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Smart Data for Resilient Forests

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

INSPIRES Year 2 Annual Progress Report

August 1, 2020-July 31, 2021

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Date Submitted: May 7, 2021

University of New Hampshire

1865 THE UNIVERSITY OF MAINE

The University of Vermont

Contents

EXECUTIVE SUMMARY

Forests are an economically important and ecologically critical component of New England's working landscape. New England's forests are 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.

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 Forest Ecosystems Research Consortium that facilitates analysis of ecosystem health and resilience in response to multiple agents of environmental change.

Project Goals

Maine, New Hampshire, and Vermont encompass major parts of the complex and highly interconnected Northern Forest Region (NFR), which has a long history of providing important environmental services to the region's rural communities. Although the economies and identities of local communities strongly depend on healthy ecosystems, forests across the region are increasingly threatened by complex and dynamically interacting stressors.

The INSPIRES project aims 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 (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?

These questions arise from our hypothesis that novel Big Data acquisition, integration, and analysis will allow us to address these issues in a way that informs how we approach challenges and opportunities related to the current and future integrity of forest ecosystems. Over the long-term, we hope to extend this framework beyond the region, particularly to other ecosystems of high interest.

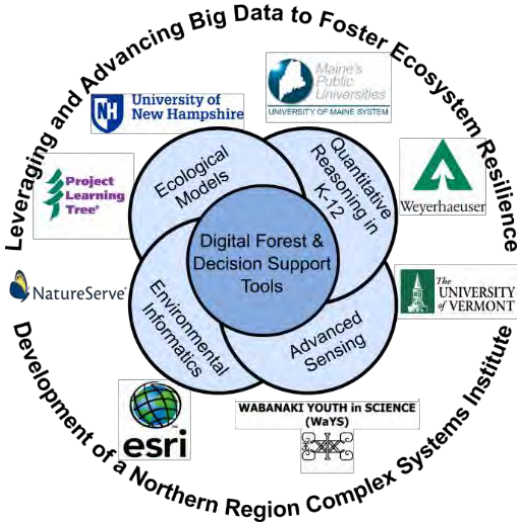

Figure 1. INSPIRES Digital Forest Research and Workforce Development Framework

Year 2 Goals

The primary goals of Year 2 are to: (1) continue to refine theme strategic materials and implementation of specific research objectives through active team- and consensus-building; (2) provide opportunities for cross-theme and inter-institution collaborations; (3) conduct a strategic project external assessment by the evaluator and panel of experts; and (4) communicate project progress and challenges to an institutional advisory board to help strengthen inter-jurisdiction collaborations.

Institutional Roles

The participating institutions are the University of Maine (lead), the University of New Hampshire (Co-PI) and the University of Vermont (Co-PI). The PIs at these three institutions make up the Core Leadership Team (CLT; Table 1), a collaborative effort to set project goals, strengthen cross-institutional cooperation, and to support team members. In addition, upper administrative officials as these institutions comprise the Tri-Jurisdictional Institutional Advisory Board. The INSPIRES team includes a number of scientists and researchers from three additional academic institutions (Dartmouth College, University of Maine Augusta, and Unity College) and two non-profit organizations (Schoodic Institute at Acadia National Park and the Appalachian Mountain Club).

Project Summary, Year 2

The INSPIRES project started August 1, 2019 and is an interjurisdictional partnership between research and higher educational institutions in Maine, New Hampshire, and Vermont. The INSPIRES team currently involves 64 individuals with the majority being faculty from the three states (36; ME = 19, NH = 11, VT = 6), bolstered by undergraduate/graduate students (18), post-doctorate researchers (2) and professional staff (8). Despite the continued challenges imposed by the ongoing pandemic, the team has remained diverse (54% female), has built strong linkages across jurisdictions, and many of the faculty remain early career (50%). The structure of the project is still 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 are building an understanding of current and future changes in the Northern Forest with a focus on key ecological and socioeconomic drivers.

Table 1. 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

Despite the ongoing pandemic, Year 2 INSPIRES team members were successful in developing strategies to enhance team building, completing the planned external project review, and supporting enhanced interjurisdictional research collaboration, particularly among the project's student participants. Continuation of regular research theme and project meetings, along with wide participation at quarterly all-team meetings (in-person prior to the onset of the pandemic and virtual after), is essential for enriched teamwork and relationship-building. These internal efforts were reinforced by an external facilitator (Dr. Pips Veazey) who worked with the CLT and was invited to the December all-

team meeting. Dr. Veazey shared insights on team science, highlighted successful characteristics of effective collaborations, and led a team-building exercise. The CLT (Table 1) continues to meet at bi-weekly or monthly intervals to set priorities, discuss concerns, brainstorm contingencies for ongoing pandemic impacts to the project's research, and plan all-team meetings. Quarterly all-team meetings primarily focus on project and research theme updates and discussion. Largely led by early career scientists, individual research themes regularly interact to gain understanding of team member research interests, complete strategic materials, including collaborative research agendas, and outline key research milestones. These milestones are essential to monitor project progress. Monthly meetings of INSPIRES graduate students were initiated in Year 2 to provide mentoring opportunities through connections with early-career scientists on the project and to build community and collaboration across disciplines and institutions. The Collaborative Research Committee (CRC) has been formed with the primary objective of providing active engagement across institutions to further team relationships and identify key linkages among a diverse set of disciplines such as engineering, computer science, ecology, biometrics, ecosystem modeling, and STEM education. Finally, a Data Sharing Subcommittee was convened with cross-theme representation and developed an implementation strategy as well as best practices for the project's data management plan.

Travel and health safety concerns surrounding the pandemic limited interstate travel, restricted access to field sites and forced the CLT to revise its plan for an external evaluation in-person research site visit in June. In addition, the sudden dissolution of the external evaluator (American Association for the Advancement of Science, Research Competitive Program [AAAS-RCP]) in September necessitated additional negotiations to secure a new evaluator (The Implementation Group; T.I.G.) and reinitiate the evaluation process (see Evaluation section of this report). The CLT successfully collaborated with T.I.G. to convene a multi-day remote external evaluation panel in January 2021. This external evaluation panel assessed the project's progress and provided specific recommendations for improvement (the report and responses were submitted to NSF in April 2021). Key findings from the external panel include:

- The leadership team has developed an effective and collegial working environment during the project start-up phase, which is a crucial asset to the overall project.
- The panel found that integration across jurisdictions and institutions is an exceptionally strong aspect of INSPIRES.
- The recruitment of post-docs, graduate students, and undergraduate students across the three institutions is commendable, as is the engagement with a broad range of regional stakeholders, particularly given the challenges of Covid.
- The panel was impressed with the success the team has made in pursuing and securing additional resources in support of the efforts initiated by INSPIRES, as well as the progress they have made in advancing and implementing their research and program development, particularly given the challenges posed by Covid-19.
- In reporting, detail not only the effects of Covid-19 on the project but also describe specific strategies developed to mitigate its impacts.
- The panel found that the project has successfully fostered interdisciplinary integration.
- The team should formalize a Data Management Plan.
- The panel commended the leadership team for its commitment to reducing administrative burdens of the early career faculty.

The Core Leadership Team presented the external review findings and responses, as well as an update on INSPIRES research progress, to the inter-institutional advisory board (IAB) composed of leaders from all three institutions in late April. The IAB gave input on potential strategies for enhancing inter-institutional collaborations and the broader value of the INSPIRES project to the institutions involved as well as the overall region. Discussion focused on two opportunities: 1) incorporating indigenous learning (e.g., traditional ecological knowledge) in university programs, and 2) establishment of a regional complex systems consortium. The IAB will meet again early in Year 3 of the project.

Despite the rather challenging circumstances caused by the ongoing global pandemic that has continued to impose high uncertainty and restrictions (e.g., travel, hiring, spending), the INSPIRES team was able to collaborate and move planned research forward in Year 2. Project outputs have increased from Year 1 and several new research proposals have been funded that help leverage the collaborations created through INSPIRES. In addition, several new graduate students have been recruited and have participated in monthly INSPIRES student meetings led by Co-PI D'Amato along with several early-career faculty involved with the project. During these meetings, best practices for graduate students, strategies for building effective collaborations, and details on the science being conducted in INSPIRES is discussed.

Overall, the INSPIRES team continues to make substantial forward progress and remains on track as it heads into the last two years of the project. Because of the emphasis and support of collaborative team science, as elaborated in this report, 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 Achievements

- PI Weiskittel was invited to present INSPIRES at the NSF Track 2 Kick-Off event in November 2020 and the NSF EPSCoR PI meeting in May 2021
- An external evaluation panel conducted a strategic assessment of the project and provided a formal report with specific recommendations in January 2021
- Core Leadership Team (CLT) presented project progress and challenges to an Inter-institutional Advisory Board (IAB)
- Collaborative Research Committee (CRC) was formed and met monthly to discuss cross-theme and cross-institution collaboration opportunities and needs
- First-wave deployment of Mayfly-based sensor suites at 5 locations
- Collection of field data for physiological variables needed to parameters models
- Project annual retreat featured a team science expert (Dr. Pips Veazey) who conducted a team-building exercise for defining a shared vision
- Virtual yet highly interactive quarterly all-team meetings foster team-building and highlight ongoing collaborations as well as project progress
- Regular stakeholder events featuring INSPIRES participants and ongoing research were conducted
- Data Sharing Subcommittee (DSS) established a Slack channel and shared calendar facilitating team collaborations with regular weekly meetings scheduled
- DSS developed a data sharing document for the INSPIRES team to guide them on best practices for data sharing inside INSPIRES and to identify each theme's outputs and estimated schedule
- Recruitment and hiring of 1 post-doc, 6 graduate students, and 2 undergraduate students across the three institutions
- 50% of the project's participating faculty are early-career
- 21 (16 published; 3 in press; 2 under review) peer-reviewed articles, 14 presentations, 3 data/model/technology products, and 14 presentations (7 by early-career faculty, 2 by trainees)
- In Year 2 (through March 2021), research proposals requesting $41,132,273 were submitted with 12 awarded ($11,035,918) and $35,043,997 pending
- Ongoing updates to project jargon and acronym dictionary
- Preliminary completion of an integrated ecological model resulting from the merger of the PnET-CN and LANDIS models
- Annual survey of project participants completed and analyzed
- Regular graduate student meetings with early career faculty and mentors
- Establishment of Twitter and Instagram accounts to share and highlight team news and project developments

- Profiles of INSPIRES graduate students generated and used for the project's external communications
- Eight high school teachers in Maine and nine teachers in Vermont were selected to participate in the project with active recruitment for additional teachers in New Hampshire ongoing

Intellectual Merit

The project's intellectual merit stems from our approach of integrating basic field measurements, novel environmental sensors, big-data analytics, and ecosystem models to improve understanding of ecosystem function and how forests are responding to environmental change. As highlighted in the project's Data Outcome Portal's snapshot, the INSPIRES effort has resulted in several important outcomes with high intellectual merit. In under 2 years, this has included 38 submitted proposals (13 to NSF), 17 proposals funded (5 from NSF), 21 publications, 2 conference proceedings, and 26 presentations. The funded proposals include awards from the National Science Foundation Collaborative Research, USDA NIFA, USDA Conservation Innovation, and two NASA grants. In addition, early-career Senior Personnel submitted several grants to a variety of agencies including the National Science Foundation, Northeast Climate Adaptation Science Center, Northeastern States Research Cooperative, USDA, and NASA. In terms of publications and presentations, significant INSPIRES outcomes have been achieved in Year 2 of the project. This has included 15 peer-reviewed publications with an additional 3 accepted, 1 awaiting publication, and 3 under review.

