5. Those reporting planned engagement (or continued engagement) with external stakeholders were affiliated with project themes 1 (n=1), 3 (n=2), and 4 (n=1). The different stakeholder groups that will/continue to be engaged by each project theme are depicted in Figure 17.

Participants provided several reasons for engaging external stakeholders in project activities, including:

- Advising on forest management for climate mitigation
- Access to data
- Access to resources
- Technology deployment

Figure 16: Stakeholders Currently Engaged

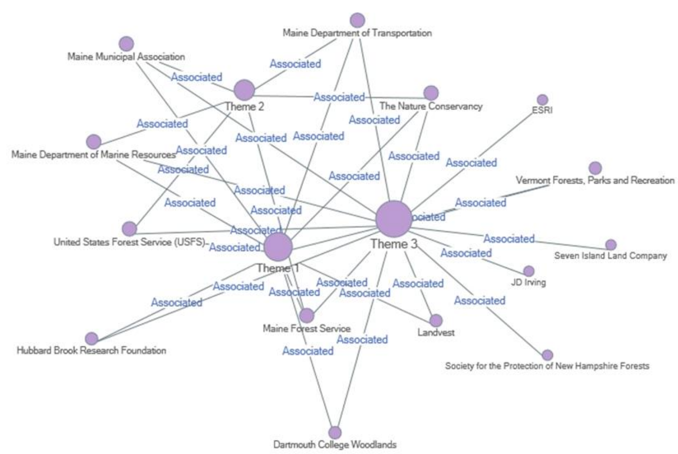
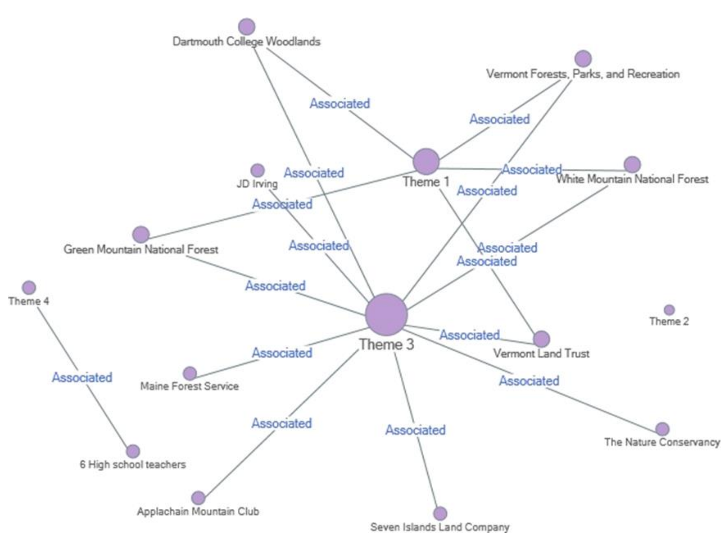


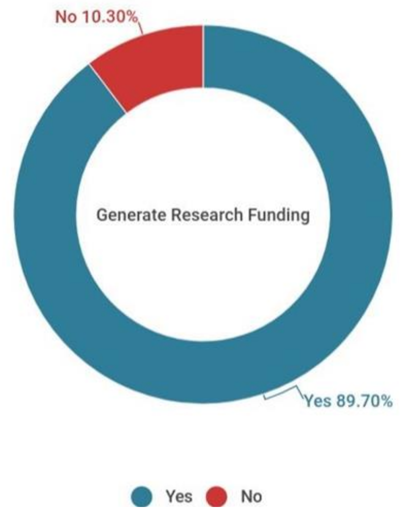
Figure 17: Planned/Continued Future Engagement with Stakeholders



Annual stakeholder surveys will assess the nature and outcomes of these partnerships (e.g., co-creation and/or utilization of research products) as well as the extent of alignment of project goals with external stakeholders' goals. Eventually, the goal is to assess which stakeholder partnerships are most successful in terms of producing strategic value that extends beyond the project.

Anticipated Project Impacts

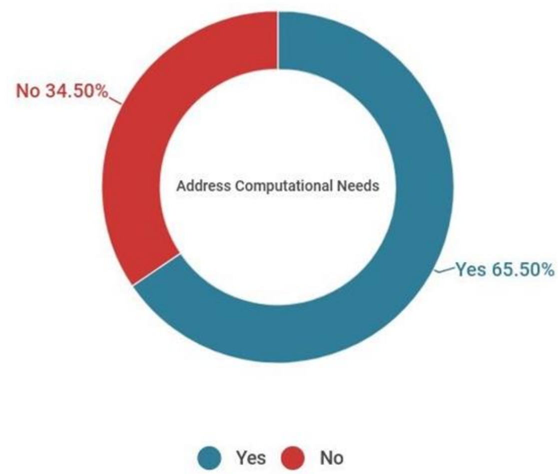
The survey included five questions asking the participants about their expectations for project impacts. The questions were:



1. Do you expect the project's research findings or methodological or theoretical developments to generate subsequent research funding by members of the project team?

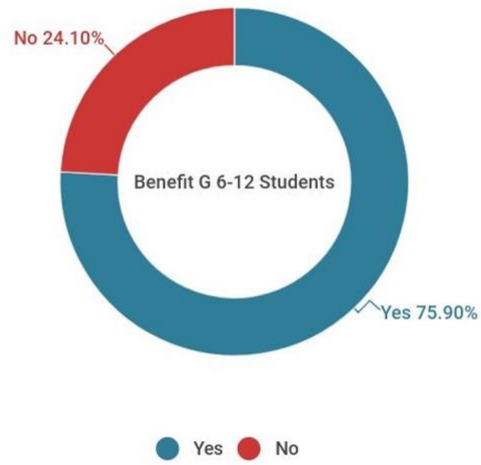
- 26 (89.7%) answered yes, and a few respondents offered comments to specify the nature of these impacts:
- Development and application of earth system modeling components
- Sensor network developments (unique opportunities for future NSF and AFRI proposals examining drivers of carbon dynamics across region)
- Project developments pertaining to machine learning and data assimilation would enable rapid development of spatial data and deployment of spatial models suitable for a large set of research applications

2. Do you expect your work as part of the project to contribute to addressing the region's computational needs in relation to monitoring and modelling forest ecosystems in the future?



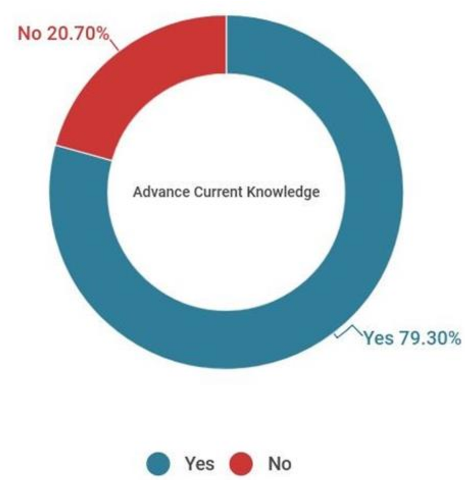
- Of the total 29 participants, 19 (65.5%) answered yes, and a few respondents offered comments to specify the nature of these impacts:
- Teaching teachers and students about the forest ecosystems modeling/data analysis (Indirect impact)
- More on network development (actual field sites), rather than the computational side
- Supporting education around themes of project
- High performance computing
- Bridging sensor networks, remote sensing, and forest ecosystem modeling
- With the deployment of sensor networks to understudied research forests, we'll have a better understanding of how well certain models perform in detail
- By including the content of the study into high school classrooms
- Improved models to assess forest ecosystems
- Cheaper sensor and datalogging/wireless technology
- Regional remote sensing products derived from efficient, multi-objective machine learning algorithms
- Data assimilation and inverse parameterization processes for forest landscape models
- Supporting teachers to help with workforce development to meet future needs
- Expanding and improving upon available computational infrastructure

3. Do you expect your work as part of the project to contribute to advancing the current knowledge of forest stressors in the Northern Forest Region?



- Of the total 29 participants, 23 (79.3%) answered yes, and a few respondents offered comments to specify the nature of these impacts:
- Research results have the potential to provide an interesting understanding of forest stressors and to advance the current knowledge
- Climate change, pollution, disturbance and land use change impacts on carbon cycling
- Work done on EAB in Corinth, VT and any sampling/sensor work done there will be helpful for understanding that stressor in particular
- Including the content of the study into high school classrooms
- Integrated modeling analyses
- Regional remote sensing of forest canopy disturbance
- Retrospective analysis of forest canopy change
- Regional remote sensing of forest canopy composition and composition change
- Leveraging extensive network of sites and examining emerald ash borer impacts on forest dynamics. Coupling these with sensors and models will enhance ability to understand impacts of this key stressor
- Better understand relative influences of various key factors like disturbance and harvesting

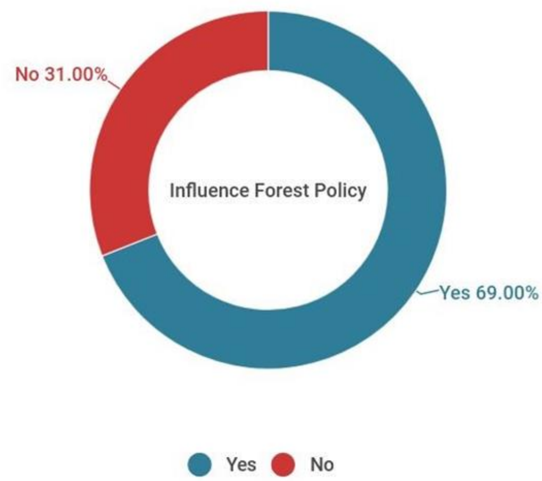
4. Do you expect your work as part of the project to benefit G6-12 students?



- Of the total 29 participants, 22 (75.9%) answered yes, and a few offered comments to specify the nature of these impacts:
- Training the teachers of these students
- Take the sensor network piece and bring it to schools as part of a DIY/Arduino learning module.
- Including the content of the study into high school classrooms and researching the QR skills needed by teachers to support their students' development of QR skills
- Teacher Professional Development, Curriculum Development
- Publication of outcomes of research with teachers in peer-reviewed journals
- Development of science modules related to sensors and modeling
- Develop engaging educational modules for use in high school classes
- Improved access to data and curriculum materials

5. Do you expect your work as part of the project to influence future forest policy/management decisions?

- Of the total 29 participants, 20 (69%) answered yes, and a few offered comments to specify the nature of these impacts:
- Management scenario modeling
- Integrated modeling
- Examination of impacts of different land management scenarios on the ability of forests to sustain key ecosystem services over the next 100 years



The survey responses make it clear that a significant number of participating faculty and researchers expect their work as part of the INSPIRES project to result in impacts in one or more area targeted by the project. The comments provided by the participants in response to these five questions will be used to draft more specific questions for the annual survey to tease out project impacts in different areas and track progress over time.