Overall, the strong intellectual merit outcomes produced in Year 2 highlight the level and strength of current collaborations within INSPIRES. Like the recently submitted NSF DISES 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 the current state of knowledge and outline strategies for future research will be prioritized in Years 3 and 4 of the project.

Broader Impacts

As outlined in the project's implementation plan, broader impacts and effective engagement with stakeholders is a high priority for INSPIRES. In Year 2, INSPIRES conducted several project outreach events that featured INSPIRES participants and ongoing research despite limitations from the Covid-19 pandemic. This included a monthly webinar series focused on the science and practice related to forest climate change in Maine (https://crsf.umaine.edu/fcci-webinars/). The webinars were well attended (50-60 participants), recorded for future reference, and were highly interactive, featuring an open dialog between scientists and land managers. In March 2021, INSPIRES co-sponsored a facilitated workshop on forest regeneration that was attended by PI Weiskittel and Co-PI D'Amato as well as other scientists, land managers, and conservationists (Appendix 7. Regeneration of Northern Hardwoods in the Northern Forest Roundtable). Key outcomes of the meeting were a clear need for additional research on better defining useful forest regeneration metrics, being able to understand key regional drivers, and predicting the potential influence of climate change on future dynamics, which are all relevant and important for INSPIRES. Continued workshops and webinars are planned for future years of INSPIRES. In addition, the project's external website was updated and revised, and a public website for educators was developed (https://www.mainestempartnership.org/index.php/track-ii-inspires). Social media (Instagram and Twitter) accounts for INSPIRES were created and being managed and promoted by project graduate students, in conjunction with the Team Slack channel and INSPIRES website (Appendix 6. INSPIRES Communications and Resources). Plans for future stakeholder outreach were discussed at the March all-team meeting and suggestions include a project fair to showcase the project and generate more interest from the public, generation of more project communication materials, and conducting a summer workshop for high school teachers.

Project Problems and Mitigation Efforts

Although the project largely remains on schedule with strong participation across the institutions involved, problems have been encountered and mitigation efforts implemented. The primary challenge has been the ongoing Covid-19 global pandemic, which has created numerous barriers (reduced access to field sites, delays in recruitment), demands on project participants, and high uncertainty for future planning. A recent survey of the INSPIRES team (Figure 2) indicated that nearly everyone has been impacted by the pandemic with most either "surviving" or "struggling" and only one team member who is "excelling." The pandemic has been particularly challenging for early career faculty and students as there is no clear boundary between professional and personal matters along with the abrupt switch to a virtual classroom environment and inability to interact spontaneously with colleagues. One INSPIRES graduate student decided to take a leave of absence from graduate school citing these issues. In addition, the pandemic has eliminated planned in-person meetings or field trips, while significantly delaying project field or lab work.

Figure 2. Covid-19 Impacts on Team Members (anonymous survey conducted during March 2021 All-Team meeting).

A number of mitigation efforts have been implemented to address these challenges, such as shifting effort from extensive field data collection to computer-based activities such as modeling, shared resources for handling the pandemic, regular meetings where the pandemic is acknowledged and discussed (Figure 3), efforts by CLT to reduce administrative burdens on team members, implementation of safety protocols (e.g., masks and distancing) for in-person interactions per CDC guidelines, adaptation to virtual workspaces, and communication of potential impacts or implications to university administrators. Project leaders have adapted, rescheduled, and revised field and lab work in response to current reduced restrictions on travel and expenses; additional ramp-up is now underway for field/lab work planned for the summer 2021.

In September 2020, the project's contracted outside evaluator (AAAS-RCP) closed their program without warning (see details in Evaluation section, below). Given the planned external review for January 2021, the CLT worked quickly to find a new evaluator (The Implementation Group, T.I.G.), negotiate a contract for remaining project years (which required additional paperwork and university approvals), and arranged for a variety of inter-institutional team members to be available for the review. The virtual external panel review was successfully conducted, and a report generated.

Figure 3. Team members shared coping strategies in response to Covid-19 related stresses at March 2021 All-Team meeting.

Novel Opportunities

A second NSF EPSCoR Track 2 project on Big Data involving both the University of Maine and University of Vermont led by Dr. Brian McGill was funded by NSF in 2020. Dr. McGill and PI Weiskittel have discussed collaboration opportunities between that project and INSPIRES. Additional project synergies have been created through two shared positions being used to support both projects. The first is a professional scientific programmer (Leo Edmiston-Cyr) who led the INSPIRES Data Sharing Subcommittee further described below. The second is a part-time project coordinator (Stefania Marthakis) who has assisted both projects with the Data Outcome Portal, annual reporting, and communications including the INSPIRES student profiles provided in this report (Appendix 3. INSPIRES Student Profiles). The linkages between these two Track 2 projects have created unique opportunities for both efforts and led to the creation of an NSF science synthesis center pre-proposal led by Dr. McGill with Dr. Weiskittel as Co-PI, which was successfully submitted in April.

Changes in Strategy

As highlighted above, the pandemic has required both a highly adaptive and entirely virtual strategy to team building and project implementation. A shared leadership model has been implemented throughout INSPIRES, which has helped to build both intra- and inter-jurisdictional collaborations. To ensure successful team cohesion and reduce Zoom fatigue, virtual meetings have been limited to 2-3 hours and include mixed participation opportunities through breakout rooms, polls, and open discussion. Meeting participation has been strong despite their virtual nature with theme meetings often having 5-15 participants, while attendance at all-team meetings have ranged from 35 to 50 participants. In addition, individual themes have created recurring virtual meetings for collaborative work on sensor development, data processing, and modeling allowing for continued interaction and scientific progress despite the lack of in-person opportunities. In the future, the desired plan is to use a mix of in-person and virtual meetings to help create positive team synergies. Beyond the delayed field and lab work and additional personal and professional stresses created by the pandemic, the INSPIRES efforts remains largely on track in terms of both milestones and outcomes.

RESEARCH PROGRAM

Background

Societal demands on the Northern Forest and the ecosystem services they provide continue 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 challenges, the tri-jurisdictional INSPIRES faculty are collaborating on the development of a regional Complex Systems Research Consortium to facilitate analysis of forest ecosystem integrity and resilience from multiple scientific perspectives.

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 interdisciplinary effort is organized across four integrated themes (Table 2) 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.

INSPIRES faculty and students are working across the four research-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 and under alternative scenarios of future environmental and management changes.

The CLT is responsible for achieving the project's objectives and providing guidance to team members. It is composed of the PI and co-PIs, representing the lead institutions. With themes and projects well underway in Year 2, the CLT now meets monthly via videoconference to review research progress, develop team activities, and discuss issues relevant to project governance. For full transparency, CLT meetings are regularly scheduled, open to all team members, and meeting notes made available through the shared OneDrive folder.

Table 2. INSPIRES Research Approach and Goals by Theme

Theme	Research Approach	Research Goals
Theme 1. Advanced Sensing and Computing Technologies	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	Research Approach	Research Goals
Theme 2. Smart Environmental Informatics	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	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 imagery, 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	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.

Significance of Accomplishments

Primary Year 2 research activities of the INSPIRES project focused on deployment of wireless environmental sensors at selected field sites (Theme 1), creation and analysis of regional spatial datasets (Theme 2), model calibration and comparison (Theme 3), and high school teacher needs interviews (Theme 4). INSPIRES graduate student projects now represent the core of Year 2 research activities, which is expected to further increase in Years 3 and 4 of the effort. To enhance collaboration, researchers have identified core research sites across the three jurisdictions, which will be used for the wireless sensor deployment (Theme 1), targeted remote sensing acquisitions (Theme 2), and model testing (Theme 3), which will provide unique opportunities for student-led science projects in Theme 4.

Research themes continue to conduct 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 (incorporating pandemic-related restrictions) for field research activities and analytical techniques for summer 2021, such as wireless sensor deployment, remote sensing acquisitions, and model parameterization and calibration for predicting regional forest dynamics. Cross-theme coordination with Theme 4 team leads to discuss integration of research outcomes into G6-12 curriculum has been

ongoing with strong support and interest from Themes 1-3 with teaching trainings and workshops planned for summer 2021. 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.

As detailed in the following pages, most INSPIRES research themes in Year 2 focused on continued synthesis of available knowledge, identification of key knowledge gaps, refinement of research goals, hypotheses, and objectives, and research milestones by project year. Cross-theme collaboration opportunities were a key focus in Year 2 with the hope of implementation in Years 3 and 4. Theme participation remains high with strong representation across jurisdictions as well as integration of students as well as early-career faculty. The creation of the data sharing implementation plan and a standardized format for data sharing has helped to facilitate collaborations across themes and jurisdictions. Online tools, particularly R-Shiny applications, for data visualization, querying, and analysis are being explored and actively developed to further enhance future collaborations across themes and jurisdictions. These collaborations have already led to new partnerships and several ideas for future proposals as well as publications. In addition, strong linkages to important regional stakeholders such as the Schoodic Institute, Appalachian Mountain Club, the National Park Service, US Fish & Wildlife Service, and many private landowners have been maintained and strengthened in Year 2 of INSPIRES.

Theme 1. Advanced Sensing and Computing Technologies

Background

The primary research task in Theme 1 is to overcome gaps in spatial and temporal data coverage of key environmental data through the development and deployment of novel wireless sensors and existing low-cost sensors. Year 1 focused on determining where sensors could be deployed and what could be measured. Using this assessment, our work in Year 2 focused on deciding what ecosystem parameters would be measured at specific sites and how the system would be built. The team then split into two notable subgroups: one focused on development of a new wireless soil sensor probe (UMaine) while the other focused on building a sensor suite with existing low-cost sensors (Dartmouth, UNH, UVM). These subgroups met weekly to develop the respective systems and eventually deploy field tests. The entire theme continues to meet once a month to report progress and work through challenges. Members of Theme 1 also helped to form subcommittees on cross-theme collaboration and data management planning which also meet monthly. Key research goals, questions, and motivating hypotheses from the proposal were refined and are outlined below from the initial proposal.