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4. INSPIRES AUTHORSHIP AGREEMENT

INSPIRES Authorship Guidelines for Collaborative Publications

Manuscript title:
Co-author list:
Target journal:

Instructions: Each coauthor should add their initials in the cell next to the contribution. If possible, please also add a short-description of the activity. As a starting point, we recommend that co-authors participate in at least a single activity in 2 of the 4 major categories in the following table, or participate in a total of 3 activities combined. However, we expect there to be exceptions and a substantial contribution in a single area can warrant co-authorship.

Activities	Contributing authors
Category 1: CONCEPT AND DESIGN	
a) **Conceived of the MS idea/concept**– individually or collectively, helped to frame the overall idea for the MS, research questions or scope; architecture of research approach, drafted conceptual figures or tables	
b) **Designed/outlined the MS** – individually or collectively helped to determine structure and content of the MS	
c) Supervised co-authors and MS progress – oversaw the MS progress	
d) Other -	
Category 2: DATA/ANALYSIS/MODELING *Papers led by graduate students may have fewer contributions from co-authors in this category because the students should have primary responsibility for these activities	
e) **Synthesized, compiled or analyzed data** – at a level that constitutes a unique intellectual contribution (i.e.. beyond working up summary statistics or following prescribed instructions) and drafted figures or tables.	

f) **Wrote code (or performed analysis) for an analysis or model for widely-used and cited methods** – provided code for an analysis for a fairly standard model, requiring a relatively small amount of time & intellectual investment	
g) **Developed code (or performed analysis) for a NOVEL analysis or model** – developed code and novel method/analysis, requiring a large amount of time & intellectual investment. **For ecology paper, this contribution by a CS/stats scholar is typically sufficient to be a co-author, regardless of other contributions (although we expect frequent participation in MS development)*	
h) **Interpreted results** – individually or collectively helped to interpret meaning of results and/or provided valuable insight on their broader relevance	
i) Contributed data that were not previously published	
j) Other -	
Category 3: MANUSCRIPT PREPARATION	
k) **Wrote sections of text** - even if eventually these sections were not included in final version	
l) **Substantial MS editing -** to a level that introduced important concepts, perspectives or ideas, or substantially enhanced the direction or quality of the MS.	
m) Other:	
Category 4: PROJECT Supervision and MENTORING	
n) **Project supervision** – provided overall supervision of the project and/or acquisition and management of funds that enabled the project to take place.	
o) **Student or post-doc mentoring** - Served as advisor/supervisor to the lead author of the manuscript throughout their career on the project and through the development of the manuscript effort. **Generally assumed to be a co-author, provided there is ample participation in MS development and other contributions above. Mentoring investment of some grad student committee members may also rise to this level.*	
Category 5: OTHER	
p) Other contributions not listed above (e.g., person has a light-bulb moment that completely changes scope/slant of project), please specify	

All authors are expected to perform a critical review of the manuscript at least once for intellectual context and presentation (i.e., not just spelling/grammatical edits, and preferably beyond comments that simply suggest revisions).

Overview[7]

This document is meant to provide a recommended set of guiding principles and a strategy for ensuring transparent and fair authorship assignment for manuscripts that originate from team-based, data-intensive research projects. The goal is to recognize many varied contributions to a manuscript, while also ensuring that all co-authors are contributing sufficiently to warrant co-authorship—**which we define as contributions in effort, original ideas or other intellectual content that substantially enhance the direction or quality of the manuscript or analysis.** Although not all manuscripts may fit these guidelines exactly, this document should be used to start the conversation about authorship. Included in this document is a memo that a lead author on a research effort (i.e. a proposed manuscript) should send to all project team members during the early phase of the effort. Early notification of a research effort to the entire team ensures that everyone knows what research is being conducted and by whom, and that all interested contributors are identified early in the research process. Once co-authors are identified, and research continues, the memo is re-sent to only those participants who have signed on as co-authors, unless new co-authors are brought on later to fill a previously unidentified need. Then, when research is in the final stages (i.e. the manuscript is close to submission), the memo is re-sent to co-authors for updating as part of the process of writing an author contribution paragraph. This iterative process facilitates open conversations about author responsibilities and potential author-order of the manuscript. This document and the strategy described can be especially important when the project in question includes personnel from multiple institution types and different universities, disciplines, and career stages. Please see *Cheruvelil et al. 2014* for more information on this, as well as other team policies. This policy document was first drafted by participants of the CSI-Limnology Project (www.csilimnology.org) during 2011 and has been subsequently revised to reflect the needs and perspectives of other groups who have adopted it. It should be viewed as a living document that changes over time to reflect changing team membership, project goals, and effective strategies for managing co-authorship. In particular, as new members join a team from different disciplines or with other new perspectives, the authorship guidelines should be re-evaluated to ensure that it fits the needs of all team members.