Highlights

- Developed and deployed Mayfly based intensive sensor suite in Corinth, VT (2; Figure 4), Thompson Farm, NH (1), Old Town, ME (1; Figure 6), Bartlett, NH (1). Sensor suite included Photosynthetically Active Radiation (PAR), snow depth, atmospheric temperature and relative humidity, soil temperature and volumetric water content (2 depths), soil matric potential (2 depths). Stations were checked every few weeks to download data and check infrastructure.
- Completed design phase of wireless soil moisture probe at the University of Maine and began field comparison with more standard research-grade sensors (Figure 5).
- Robust discussion among theme members and with members of the Smithsonian Educational Research Center to understand techniques of measuring ecosystem respiration with K30 CO_2 sensors.
- K30 CO_2 sensor correctly re-addressed and code modified for use with Mayfly microprocessor.
- Discussed authorship and data sharing early and often, which sparked the development of Data Management Plan (all themes).

Figure 4. INSPIRES students and researchers (left) deploying new sensor suite (center) at the Corinth/Washington Forest in northern Vermont in October. The sensor suites have been measuring continuously through the winter (right).

Figure 5. The “brain box” of the sensor suite houses the green Mayfly microprocessor, din rail and connectors, and black charge controller. The wires of all sensors feed into this box from the bottom ports to connect to power, receive and deliver data, and keep the system grounded.

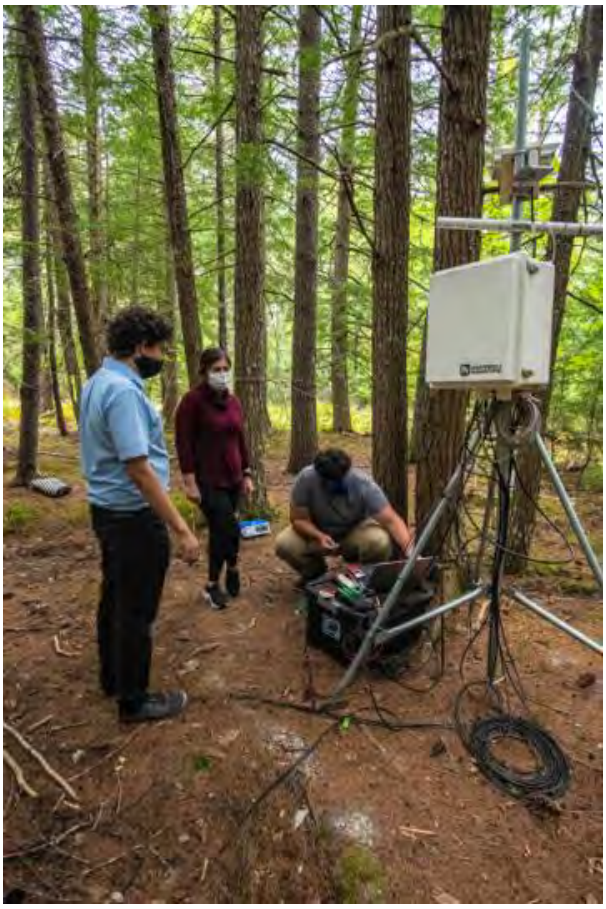

Figure 6. University of Maine INSPIRES researchers and students testing newly developed wireless sensors in the field near Old Town Maine.

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11-10 20:00 THF_M   v    2247.81 11.4     3
11-10 20:00 THF_M   V    2397.39 11.0     4
11-10 20:00 THF_M   Par:     -0.19 mV     -0.94 µmol m-2*s-1
11-10 20:00 THF_M   TempRH: 14.20 *C     81.40 % hum
11-10 20:00 THF_M   Snowdepth:   2490 mm
11-10 20:00 THF_M   Battery:     12.08 volts
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Figure 7. Screenshot of incoming data from sensor suite showing two different depths of soil moisture, PAR, air temperature and relative humidity, rangefinder depth to ground, and the battery charge.

Team Members

- 8 faculty (6 early career), 5 research technicians, 1 post-doc, 6 graduate students, and 3 undergraduate students; 11 VT, 7 ME, 4 NH

Name	Affiliation	Jurisdiction	Institution	Early Career	Role
Aimee Classen	Gund Institute for Environment/ Rubenstein School of Environment and Natural Resources	VT	UVM/ UMichigan	N	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
Apryl Perry	Earth Systems Research Center	NH	UNH	N	Research Technician
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
Karin Rand	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Research Technician
Kenneth Bundy	Department of Mathematics	ME	UMAB	Y	Faculty
Lindsay Barbieri	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Grad Student
Marie English	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Research Technician
Melissa Pastore	Rubenstein School of Environment and Natural Resources	VT	UVM	Y	Post-Doc
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
Peter Clark	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Grad Student
Sarah Nelson	School of Forest Resources	ME	UMO	N	Faculty
Sonia Naderi	Department of Electrical and Computer Engineering	ME	UMO	N	Grad Student
Sophie Marinace	Rubenstein School of Environment and Natural Resources	VT	UVM	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

Research Milestones Progress

Objective	Projects	Project responsible parties	Year 2 Milestones	Milestone Progress
1.1	1.1a Wireless sensor research and development	Abedi, Contosta, Adair, Naderia	• Finalize testing of developed wireless sensors • Deploy prototype sensors at selected field sites • Examine available data	• Developed and deployed sensor suite in Corinth, VT (2), Thompson Farm, NH (1), Old Town, ME (1), Bartlett, NH (1). • Planning on deploying 7 more in Summer 2021. • Incoming data being analyzed, reviewed, filled, and parsed as needed. • Prototype of novel wireless soil moisture sensors developed and tested at Old Town Forest. More will be tested and deployed in the spring.
1.2	1.2a Wireless sensor network design	Abedi, Contosta, Adair, Lutz	• Test alternative network configuration to maximize data collection • Optimize network design for efficiency	• Machine Learning models have been developed for routing and scheduling wireless transmissions. • Simulations have been completed to develop multi-agent control systems for packet scheduling • Optimal model development for routing systems has started.
1.3	1.3a Cyber-based big data harmonization, ML & interface	Abedi, Bundy	• Define consistent cloud-based computational frameworks for storing and accessing environmental data	• Survey of data management needs has been completed. • Data specialists defined data management plan for theme and standards • Cross-theme data sharing has started. • Pilot online interface for data visualization has been created and shared

Significant Problems/Unexpected Results/Novel Opportunities

- Restrictions on travel and field work delayed sensor deployment
- Sensor components had delayed delivery time due to low inventory
- Shift from Box to OneDrive for document storage resulted in some file access issues between universities
- Linking K30 CO_2 sensor use to sensors being developed in INSPIRES

Future Plans

- New collaboration with scientist working with K30 sensors in urban environments

- Continue sensor maintenance at existing sites
- Install 7 more sensors in Corinth, VT to capture silviculture treatment block variation
- Weatherize and install K30 CO_2 sensors at two INSPIRES sites in VT and NH starting in May to compare measurements with fixed, collar-based measurements of soil and deadwood flux
- Integrate K30 operating code into sensor suite code and further research continuous ecosystem CO_2 flux techniques
- Continue testing of phenology camera and snow depth rangefinder on select sensor suites
- Develop cross-theme and jurisdictional projects on cold air drainage and snow melt dynamics regionally
- Calibrate sensors for other snow measurements like Community Snow
- Continued testing of UMaine wireless soils sensor against traditional wired sensors
- Creating a manual and online video for sensor suite setup to ensure repeatability of project
- Continue wireless routing system development and implementation
- Engage Theme 4 members in fieldwork and present fieldwork to teachers as a part of the Theme 4 professional development program in July

Theme 2. Environmental Informatics and Analytics

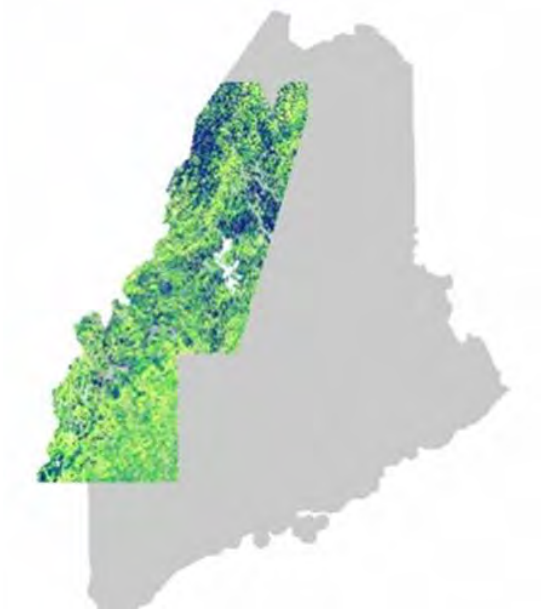


Figure 7. Map of balsam fir abundance for 4 million ha of forest in northern Maine and New Hampshire using a novel machine learning algorithm and cloud-based computing. Year 3 will focus on producing regional maps for keystone species.

Background

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. In Year 2, 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

- Processed 750 Gb of high resolution visible and near infrared imagery from a UAV collected over 2019-2020 throughout Maine forests
- Completed preliminary 20 m tree species occurrence and abundance maps for 4 million ha in northern Maine and New Hampshire using Sentinnel-2 imagery and a cloud-based machine-learning algorithm (Figure 7)
- Identified new regional climatic zones based on project future conditions, which show significant departures from the USDA plant hardiness zones (Figure 8)
- Refined machine learning classifier algorithms to detect individual tree crowns from high-resolution remote sensing images (Figure 9)
- Developed a streamlined and novel workflow for querying of multiple available spatial datasets to be deployed in the Digital Forest framework (Figure 10)
- Updates and significant refinement to the software system for processing remote sensing data, lecospec (https://github.com/nelsopet/lecospec), are happening through collaborations across themes

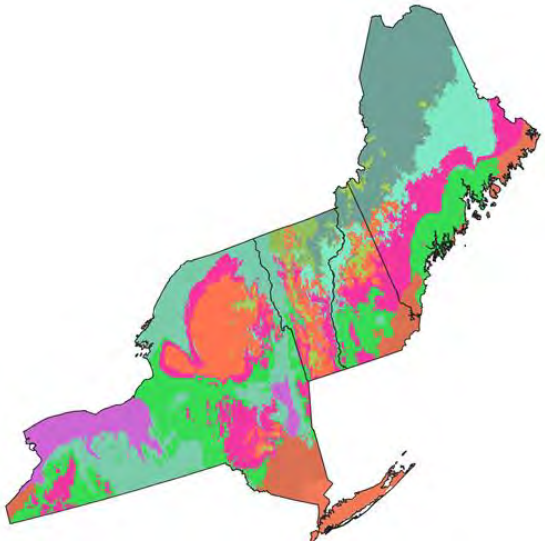


Figure 8. Revised regional climatic zones based on projected down-scaled GCMs across the study area.