Guiding principles of authorship for manuscripts originating from this project

- All members of a research team should have the option to participate in most efforts.
- Agreeing to serve as co-author means that you have agreed to actively participate in the effort, and that you have the time available to ensure forward progression of the effort (i.e., you will not slow the research effort down). At any stage, if a co-author is not able to contribute to the effort in a timely manner, then it is recommended that they step down from the research effort/manuscript. The willingness of co-authors to self-evaluate their own contributions and voluntarily step down if they haven't been able to contribute at a level that warrants co-authorship is important for ensuring that this the authorship process is carried out smoothly and equitably.
- All co-authors agree to the terms in this authorship agreement.
- Lead- or co-lead-authors should be proactive in notifying the entire team about potential manuscript ideas early in the process, and communicating with the team when they are ready to engage with potential co-authors.

[7] The effect of cross-scale interactions on freshwater ecosystem state across space and time
PI's: P.A. Soranno, K.S. Cheruvelil, E.H. Stanley, J.A. Downing, N.R. Lottig, P-N. Tan.
NSF, Emerging Frontiers Division, Macrosystems Biology Program. 2011-2016. Awards: 1065786, 1065818, 1065649

- Lead- or co-lead-authors are responsible for communicating authorship guidelines to their co-authors early in the process, and throughout the process.
- Lead authors or co-lead-authors are expected to actively communicate with co-authors throughout the process so that co-authors can contribute and know where the effort stands.
- We do not believe in the practice of honorary authorship (i.e., gift authorship, ghost authorship, or authorship in the name of inclusion, or other such reasons without significantly contributing to and participating in the effort). This practice devalues the contributions of co-authors in general and it goes against the principles and strategies outlined in this document.
- In general, providing data is not considered a contribution in-and-of-itself that is large enough to constitute co-authorship if the data being provided have been published previously, are already publicly available, or if the data represent a minor and tangential part of the study. However, during the data-sharing process, if any data-provider has expressed an interest in collaborating on specific projects, it is the team's responsibility to contact that person and explore collaboration and co-authorship. Such a person would be included as a co-author if they agree to participate following the guidelines outlined here. Note that if a team member proposes a manuscript that contains only a single dataset, then it is his/her responsibility to contact the data providers prior to doing so to ask permission as a courtesy. Use of data from external sources must also abide by the data use policies of the provider.

General strategy for assigning authorship in multi-authored publications

1. **Types of contributions of co-authors.** We provide a list of common author contributions, in four main categories (see next page). This list is not intended to be exhaustive, and additional contributions can be added to each section.
2. **Total number of contributions that constitute co-authorship.** Although it is extremely difficult to put a number on the total contributions made by an author, we propose the following guidelines as a starting point. It is recommended that co-authors participate in at least a single activity in 2 of the 4 major categories in the following table AND participate in a total of 3 activities combined. Note that some contributions that are often relegated to the acknowledgments section are included in the table--participants who contribute in only one or two of these activities would be placed in the acknowledgments because they have not participated in the minimum number of activities required for co-authorship.

   Exceptions to this guideline: We recognize that not all manuscripts will neatly fit within this guideline and that some of these recommendations may need to be relaxed or expanded. We list three examples below. This document still serves as a starting point for discussions.

   a. *Computer science/statistical manuscripts in which non-ecologists take the lead on manuscripts*. It will be important that the domain experts (ecologists) be listed as co-authors even if they do not meet the above minimum requirements because they serve an important role in project conception and model interpretation.
   b. *Ecological manuscripts in which computer scientists or statisticians provide relatively novel or new analytical techniques* in the form of model structure or code to implement such models. These individuals (computer scientists/statisticians) should be listed as co-authors even if they do not meet the above minimum requirements because the use of such novel methods could not have happened otherwise.
   c. *Manuscripts that are position-pieces or commentaries*, and thus do not include analyses or rely on data and therefore do not have as many categories or activities.
   d. *Data papers* - exceptions...
   e. *Manuscripts in which the lead author is a graduate student* (who is supervised by individuals on our team) should take more ownership over the manuscript, may not include as many authors as other team papers,

or may have authors provide fewer contributions (e.g., students often do their own data analysis for their dissertation chapters).

3. **Mid-project addition of co-authors.** In some cases, co-authors may join the effort later than others, particularly if expertise is needed. In these cases, the new co-author is still held to the standards laid out in this document.
4. **All co-authors must approve the final version of the manuscript prior to submission.** In fact, it would be unethical to submit a manuscript in which all co-authors did not read and approve the final submitted version.
5. **Co-authors are held accountable for the content and conclusions of the manuscript**. This idea provides an important distinction between a co-author and someone who is acknowledged. We recognize that every co-author will not have a full working knowledge of all aspects of the research or the quantitative analysis (especially in the interdisciplinary cases described above in 2a-b); however, they need to know enough to defend the work.
6. **An author-contribution paragraph must be written for each manuscript, and submitted to the journal with the manuscript.** This step is important to ensure that all co-authors (particularly early-career individuals) get recognition for the contributions that they make to the project's highly collaborative efforts. If journals do not have the normal practice of publishing such paragraphs in the main body of the paper, we encourage making paragraph available as an online supplement or appendix.
7. **Authorship order.** The norm in our team and in ecology in general is for the lead (or co-lead) author(s) to be listed first, and the co-authors listed thereafter. The co-authors can be listed in order of contribution or in alphabetical order. Deciding between these two options relies on a discussion that the lead- or co-lead authors should initiate. They should propose a recommendation for each manuscript that is then discussed with all co-authors. Authors may want to use alphabetical order if the contributions of co-authors were about equal; whereas, they may want to use an ordering based on contributions if there seems to be a clear and obvious ordering according to contribution level. The description of the ordering style should be noted in the author-contribution statement (7 above).
8. **Conflict resolution.** If team-members do not perform the basic duties of a co-author described above, and agreed upon, then it is recommended that they step down from the research effort/manuscript at any stage. If a lead-author feels that a co-author (or vice versa) is being unresponsive, but is not stepping down, then an ad-hoc group of 3 team members will be convened to evaluate the issue (including at least one early-career individual, if possible).