- Use of machine learning classifiers to identify tree species characteristics based on hyperspectral imagery (Figure 12)
- Development of a data-driven ontology for classification of species habitat characteristics based on abundance, slope, and aspect (Figure 11).

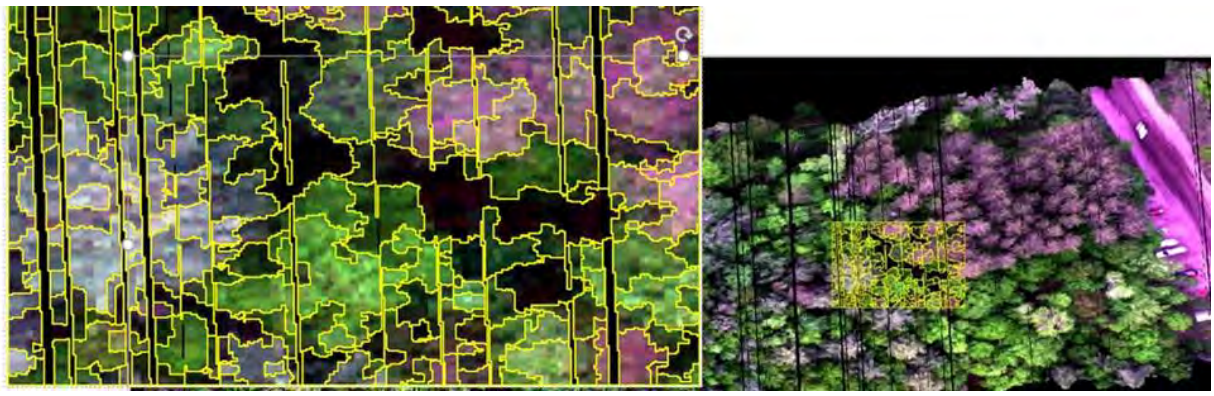


Figure 9. Application of refined machine-learning classifier algorithm for detecting individual tree crowns from high-resolution remote sensing imagery

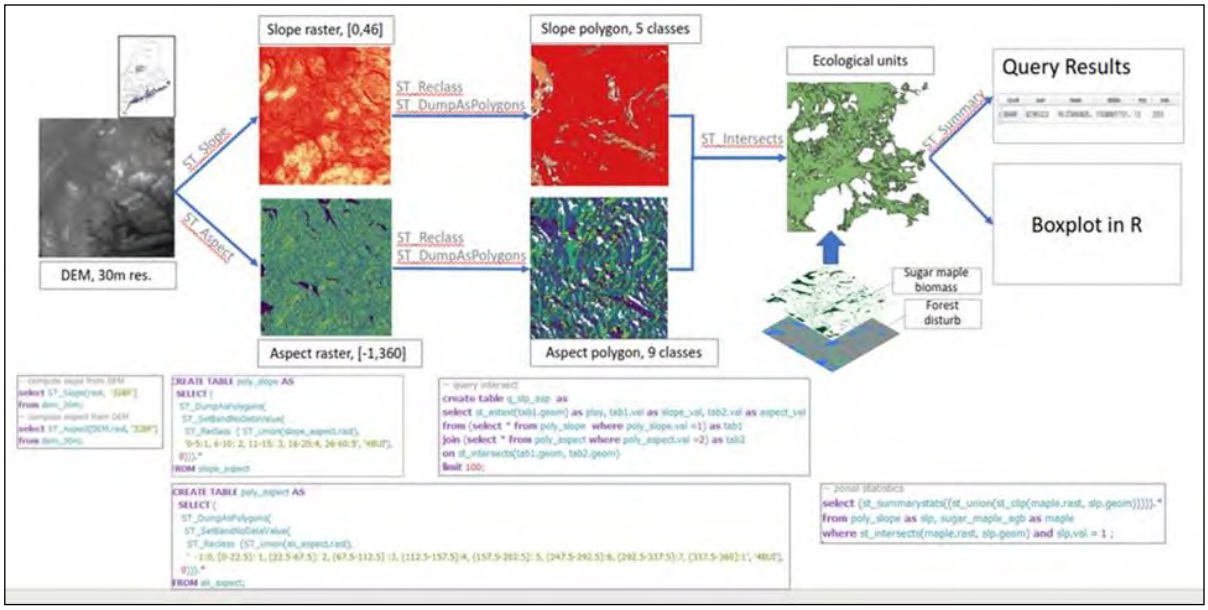


Figure 10. Spatial querying and classification workflow for available spatial data using the Digital Forest framework being developed by INSPIRES researcher Torsten Hahmann and graduate student, Kingsley Wiafe-Kwakye

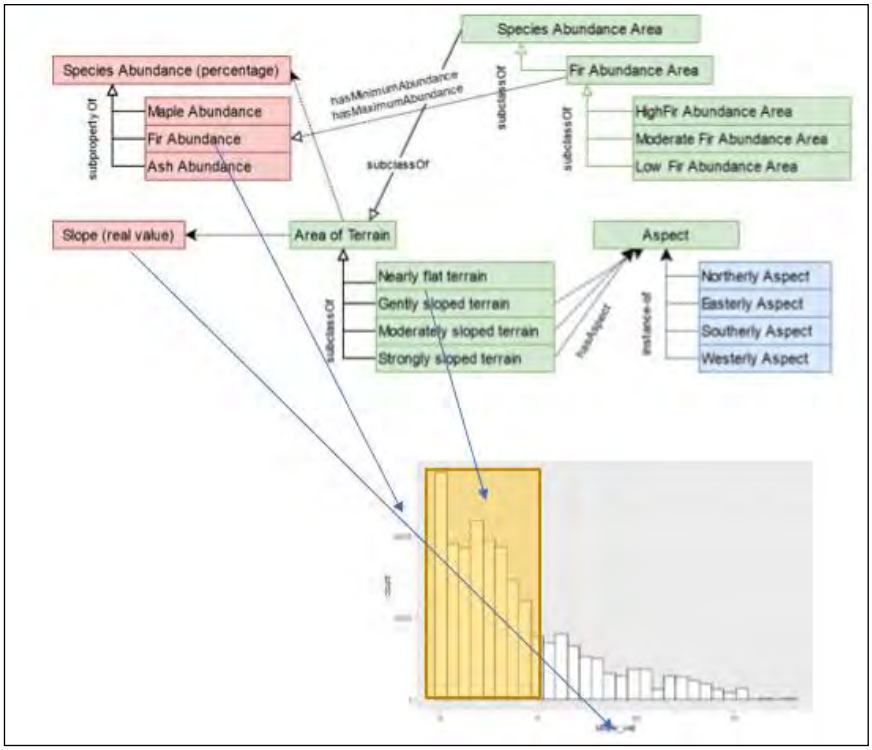


Figure 11. Development of a data-driven ontology for classification of species habitat characteristics based on abundance, slope, and aspect

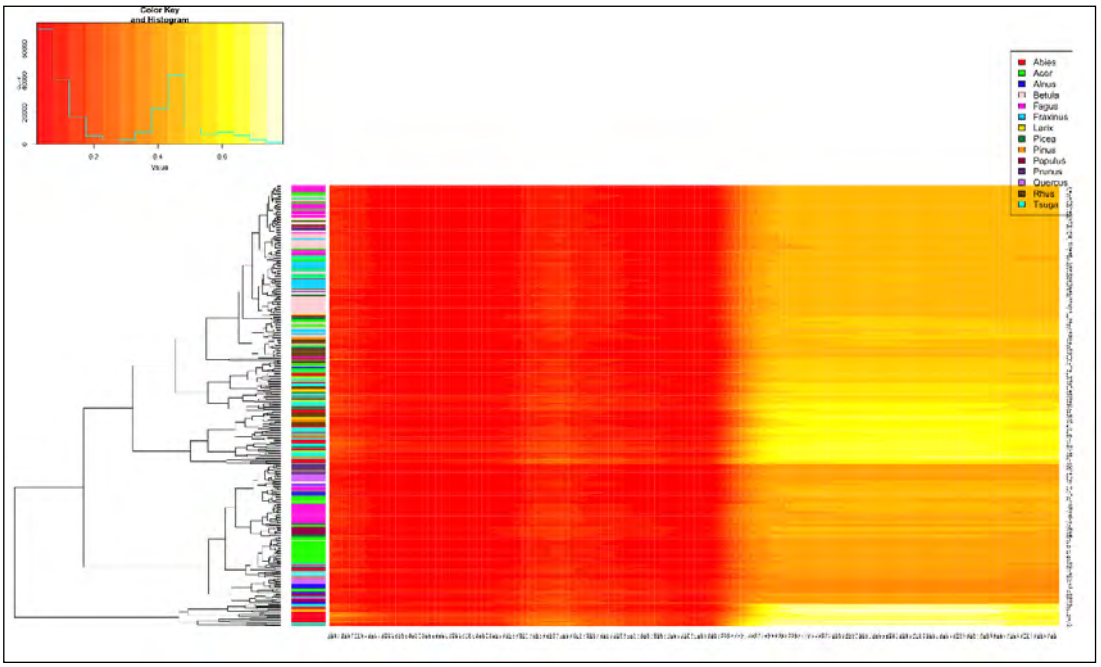


Figure 12. Classification of individual tree species based on multi-spectral wavelength signals using a novel machine-learning classifier algorithm

Team Members

- 12 Faculty (7 Early-Career), 2 Professional Staff, 4 Graduate Students, and 2 Undergraduate Students; 15 ME, 4 NH, and 1 VT

Name	Affiliation	Jurisdiction	Institution	Early Career	Role
Darren Ranco	Department of Anthropology	ME	UMO	N	Faculty
Donna Rizzo	Department of Civil & Environmental Engineering	VT	UVM	N	Faculty
Jane Pettit	Center for Research on Sustainable Forests	ME	UMO	N	Prof staff
Jing Yuan	School of Computing and Information Science	ME	UMO	Y	Post-doc
John Hastings	Earth Systems Research Center	NH	UNH	N	Grad student
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
Kevaughn Smith	School of Forest Resources	ME	UMO	N	Grad student
Kingsley Wiafe-Kwakye	Department of Spatial Information Sciences and Engineering	ME	UMO	N	Grad student
Larry Whitsel	Advanced Computing Group	ME	UMO	N	Faculty
Leo Edmiston-Cyr	Center for Research on Sustainable Forests	ME	UMO	N	Prof staff
Marek Petrik	Department of Computer Science	NH	UNH	Y	Faculty
Mary Martin	Earth Systems Research Center	NH	UNH	N	Faculty
Nick Soucy	Department of Computer Science	ME	UMO	N	Grad student
Peter Nelson	Department of Biological Sciences and Environmental Studies	ME	UMFK	Y	Faculty
Salimeh Yasaei Sekeh	School of Computing and Information Science	ME	UMO	Y	Faculty
Sam Roy	Mitchell Center for Sustainability Sciences	ME	UMO	Y	Faculty
Sean Smith	Department of Computer Science	NH	UNH	N	Undergrad
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 2 Milestones	Milestone Progress
2.1	2.1a Extension of field model beyond in-situ sensors	Nittel, Petrik, Ranco	• Develop methods to scale ecological sensor data and its uncertainty at test locations to the broader landscape	• Working to link high-resolution remote sensing data with available sensor data
2.2	2.2a Hybrid Semantic-statistical representation of forest places	Hahmann, Beard, Legaard, .1& Martin	• Develop a framework for extending ontologies with statistical representations of spatio-temporal information	• Building a data-driven ontology based on available regional forest datasets
	2.2b Provide spatial datasets for Theme 3 objectives	Hahmann, Beard, Martin	• Outline conceptual framework for Digital Forest using select spatio-temporal datasets	• Developed a protype of the Digital Forest using several available geology, soils, climate, topographic, and forest spatial datasets
	2.2c. Develop and evaluate alternative ML algorithms for analyzing spatio-temporal datasets	Legaard, Roy, Yasaei	• Develop and deploy novel machine-learning algorithms for identifying key trends through space and time	• Refined multi-objective machine-learning algorithm • Refined machine-learning clustering algorithms for classification • Improved spatial querying and classification algorithms using data-driven solutions
2.3	2.3a Analysis of forest place correlations and similarities	Beard, Legaard, Petrik, Hahmann, McGill, Roy, Ranco	• Develop new layers of regional climatic, forest type, disturbance, and potential productivity based on forecasted changes from available data sources	• Assessing new regional climatic zones based on projected down-scaled GCMs

Significant Problems/Unexpected Results/Novel Opportunities

- Restrictions on travel and field work delayed planned remote sensing acquisitions

Future Plans

- Continued expansion of regional tree species and disturbance maps for the entire study area
- Inclusion of additional spatial datasets into the Digital Forests and testing of spatial querying
- Expansion of the data-drive ontology for classification of species habitat characteristics based on additional topographic and abiotic factors like parent material, soil attributes, and climate
- Refinement of machine learning classifiers for tree crown segmentation
- Use high-resolution maps of tree species as training tiles for cross-regional and moderate-resolution mapping of tree species using available satellite imagery.
- Expansion of ForEST to include model projections of alternative futures
- Official software release of lecospec version 1.0 for public use and development

Theme 3. Integrated Ecological Modeling

Background

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 both the high spatio-temporal resolution data collected by this project's new sensor networks from Theme 1 and remote sensing data products developed by Theme 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?

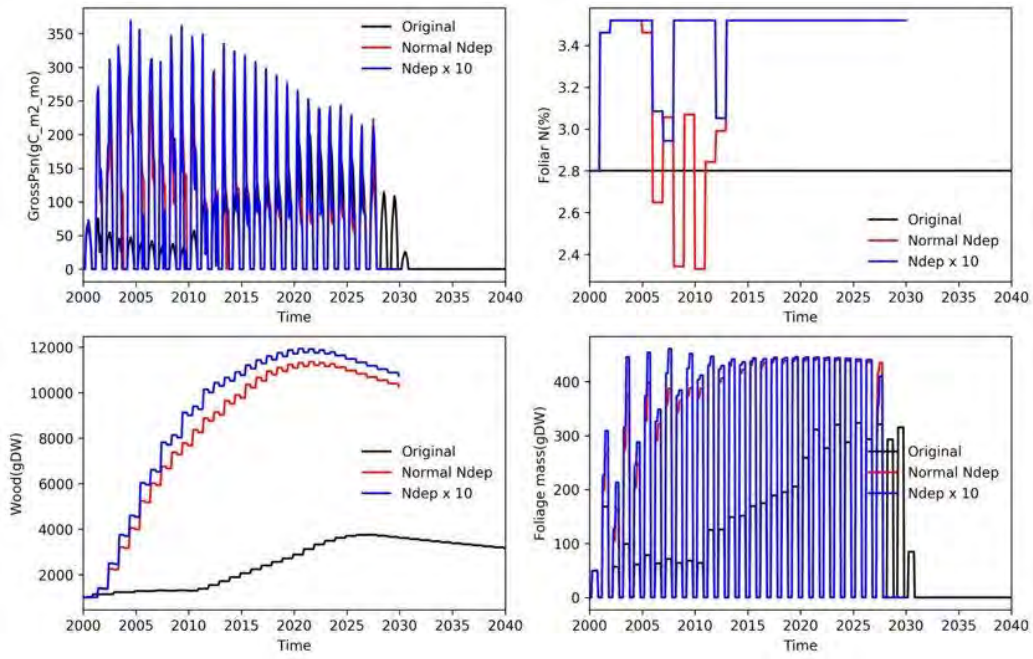


Figure 13. Preliminary testing of expanded PnET-Succession module comparing wood growth modeled under Nitrogen fertilization experiment (0, 6, and 60 kgN ha-1)

The focus of Theme 3 in Year 2 was identifying gaps (1) in model representations of key ecological processes in PnET-II and LANDIS-II and (2) in available model initialization data, particularly related to regional and local climate data that could be collected or modeled by Theme 1 or 2.

Highlights

- Continued to meet monthly to discuss advances in model development and specification, and to identify opportunities for cross-theme collaboration.
- Expanded LANDIS-II code base for LANDIS-II PnET-Succession module to incorporate nitrogen cycling routines, in collaboration with LANDIS-II Technical Advisory Committee. Model improvements provide for more realistic simulation of tree growth and species competition for light, water, and nitrogen.
- Conducted preliminary testing of expanded PnET-Succession module using Harvard Forest nitrogen fertilization experiment (Figure 13).
- Identified ecological model capacity to represent the effects of topography on local climatology as an important limitation and area of needed research; information about climatological events such as cold-air pooling in valleys is limited and missed by climate projections, limiting the ability to represent tree species migration and climate refugia from regional warming in mountainous areas in landscape models.
- Initiated collaborative action with Theme 1 to collect temperature sensor data along topographic gradients to fill important knowledge and data gaps. Advanced the development of several landscapes in western New England for simulating future forest conditions under different climate change, disturbance, and management scenarios using LANDIS-II

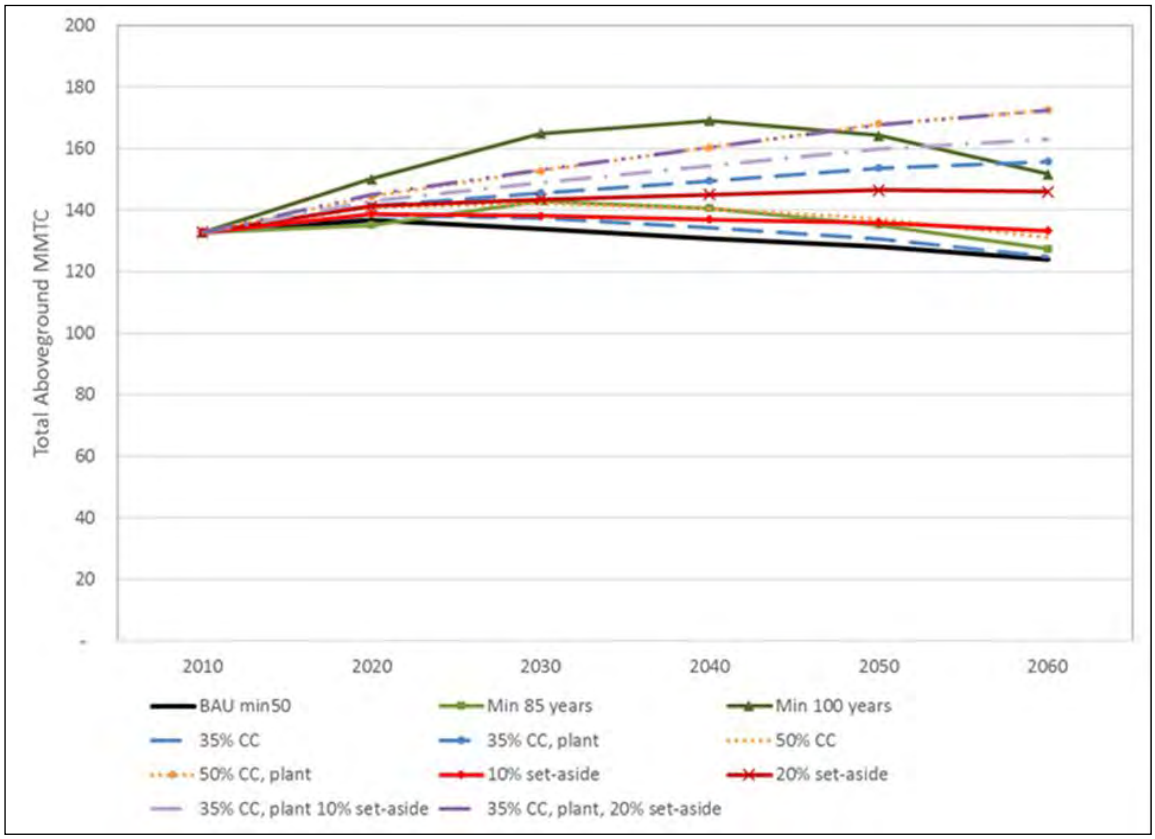
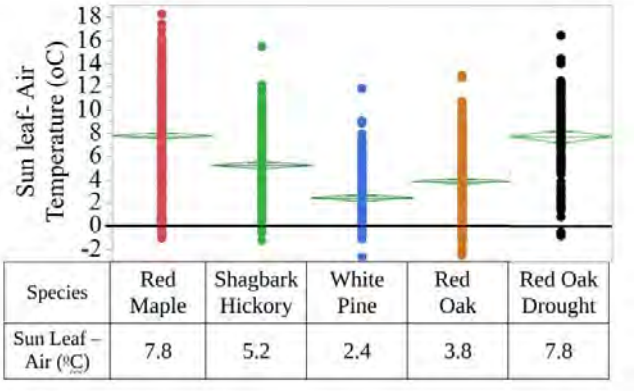


Figure 14. Total aboveground forest carbon (million metric tons) projected across alternative management scenarios for 4 million ha in northern Maine. Scenarios include business as usual (BAU), clearcutting (CC), and extended rotations (minimum harvest age).