EXAMPLE MEMO

TO: Potential co-authors

FROM: Lead author

RE: Authorship of manuscript titled: [Fill in tentative title here]

We are contacting you because you have been listed as a potential co-author on the above manuscript that is associated with the NSF EPSCoR INSPIRES project (#1920908). Please read our authorship guidelines (attached) and review the table below that provides the list of contributions and responsibilities for co-authors on manuscripts.

This table is intended to foster an open dialog on authorship that starts at the very beginning phase of a manuscript and carries through until manuscript submission and acceptance. This document is intended to clearly define each co-author's responsibilities and accomplishments throughout the effort, as well as describe the overall strategy for determining co-authorship.

We ask that in the early phases, you consider what components of the research effort you would like to contribute to; then, later in the middle of the effort, to revisit contributions; and finally, at the time of manuscript submission, we ask all co-authors to assess the contributions that they did to aid in writing the author-contribution statement that we expect all lead authors to take responsibility for drafting and submitting with the manuscript.

Table 1: Author contributions: Insert your name here and fill in table below

INSERT REVISED TABLE HERE WHEN DONE

References

Cheruvelil, K.S., P.A. Soranno, K.C. Weathers, P.C. Hanson, S. Goring, C.T. Filstrup, and E.K. Read. 2014. Creating and maintaining high-performing collaborative research teams: the importance of diversity and interpersonal skills. Frontiers in Ecology and the Environment. 12(1):31-38.

Duke, CS and JH Porter. 2013. The ethics of data sharing and reuse in biology. BioScience 63:483-489.

Weltzin, JF, RT Belote, LT Williams, JK Keller and EC Engel. 2006. Authorship in ecology: attribution, accountability, and responsibility. Front. Ecol. Environ. 4(8):435-441.

Appendix: Background on authorship policies in ecology

Weltzin et al. 2006

> "Drawing the line between acknowledgements and co-authorship can be challenging and one way of thinking about the differences may be to **consider whether or not the participant is responsible and accountable for the article.** A contributor receiving credit for the article should be willing to be held accountable for its contents and not be just responsible for a portion of work involved. In contrast, an acknowledgement may contribute formal or informal ideas to ongoing projects, collect enormous amounts of data, and develop and/or conduct statistical analyses, but may not be accountable for the final contents of all or even portions of the final manuscript."

Example author-contributions paragraph from Weltzin et al. 2006

Panel 1. Author contributions for Weltzin et al. 2006

JFW co-conceived and co-developed the idea for the manuscript, co-refined the intellectual content and scope, edited all drafts, prepared the final version of the manuscript, and facilitated the gathering of contributors. RTB co-conceived and co-developed the idea, edited all drafts, and assessed historic trends in authorship in Ecology. LTW initiated the project, co-developed and co-refined the intellectual content, and wrote the first two drafts. JKK co-developed the idea, edited all drafts, and conducted the keyword search. ECE co-developed the idea and coordinated the authorship survey. JFW is the guarantor for the integrity of the article as a whole.

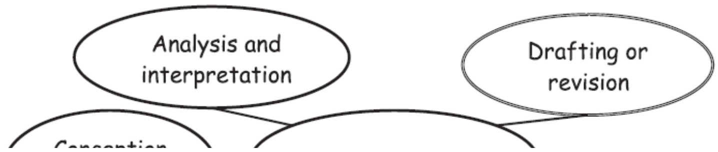
Acknowledgements from Weltzin et al. 2006

P Allen contributed to initial discussions of this topic and co-refined the intellectual content of earlier versions of the manuscript. C DeVan assisted with data collection and organization for Figure 1. The survey on authorship was developed and implemented with the help of M Fitzpatrick, C Iversen, J Nagel, and L Souza. Comments from P Cole, S Collins, O Dermody, M Fitzpatrick, C Iversen, C Reilly, N Sanders, and L Souza improved earlier versions of the manuscript.

Example authorship guidelines from Duke and Porter 2013

Authorship guideline provided by Duke and Porter.

ESA guidelines in its Code of Ethics (ESA 2006):



1. Researchers will claim authorship of a paper only if they have made a substantial contribution. Authorship may legitimately be claimed if researchers

PNAS 2006 Guidelines for Authorship

Panel 3. Guidelines for authorship, *Proceedings of the National Academy of Sciences of the United States of America* (PNAS 2006)

Authorship should be limited to those who have contributed substantially to the work. The corresponding author must have obtained permission from all authors for the submission of each version of the paper and for any change in authorship.

All collaborators share some degree of responsibility for any paper they co-author. Some co-authors have responsibility for the entire paper as an accurate, verifiable report of the research. These include co-authors who are accountable for the integrity of the data reported in the paper, carry out the analysis, write the manuscript, present major findings at conferences, or provide scientific leadership to junior colleagues. Co-authors who make specific, limited contributions to a paper are responsible for their contributions, but may have only limited responsibility for other results. While not all co-authors may be familiar with all aspects of the research presented in their paper, all collaborators should have in place an appropriate process for reviewing the accuracy of the reported results.