Species	Red Maple	Shagbark Hickory	White Pine	Red Oak	Red Oak Drought
Sun Leaf – Air (°C)	7.8	5.2	2.4	3.8	7.8

Figure 15. In situ measurements of leaf temperature (left) demonstrated important differences between species in ability to buffer high air temperatures, as well as effects of drought on leaf cooling (right).

- Completed numerous contrasting forest management simulations using LANDIS-II across two climate change scenarios over 4 million ha in northern Maine (Figure 14)
- Continued compiling data for intensive forest modeling sites and initialize landscapes across the region for LANDIS-II
- Update and modified Biomass Insects Defoliation model disturbance extension for latest version of LANDIS-II simulation model for use in spruce-budworm management simulations at U. Maine let by Simons-Legaard.
- Working to explicitly couple PnET-CN with LANDIS-II to enable nutrient cycling processes to be included as mechanisms affecting forest succession
- Collected canopy-level measurements to observe species differences in the optimum temperature range for photosynthesis and sun vs. leaf temperature (Figure 15). Models typically use air temperature rather than leaf temperature to model photosynthesis. Results demonstrated that leaf temperature can be substantially higher, which has important implications for growth predictions.

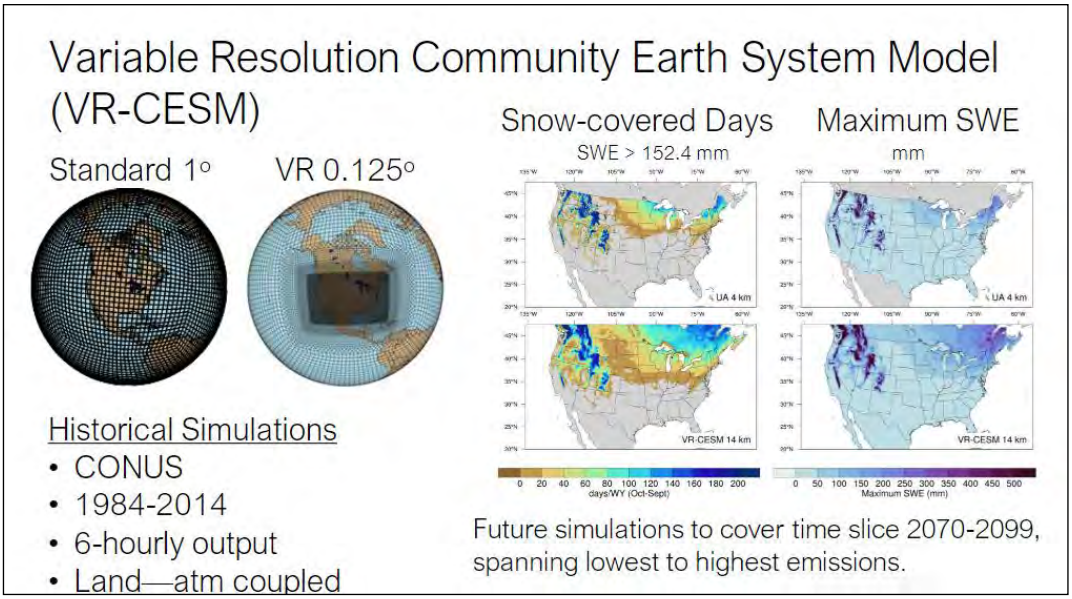


Figure 16. Simulations of future snowpack (2070-2099) were conducted using the CLM model and a finer scale mesh to improve predictions in complex terrain and across forest types. From Burakowski et al. (in preparation)

- Completed global simulations of future snowpack with the Variable Resolution Community Earth System model (VR-CESM) using refined grid. Simulations improve predictions of, for example, snow-covered days and snow water equivalent in areas of complex terrain in the Northern Forest (Figure 16. Simulations of future snowpack (2070-2099) were conducted using the CLM model and a finer scale mesh to improve predictions in complex terrain and across forest types. From Burakowski et al. (in preparation)).
- Used FVS to model alternative management strategies for restoring ecosystem services, including forest carbon and wildlife habitat, in degraded areas.
- Worked with undergraduate computer science capstone students to develop additional decision-support tools within the Forest Ecosystem Status and Trends (ForEST) web application.
- Developed preliminary table of regional scenarios (Table 3), solicited feedback from project partners, and implemented example scenarios on northern Maine test landscape.
- Published new version of Acadian variant of FVS (FVS-ACD) online that shows more logical behavior than prior versions (Figure 17. Comparison of alternative versions of the Acadian Variant of the Forest Vegetation Simulator (FVS-ACD) on representative Forest Inventory and Analysis plots in Maine for predicting basal area (top) and stem density over time).
- Supported student training opportunities in LANDIS-II and FVS.
- Supported student presentations at 2020 conference of the American Geophysical Union.

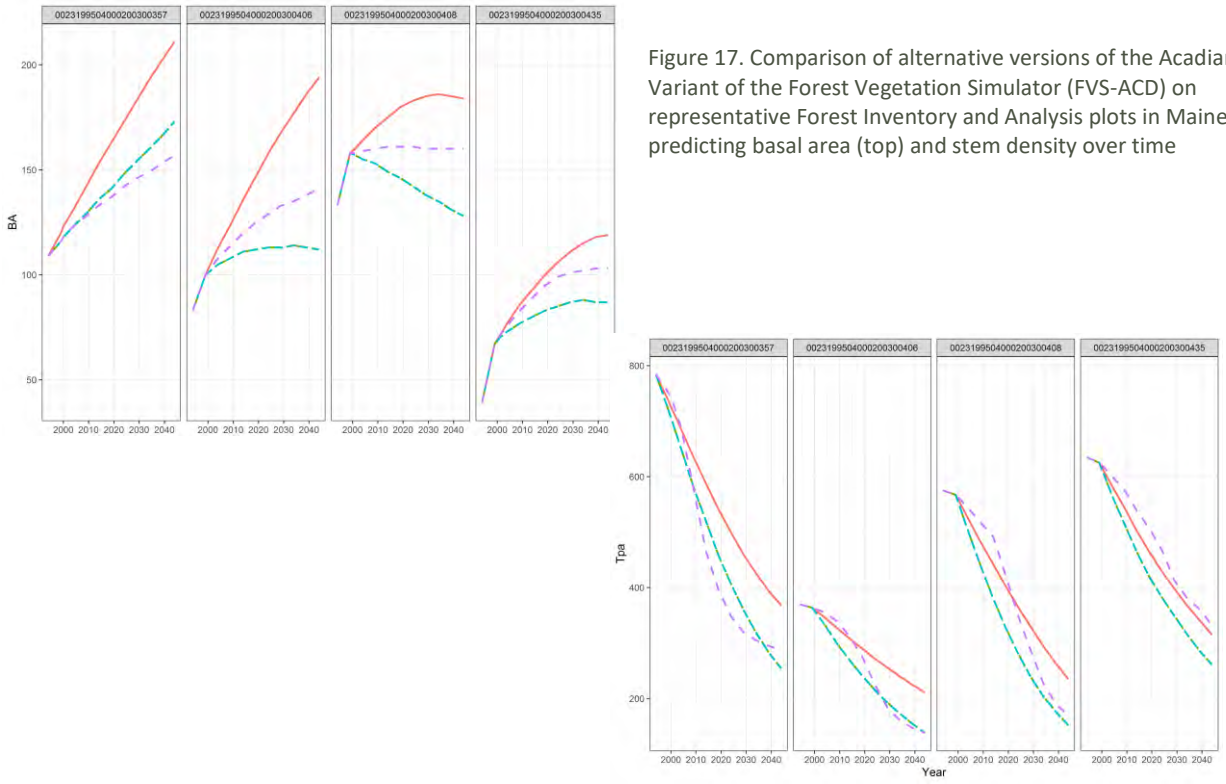


Figure 17. Comparison of alternative versions of the Acadian Variant of the Forest Vegetation Simulator (FVS-ACD) on representative Forest Inventory and Analysis plots in Maine for predicting basal area (top) and stem density over time

Table 3. Alternative projection scenarios for Maine, New Hampshire, and Vermont that varying intensity with respect to climate change, forest management, and disturbances. Abbreviations are regional climate projection (RCP), business as usual (BAU), spruce budworm (SBW), hemlock wooly adelgid (HWA), and Emerald ash border (EAB).

Maine			
Severity	**Climate Change**	**Forest Management**	**Disturbance**
Low	BAU	BAU	wind
Medium	RCP 2.6	Balanced partial/full removal	wind+SBW
High	RCP 8.6	Triad	wind+SBW+HWA+EAB+native defoliator
New Hampshire			
Low	BAU	BAU	wind
Medium	RCP 2.6	10% higher/lower harvest rate	wind+native defoliator
High	RCP 8.6	20% higher/lower harvest rate	wind+SBW+HWA+EAB
Vermont			
Low	BAU	BAU	wind
Medium	RCP 2.6	10% higher/lower harvest rate	wind+native defoliator
High	RCP 8.6	20% higher/lower harvest rate	wind+SBW+HWA+EAB

Team Members

- 10 faculty (7 early-career), 3 graduate students, 1 Research Staff; 5 ME, 2 VT, and 7 NH

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
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
Kathy Crowley	Unity College	ME	Unity	Y	Faculty
Keegan Feero	Earth Systems Research Center	NH	UNH	N	Grad Student
Lisa Scott	Department of Natural Resources and the Environment	NH	UNH	N	Grad Student

Name	Affiliation	Jurisdiction	Institution	Early Career	Role
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 2 Milestones	Milestone Progress
3.1	3.1a Inverse parameterization of ecological models	Foster, Simons-Legaard	• 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	• Compile regional FIA, long-term experimental forests, and National Forests • Use fine-scale climate and physiological measurements to assess current model parameters • Developed preliminary inverse parameterization strategy of LANDIS-II Biomass Succession module using regional FIA data • Outputs of alternative management scenarios in VT, NH, and ME on large landscapes • Preliminary implementation of PnET at Hubbard Brook, Harvard Forest and Howland • Decision-support management framework based on FVS projections
3.2	3.2a Model integration and application	Hayes, Burakowski, Ollinger	• Complete model sensitivity analyses and model evaluation; • Continue to refine model representation of disturbance and species response to climate	• Planned sensitivity assessment for soil C & N at select locations with PnET-SUCESSION • Better integration of soil C & N cycling in PnET-Succession • Improved parameterization of tree physiology in PnET • New version of FVS-ACD online • Initialize of test landscape around National Forests • Refined wood C & N decomposition modeling for PnET/Landis • More detailed assessment of within- and across-species-specific response to drought

Objective	Projects	Project responsible parties	Year 2 Milestones	Milestone Progress
3.3	3.3a Scenario assessment & trend analysis	Weiskittel, D'Amato, Ducey, Gunn	• Complete regional baseline projections and assess outcomes; • Present to stakeholders for input and feedback	• Alternative regional scenarios by state developed • Solicited and received feedback on scenarios • Implemented example scenarios (e.g. BAU, climate change, adaptive management) on test landscape

Significant Problems/Unexpected Results/Novel Opportunities

- Hiring delays due to the pandemic and challenges with recruiting and retaining graduate students

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 development of Biomass Insects module for LANDIS-II to enable projections of future forest insect outbreaks.
- Conduct multi-model comparison at selected study sites and landscape test locations.
- Continue to develop collaborative strategies with Theme 1 and 2 to align measurement collections with ecological models.
- Test temperature and water stress sensitivity in PnET using fine-scale initialization data.
- Outline and frame regional scaling of model implementation.
- 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.
- Initiate focus group and stakeholder input on completed projection scenarios and potential barriers to implementation.
- 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.
- Complete sensitivity analyses and in-depth evaluation of ecological models.

Theme 4. Quantitative Reasoning in Context

Background

Theme 4 is focused on building a collaborative three-state team and putting into place strategies for connecting classroom teachers with the work of INSPIRES. Our progress in Year 2 has included collaboration across the project themes by attending monthly meetings, developing our collaborative research across the three states, and bringing teachers from Maine into our team, recruiting teachers from VT and NH into the project, working 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

- Continue to meet on a bi-weekly basis to collaborate on the education, outreach and research goals pertaining to quantitative reasoning in the context (QRC) of the northern forest
- 8 high school teachers from across Maine recruited and interviewed (Figure 18. Eight high school teachers from across Maine recruited and interviewed in Year 2 of INSPIRES)
- Developed specific interview instruments to gather baseline data about teacher prior knowledge, beliefs and conceptions of quantitative reasoning (data gathering, analysis and representation) within the context of their current teaching practice
- Developed two distinct interview protocols, one to elicit initial conceptions of quantitative reasoning in context and a follow-up interview to explore more deeply the conceptions and practices that teachers initially revealed in the first interview
- Constructing a summer professional learning program to be offered in July 2021, which will be offered online this year.
- Actively participated in Theme 1-3 meetings over the past year.
- Have solicited interest from the full team in collaborating with the teacher professional development program
- 9 teachers from across Vermont have been recruited to participate in the teacher professional learning program and associated research project related to quantitative reasoning within the context of the northern forest over the next 2 years. These teachers currently teach MS and HS science in the following school districts in VT: Harwood Unified Union School District; Vermont Commons School; Milton Town School District; Winooski School District, Two Rivers Supervisory Union (GMUSD); Washington Central Unified Union School District; Essex School District; Champlain Valley School District; Lamoille South Unified School District.

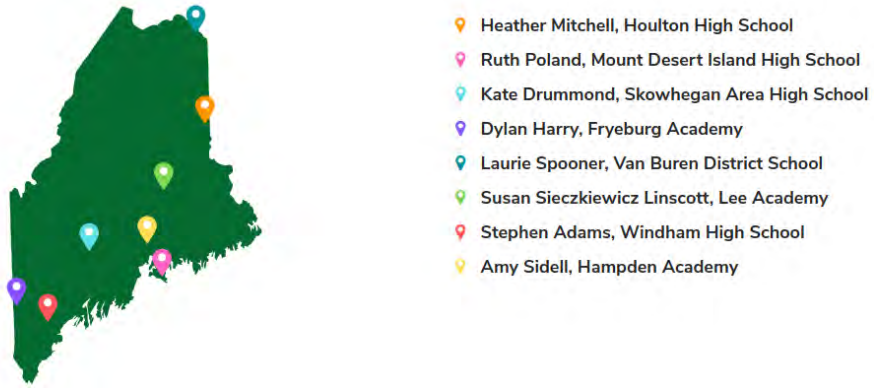


Figure 18. Eight high school teachers from across Maine recruited and interviewed in Year 2 of INSPIRES

Team Members

- 5 Faculty (1 Early-Career), 2 Professional Staff, and 3 Graduate Students; 8 ME, 1 VT, and 1 NH

Name	Affiliation	Jurisdiction	Institution	Early Career	Role
Anupam Raj	Maine Center for Research in STEM Education	ME	UMO	N	Grad Student
Erin Nason	Maine Center for Research in STEM Education	ME	UMO	N	Grad Student
Franziska Peterson	Maine Center for Research in STEM Education	ME	UMO	Y	Faculty
Hazel Cashman	Maine Center for Research in STEM Education	ME	UMO	N	Grad Student
Laura Millay	Maine Center for Research in STEM Education	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	ME	UMO	N	Faculty

Research Milestones Progress

Objective	Project responsible parties	Year 2 Milestones	Milestone Progress
4.1 Design and implementation of Big Data modules integrated into G6-12 curricular material	Peterson, Toolin, Millay, Lindsay, McKay, Shulman, Nickerson	• Recruitment materials developed and teachers recruited • Initial interview protocols developed • Initial interviews conducted • Summer professional learning program for teachers designed and carried out • Draft design of QRC curriculum materials	• 8 teachers selected in Maine and interviews conducted of each • Interviews currently being analyzed for current teacher strategies and needs • Teachers in New Hampshire and Vermont will be recruited and selected • First summer professional learning will be developed and implemented for Summer 2021

Objective	Project responsible parties	Year 2 Milestones	Milestone Progress
			• Initial drafts of curricular materials will be developed during Summer 2021
4.2. Use local Big Data to answer student- and community-relevant science questions	Peterson, Toolin, Millay, Lindsay, McKay, Shulman, Nickerson	• Initial drafts of student surveys developed for use during piloting of curricular materials	• Student surveys to be designed during summer professional learning together with initial curriculum development
4.3. Use of local Big Data to answer student- and community-relevant science questions	Peterson, Toolin, Millay, Lindsay, McKay, Shulman, Nickerson	• Pilot student projects identified and initiated	

Significant Problems/Unexpected Results/Novel Opportunities

- Travel restrictions reduced face to face interactions with teachers
- Planned teacher's summer workshop may need to be done virtually, which limits opportunities to get participants out in the field with other INSPIRES researchers

Future Plans

- Design professional learning sequence to support teachers
- Support teachers in implementing the designed units that incorporate quantitative reasoning and forestry
- Develop and conduct student surveys
- Create more student-led science projects
- Conduct and analyze the QRC interviews with the participating teachers
- Develop and implement the teacher professional learning program in July 2021
- Consider other collaborative grant opportunities pertaining to STEM education with Theme 4 staff such as the proposals described in Intellectual Merit section.
- Collaborate with Theme 4 staff to develop conference proposals and submit publications related to the QRC interviews that are currently being conducted with teacher participants.

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 review committee recognized this as a unique strength of the INSPIRES effort and the majority of participants noted new collaborations as a result of the project (see Evaluation section).

Project participants are encouraged to work on or across more than one theme or research project, this has resulted in several important project outcomes, including 5 intra- and 2 inter-jurisdictional publications, respectively. 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 example, INSPIRES has resulted in 13 intra- (5 awarded) and 7 inter-jurisdictional proposals through Year 2.

In Year 2, the number of research products were 22 (16 published; 3 in press; 3 under review) peer-reviewed articles, 14 presentations, and 3 data/model/technology products (Appendix 1. Products Year 2). The publications were in top tier ecological and remote sensing journals including *Diversity and Distributions* (Impact Factor = 3.93), *IEEE Transaction on Neural Networks and Learning System* (Impact Factor = 8.793), *Remote Sensing* (Impact Factor = 4.509) and *Forest Ecology & Management* (Impact Factor = 3.216). Several of the publications were multi-author and included INSPIRES trainees, early-career, and senior faculty as co-authors. Although slightly down from Year 1 (15 vs. 14) reflecting the lack of regional or national conferences due to the pandemic, the presentations were primarily by INSPIRES early-career faculty (7) and trainees (2) faculty given at regional (8), national (5), and international (1) meetings.

The number of proposals submitted in Year 2 are on pace to equal or exceed Year 1. As of May 2021, INSPIRES researchers have submitted a total of 17 proposals totaling $41,132,273 in requested funding, with 12 projects awarded ($11,035,918) and $37,449,226 pending. The Year 2 proposals were led primarily by early-career faculty (14) and were submitted to a variety of sources including the National Science Foundation (5) and other Federal agencies (12). Four of the proposals led by early-career INSPIRES faculty were inter-jurisdictional. Details on the specific research proposals and Year 2 awards are provided in Table 4.