Authors must indicate their specific contributions to the published work. This information will be posted online as a footnote to the paper. Examples of designations include:

- Designed research
- Performed research
- Contributed new reagents or analytic tools
- Analyzed data
- Wrote the paper

An author may list more than one contribution, and more than one author may have contributed to the same aspect of the work.

5. INSPIRES STUDENT RESPONSIBILITIES

INSPIRES Graduate Student Responsibilities Best Practices and Guidelines

(Adapted from University of Michigan's How to Mentor Graduate Students: A Guide for Faculty; Full Text Available Online)

I. I acknowledge that I have the primary responsibility for the successful completion of my degree including meeting program of study, comprehensive exam, thesis, and graduation deadlines. I will be committed to my graduate education and will demonstrate this by my efforts in the classroom and in research settings. I will maintain a high level of professionalism, self-motivation, engagement, curiosity, and ethical standards.

2. I will be knowledgeable of the policies and requirements of my graduate program, graduate school, and institution. I will commit to meeting these requirements, including teaching responsibilities.

3. My work with the NSF-INSPIRES team and this opportunity to be a member of a transdisciplinary project will require me to be as fully engaged with my fellow graduate students, faculty, and stakeholders as I can. This will include, but not be limited to, team writing activities (scholarly papers with colleagues) and some group presentations.

4. I will work with my research group to identify and secure an enriching internship opportunity.

5. I will meet regularly with my faculty mentor(s) and provide her/him with updates on the progress and results of my research activities.

6. I will work with my faculty mentor(s) to develop a thesis/dissertation project. This will include establishing a timeline for each phase of my work. I will strive to meet the established deadlines.

7. I will work with my faculty mentor(s) to select a thesis/dissertation committee. I will commit to meeting with this committee each semester. I will be responsive to the advice of and constructive criticism from my committee.

8. I will learn and participate in the process of actively engaging with various external stakeholders that are a part of this INSPIRES, while adhering to the policies and procedures for effective stakeholder engagement as well as keeping my faculty mentor(s) well informed on any or all external communications with stakeholders.

9. I will attend and participate in relevant group meetings and seminars that are part of my educational program.

10. I will comply with all institutional policies, including academic program milestones. I will comply with both the letter and spirit of all institutional research policies (e.g., safe laboratory practices and policies regarding animal-use and human-research) at my institution.

11. I will participate in my institution’s Responsible Conduct of Research Training Program and practice those guidelines in conducting my thesis/dissertation research.

12. I will be a good research citizen. I will agree to take part in relevant shared research group responsibilities and will use research resources carefully and frugally. I will be attentive to issues of safety and courtesy, and will be respectful of, tolerant of, and work collegially with all research personnel.

13. For use in relevant fields: I will maintain a detailed, organized, and accurate records of my research, as directed by my faculty mentor(s). I am aware that my original notes and all tangible research data are the property of my institution but that I am able to take a copy of my notebooks with me after I complete my thesis/dissertation.

14. I will discuss policies on work hours, sick leave, and vacation with my research faculty mentor(s). I will consult with my faculty mentor and notify any fellow research group members in advance of any planned absences.

15. I will discuss policies on authorship and attendance at professional meetings with my research faculty mentor(s). I will work with my faculty mentor to submit all relevant research results that are ready for publication in a timely manner.

16. I acknowledge that it is primarily my responsibility to develop my career following the completion of my graduate degree. I will seek guidance from my research faculty mentor(s), career counseling services, thesis/dissertation committee, other mentors, and any other resources available for advice on career plans.

17. I will actively seek additional funding for my project by applying for small grants available from institution or from external entities making grants available to graduate students.

18. I will strive to have drafts of my publications before I leave the institution. If I am unable to do this, I agree that after 1 year post graduation, if I am unable to demonstrate progress, my faculty mentor(s) may assume primary authorship and submission with me as a co-author.

Signature of graduate student:

Date:

Degree Program:

Faculty Mentor(s):

Last Updated: 9/2019

6. INSPIRES MENTORING AGREEMENT

INSPIRES Graduate Student Mentoring Best Practices and Guidelines

(Adapted from University of Michigan's How To Mentor Graduate Students:
A Guide for Faculty; Full Text Available Online)

• I will encourage and adhere to the suggested best practices for co-mentoring students as expected for all INSPIRES projects by year two of the research program.

• I will be 100% committed to mentoring the student, particularly as it relates to the education and training of the graduate student as a future member of the scholarly and conservation science community.

• I will be 100% committed to the student's research project by : (1) working with the student to plan the project and to provide direction as needed; (2) working with the student to set timely, reasonable, and attainable goals; and (3) working with the student to establish, and amend as needed, a detailed timeline for the successful completion of the project. I recognize the possibility of conflicts between the interests of my own larger research program and the particular research goals of the student, and will not let my larger goals interfere with the student's pursuit of their thesis/dissertation research.

• I will be conscious of the additional demands and higher expectations placed on INSPIRES students, but will work with each individual to ensure that their research and coursework responsibilities should be treated equally.

• I will work to actively and effectively engage with various external stakeholder organizations, particularly as it can promote and enhance my student's experience during and after their program.

• I will be committed to meeting with the student both individually and with their co-mentor on a regular basis.

• I will be committed to providing agreed-upon resources for the student as appropriate or according to my institution's guidelines, in order for them to effectively conduct thesis/dissertation research.

• I will be knowledgeable of, and guide the student through the requirements and deadlines of their graduate program as well as those of the institution, including teaching requirements and human resources guidelines. However, it is ultimately the student's responsibility to meet these obligations and manage the time to do so.

• I will help the student select a thesis/dissertation committee, particularly a potential co-mentor. I will help assure that this committee meets at least once per semester to review the student's progress.

• I will guide the student in the development of a study plan that reflects the student's professional and educational goals.

• I will lead by example and facilitate the training of the graduate student in complementary skills needed to be a successful researcher. These include oral/written communication skills, grant writing, time management, research compliance policies, the ethical conduct of research, and scientific professionalism. I will encourage the student to seek additional opportunities in career development training by providing networking and workshop/conferences attendance opportunities.

• I will expect the student to share common research responsibilities in my research group and the larger INSPIRES group by using resources carefully, efficiently, and frugally.

• I will discuss authorship policies regarding any products (e.g., poster, presentations, papers) with the student. I will acknowledge the student's contributions to projects beyond their own, and I will work with the student to publish their work in a timely manner.

• I will discuss requirements to acknowledge financial support from NSF and the INSPIRES program, and other resources provided by collaborators, and other sources.

• I will discuss any potential intellectual policy issues with the student with regard to disclosure, patent rights and publishing research discoveries, when they are appropriate.

• I will encourage the student to attend and present at professional meetings and make an effort to help them to secure funding for such activities.

• I will provide career advice and assist in finding a position for the graduate student following their graduation. I will provide honest letters of recommendation for their next phase of professional development. I will also be accessible to give advice and feedback on career goals.

• I will try to provide for every student under my supervision an environment that is intellectually stimulating, emotionally supportive, safe, and free of harassment.

• Throughout the student's time in graduate school, I will be supportive, equitable, accessible, encouraging, and respectful. I will foster the graduate student's professional confidence and encourage critical thinking, skepticism and creativity.

• I will do my best to participate in any and all related INSPIRES activities that involve my student.

• I will annually review my experiences as mentor, particularly as a co-mentor, and share any relevant insights with the larger INSPIRES Team.

• As either a mentor or co-mentor, I will conduct an exit interview with each completed student and ask for specific feedback on improving their experience.

NAME DATE

TITLE

ORGANIZATION

7. INSPIRES TEAM ROSTER

Name	Theme	Affiliation	State	Institu-tion	Early Career	Career Level/ Position	Expertise	Commi ttee(s)	Rank	Advisor
Aaron Weiskittel	3	Center for Research on Sustainable Forests	ME	UMO	N	Senior/ Faculty	biometrics, sampling	CLT	Professor	
Ali Abedi	1	Department of Electrical and Computer Engineering	ME	UMO	N	Senior/ Faculty	Wireless sensors and networks	CLT	Professor	
Kate Beard-Tisdale	2	School of Computing and Information Science	ME	UMO	N	Senior/ Faculty		CLT	Professor	
Anthony D'Amato	3	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Senior/ Faculty	forest ecology, silviculture, carbon dynamics	CLT MEE	Associate Professor	
Scott Ollinger	3	Earth Systems Research Center	NH	UNH	N	Senior/ Faculty		CLT CRC	Professor	
Carol Adair	1	Rubenstein School of Environment and Natural Resources	VT	UVM	Y	Early/ Faculty	Biogeochemistry /ecosystem ecology, modeling, sensors, soil carbon		Associate Professor	
James Bagrow	2	Mathematics and Statistics/Vermont Complex Systems Center	VT	UVM	Y	Early/ Faculty			Assistant Professor	
Elizabeth Burakowski	3	Institute for the Study of Earth Oceans and Space	NH	UNH	Y	Early/ Faculty	snow, albedo, climate modeling, remote sensing, citizen science, K-12 education	MEE CRC	Assistant Professor	
Aimee Classen	1	Gund Institute for Environment/Rubenstein School of Environment and Natural Resources	VT	UVM	N	Senior/ Faculty	ecosystem ecology/ biogeochem, soil models, scaling, biodiversity		Professor	
Alix Contosta	1	Earth Systems Research Center	NH	UNH	Y	Early/ Faculty	terrestrial ecology / biogeochemistry ;	CRC	Assistant Professor	
Mark Ducey	3	Department of Natural Resources and the Environment	NH	UNH	N	Senior/ Faculty	biometrics, sampling, quantitative silviculture		Professor	
Jane Foster	3	Rubenstein School of Environment	VT	UVM	Y	Early/ Faculty	forest and landscape ecology, remote		Assistant	

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		and Natural Resources					sensing, carbon cycling		Professor	
John Gunn	3	Department of Natural Resources and the Environment	NH	UNH	Y	Early/ Faculty	forest management, carbon dynamics, life cycle assessment, forest ecology		Assistant Professor	
Torsten Hahmann	2	School of Computing and Information Science	ME	UMO	Y	Early/ Faculty			Assistant Professor	
Daniel Hayes	3	School of Forest Resources	ME	UMO	Y	Early/ Faculty	ecosystem modeling, remote sensing		Assistant Professor	
Erin Simons-Legaard	3	School of Forest Resources	ME	UMO	Y	Early/ Faculty			Assistant Professor	
Kasey Legaard	2	Center for Research on Sustainable Forests	ME	UMO	Y	Early/ Faculty			Assistant Professor	
Sara Lindsay	4	School of Marine Sciences	ME	UMO	N	Senior/ Faculty			Assistant Professor	
Mary Martin	2	Earth Systems Research Center	NH	UNH	N	Senior/ Faculty			Professor	
Susan McKay	4	Maine Center for Research in STEM Education (RiSE Center)	ME	UMO	N	Senior/ Faculty			Professor	
Laura Millay	4	Maine Center for Research in STEM Education (RiSE Center)	ME	UMO	N	Professional Staff	education research		Other	
Peter Nelson	2	Department of Biological Sciences and Environmental Studies	ME	UMFK	Y	Early/ Faculty	remote sensing, hyperspectral, data analysis, UAVs, community ecology		Assistant Professor	
Sarah Nelson	1	School of Forest Resources	ME	UMO	N	Senior/ Faculty			Other	
Silvia Nittel	2	School of Computing and Information Science	ME	UMO	N	Senior/ Faculty			Associate Professor	
Laura Nickerson	4	Leitzel Center for Mathematics, Science, and	NH	UNH	N	Senior/ Faculty	education research, professional		Assistant	

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		Engineering Education					development for teachers in STEM and CS		Professor	
Franziska Peterson	4	Maine Center for Research in STEM Education (RiSE Center)	ME	UMO	Y	Early/ Faculty			Assistant Professor	
Marek Petrik	2	Department of Computer Science	NH	UNH	Y	Early/ Faculty			Assistant Professor	
Donna Rizzo	2	Department of Civil & Environmental Engineering	VT	UVM	N	Senior/ Faculty			Professor	
Darren Ranco	2	Department of Anthropology	ME	UMO	N	Senior/ Faculty			Professor	
Sam Roy	2	Mitchell Center for Sustainability Sciences	ME	UMO	Y	Early/ Faculty	GIS, multi-objective optimization, machine learning, scenario analysis		Research Assistant Professor	
Bruce Segee	1	Advanced Computing Group	ME	UMO	N	Senior/ Faculty			Professor	
Regina Toolin	4	College of Education and Social Services	VT	UVM	N	Senior/ Faculty			Assistant Professor	
Sonia Naderi	1	Department of Electrical and Computer Engineering	ME	UMO	N	Grad Student			Post-Doc	Abedi
Meg Fergusson	ALL	Center for Research on Sustainable Forests	ME	UMO	N	Support Staff				
Leslee Canty-Noles	ALL	Center for Research on Sustainable Forests	ME	UMO	N	Support Staff				
Heather McInnis		American Association for the Advancement of Science	DC	AAAS	N	Evaluator	Strategic Assessment & Site Visits (Y1 &3)			
Maysaa Alobaidi		American Association for the Advancement of Science	DC	AAAS	N	Evaluator	Data-driven Evaluation Design & Support			
Larry Whitsel	2	Advanced Computing Group	ME	UMO	N	Senior/ Faculty			Other	

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Kenneth Bundy	1	College of Professional Studies	ME	UMAB	Y	Early/ Faculty	Statistics, time series analysis, machine learning, AWS		Other	
Rebecca Sanders-Demott	1	Earth Systems Research Center	NH	UNH	Y	Post-doc	forest ecology, ecosystem ecology, biogeochemistry		Post-Doc	Ollinger
Andrew Ouimette	1	Earth Systems Research Center	NH	UNH	Y	Early/ Faculty	forest ecology, ecosystem modeling, quantifying carbon and nitrogen fluxes		Other	
Dave Lutz	1	Environmental Studies	NH	Dartmouth	Y	Early/ Faculty			Assistant Professor	
Salimeh Yasaei Sekeh	2	School of Computing and Information Science	ME	UMO	Y	Early/ Faculty			Assistant Professor	
Michelle Gregoire		EPSCoR	NH	UNH	N	Support				
Lisa Scott	3	Department of Natural Resources and the Environment	NH	UNH	N	Grad Student				Gunn/ Petrik
Valeria Briones	3	School of Forest Resources	ME	UMO	N	Grad Student				Abedi
Zaixing Zhou	3	Earth Systems Research Center	NH	UNH	Y	Early/ Faculty			Research Assistant Professor	
Jing Yuan	2	School of Computing and Information Science	ME	UMO	Y	Post-doc				Beard-Tisdale
Thayer Whitney	1	Dept. of Electrical & Computer Engineering	ME	UMO	N	Undergr				Abedi
Victoria Nicholas	1	Dept. of Electrical & Computer Engineering	ME	UMO	N	Undergr				Abedi
Marina Van der Eb	4	Maine Center for Research in STEM Education	ME	UMO	N	Faculty				
John Den Uyl	1	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Grad Student				Adair/ Classen/ D'Amato

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Paulina Murray	1 2	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Grad Student				Adair/ Classen/ D'Amato
Gavin Briske	1	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Grad Student				Adair/ Classen/ D'Amato
Karin Rand	1 2 3	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Research Technician				Adair/ Classen/ D'Amato
Lindsay Barbieri	1	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Grad Student				Adair/ Classen/ D'Amato
Olivia Vought	1	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Undergr				Adair/ Classen/ D'Amato
Kevaughan Smith	2	School of Forest Resources		UMO	N	Grad Student				Hayes/ Nelson