Table 4. Year 2 Proposals and Funding Status

PI	Proposal Title	Funding Organization	Amount Requested	Status	Amount Awarded
Hayes, Daniel*	Supporting Stakeholder Data Requirements for Decision-Making in Managed Forests: An Landscape Model-Data Framework for High Resolution Carbon Accounting and Uncertainty Estimation	NASA CMS	$940,308	Awarded	$940,308
Burakowski, Elizabeth*	Convergent Arctic Research Perspectives and Education (CARPE)	NRT	$299,658	Submitted	

PI	Proposal Title	Funding Organization	Amount Requested	Status	Amount Awarded
Burakowski, Elizabeth*	Land Use Change and the Surface Climate: Measuring and Modeling The Environmental Persistence of the New England Colonial-era Forest Management	Human and Environment & Geographical Sciences	$398,998	Not Awarded	
Burakowski, Elizabeth*	Community Snow Observations II (CSO2): Linking Citizen Science, Computer Modeling, and Remote Sensing	NASA Citizen Science	$1,000,000	Not Awarded	
Classen, Aimee	Consequences of winter perturbations on hydro-biogeochemical export and connectivity in contrasting ecosystems	DOE	$1,000,000	Submitted	
Classen, Aimee	The potential for advanced snowmelt timing to decouple plant and mycorrhizal fungal phenology and biogeochemical cycling	DOE	$1,000,000	Submitted	
Classen, Aimee	BII: The Ecological Consequences of Disrupting the Environmental Clock (ECODE)	NSF BII	$12,499,985	Submitted	
Contosta, Alix*	MRA: Vanishing winters, lengthening springs, and changing carbon carbon fluxes across seasons	NSF Macrosystem Biology	$1,199,387	Awarded	$1,199,387
D'Amato, Anthony⁺	Managing for the cold: Developing forest practices to preserve cold habitat in Northern Forests	Northeast Climate Adaptation Science Center	$397,606	Submitted	
Gunn, John*	Evaluating Poor Quality Forest Stands and Demonstrating Rehabilitative Silviculture in New Hampshire	USDA Forest Service Landscape Scale Restoration Grants	$133,407	Submitted	
Nelson, Peter*	Assessing Citizen Science Labeling to Improve Training Data Quality for Land Cover Protocols within the GLOBE Observer Community	NASA-EPSCoR	$100,000	Submitted	
Nelson, Sarah	Managing for the Cold: how can forest practices help preserve cold refugia in Northern Forest ecosystems?	Northeastern States Research Cooperative	$144,354	Not Awarded	
Simons-Legaard, Erin*	Quantifying the Carbon Sequestration and Economic Potential of Natural Climate Solutions from Maine's Working Forests	R01	$185,226	Submitted	
Simons-Legaard, Erin*⁺	DISES: Perceptions of ecological risk and the landscape dynamics of forest management, insect outbreaks, and climate change	R01	$916,672	Submitted	

PI	Proposal Title	Funding Organization	Amount Requested	Status	Amount Awarded
Simons-Legaard, Erin*+	Perceptions of ecological risk and the landscape dynamics of climate change, insect outbreaks, and adaptive forest management	DISES	$916,672	Submitted	
Weiskittel, Aaron	Enhancing Health, Ecosystem Services, Productivity, Resilience & Utilization of Forests by Increasing Use of Data and Climate-Adapted Management: A Cross-Regional Collaboration	USDA SAS	$10,000,000	Submitted	
Weiskittel, Aaron	Promoting Economic Resilience and Sustainability of the Eastern US Forests (PERSEUS)	USDA SAS	$10,000,000	Submitted	
	Total Submitted Yr 2		**$41,132,273**		
		Pending	**$37,449,226**		
Submitted Year 1, Awarded in Year 2					
Contosta, Alix*+	SitS: FroSen: Novel soil frost sensing systems for tracking freeze-thaw cycles and their implications for ecosystem carbon and nutrient dynamics	USDA NIFA AFRI Foundational Program	$1,199,160	Awarded	$1,199,160
D'Amato, Anthony	Assessing Nutrient Sustainability In Forest Management: Novel Applications Of Metal Isotopes And In-Situ Mineral Measurements	USDA NIFA AFRI Foundational Program	$470,835	Awarded	$470,835
D'Amato, Anthony	Adaptive forest management options for white ash influenced by the invasive emerald ash borer	USDA AFRI NIFA CARE Program	$300,000	Awarded	$300,000
Gunn, John*	Identifying Poor Quality Forest Stands and Demonstrating Rehabilitative Silviculture in New Hampshire	USDA Conservation Innovation Grants	$120,000	Awarded	$120,000
Hahmann, Torsten*	Cellulose ontology and informatics: a tool to accelerate the development of cellulosic materials and products	US Forest Service	$30,000	Awarded	$30,000
Hahmann, Torsten*	Cellulose Materials Informatics: Building A Knowledge Graph For Cellulose Materials Discovery And Research (Cellograph)	USDA-NIFA	$500,000	Awarded	$500,000
Hayes, Daniel*	The FORest Carbon Estimation (FORCE) Project: Mapping GEDI-derived forest structure metrics in the U.S. and Canada with plot-based inventory and multimodal remote sensing data in a hierarchical spatial modeling framework	NASA GEDI	$497,469	Awarded	$497,469
Ranco, Darren	New Beginnings for Wabanaki Students	USDA-NIFA--New Beginnings for Tribal Students	$283,000	Awarded	$283,000

PI	Proposal Title	Funding Organization	Amount Requested	Status	Amount Awarded
Rizzo, Donna	Collaborative Research: Network Cluster: Using Big Data approaches to assess ecohydrological resilience across scales	National Science Foundation	$3,199,116	Awarded	$2,499,000
Rizzo, Donna	FW-HTF-RL: Testing a responsible innovation approach for integrating precision agriculture (PA) technologies with future farm workers and work	National Science Foundation	$2,996,759	Awarded	$2,996,759
			Total Awarded Yr 2		**$11,035,918**

*Early-career faculty

[+]Inter-jurisdictional proposal

Inter-jurisdictional Collaboration

A key tenet of the INSPIRES effort is on ensuring and enhancing successful inter-jurisdictional collaboration across the primary institutions, which has been a significant challenge created by the ongoing global pandemic. In Year 1, the Core Leadership Team strategically focused on developing a detailed project implementation plan including governance, communications, and detailed theme research milestones, which was hoped to foster innovation and cross-theme, inter-jurisdictional collaboration. Year 2 of INSPIRES has been focused on continuing to build cross-theme, inter-jurisdictional collaboration in the face of the ongoing pandemic. Based on these efforts, several new cross-theme, inter-jurisdictional ideas have successfully emerged such as cold-air drainage, managing for the cold, regional site evaluation methodologies, and shifting climatic zones, which each lends itself to the integrative and synthetic publications that were recommended by the external review panel.

As noted above, maintaining ongoing and open dialogs across team members, particularly inter-jurisdictional ones, has been rather difficult to achieve during the pandemic. It is hoped that dedicated time can be devoted to this at future events such our next in-person retreat in January 2022. Until then, efforts will be made to encourage and shift focus onto inter-jurisdictional collaboration like synthetic publications with early-career researchers taking the lead. In addition, the formation of the collaborative research committee in Year 2 and ongoing meetings of this committee should help to build effective inter-jurisdictional collaboration going forward. As noted in our Year 2 voluntary researcher assessment, most respondents believe (73.7% agree, 68.4% strongly agree) that INSPIRES has led to collaborations that have facilitated knowledge generation and transfer among researchers from different disciplines and allowed individuals to pursue new ideas, respectively. These collaborations primarily have happened across jurisdictions and have been actively encouraged by the Core Leadership Team. As outlined in our Year 2 Data Outcome Portal report, INSPIRES has already resulted in 2 inter-jurisdictional publications and 7 inter-jurisdictional proposals. Many of these inter-jurisdictional publications and proposals included multiple authors and jurisdictions that were led by early-career faculty.

A detailed Social Network Analyses was conducted in our Year 1 evaluation (see Pages 99-103 of our Year 1 Annual Report) and another one is planned for the Year 3 assessment to highlight new inter-jurisdictional collaborations across the primary institutions that has been created by INSPIRES. As suggested in our external review panel report, it was recommended that the Core Leadership Team consider “a few strategies for increasing the project’s already impressive cross-jurisdictional efforts” such as different meeting structures, offering “seed grants”, and finding ways to better highlight examples of inter-disciplinary collaboration. The Core Leadership Team has discussed these suggestions and provided a detailed response to them. As noted in our response, the Core Leadership Team has employed mixed and highly interactive approaches to enhance inter-disciplinary collaboration including a facilitated team-building exercise at the last multi-day meeting. This has helped to engage team members, generate new ideas,

and facilitate collaboration, which is often quite difficult to achieve in virtual meetings with more than 10 participants. For comparison, most INSPIRES quarterly all-team meetings have 50 or more participants. Going forward, an alternative meeting structure may be implemented by having the Co-PIs from the University of New Hampshire and University of Vermont lead quarterly all-team meeting organization and execution as University of Maine has led most of them in Years 1 and 2. In addition, we will investigate institutional resources for seed grants when we meet with our Tri-Jurisdictional Institutional Advisory Board this summer. The focus of this meeting is on better integration across jurisdictions, more effective leveraging of institutional resources, and project sustainability following the NSF grant. It is hoped that this advisory board can meet regularly to discuss these key topics. However, it is logical to offer seed grants for writing retreats, conference or workshop attendance, and professional development, which the Core Leadership Team will plan to discuss. Again, most seed grants are often used to facilitate travel, which has not been possible during the global pandemic. Finally, we will continue develop some communication tools in Year 3 that demonstrate the strong and growing inter-disciplinary collaboration on this project.

In particular, the external review panel found that the "educational component of cross-jurisdictional interactions is excellent, in that it appears to be far more substantial, multi-faceted, and integrated with the research than other Track-2 projects that the panel is aware of. This fulfills an important part of the mission for Track-2 awards, and the panel recommends this be emphasized in reporting." The Core Leadership Team especially believes that the connections built through the Theme 4 will enhance future inter-jurisdictional collaboration, which will greatly improve sustainability of the effort after Year 4.

Workforce Development

In Year 2, the project continued to enhance the research and analytical skills for early career faculty, as well as the graduate and undergraduate students and research technicians supported across institutions. This included the numerous inter-jurisdictional research proposals led by early career faculty described above, as well as mentoring and training opportunities afforded by individual INSPIRES PIs and monthly graduate student meetings. For the latter, a key area of focus of monthly graduate student meetings has been on the career journeys of early career scientists supported by INSPIRES, providing both a mentoring opportunity for early career faculty on the project, as well as key insights to graduates students on skills needed for a successful career in the forest and data sciences. Several undergraduate students supported by INSPIRES during years 1 and 2 of the project have been accepted into forest science graduate programs for fall 2021, with one representing an inter-jurisdictional collaboration between UVM and UMaine. Beyond early career faculty and students, several research technicians supported by INSPIRES are recent graduates of biology, environmental science, and natural resources undergraduate programs, with this project serving to enhance skillsets around programming, sensor development, and overall science leadership, particularly as it relates to coordinating inter-jurisdictional and cross-theme collaborations.

Plans for Year 3 surrounding workforce development will include a continued commitment to supporting and promoting leadership and training opportunities for early career scientists and students on the project. In addition, graduate students were informally polled to identify training areas of most interest in the coming year, with collaborative science and manuscript development unanimously chosen as a priority. As such, we have tentatively planned an in-person July graduate student retreat that would include training opportunities on successful team building in science and approaches to scientific writing and data analysis. Plans for this retreat may need to be adjusted depending on Covid-19 protocols for travel across institutions.

Research Capacity

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. A key aspect of enhancing research capacity at the project and individual researcher levels is improved access to knowledge, expertise, equipment, and collaborators through the participation in collaborative

research networks. Based on our Year 1 survey of INSPIRES researchers, the highest identified priorities for the project were conducting novel research (44%), improving research capacity and infrastructure (25%), and participating in regional collaboration (16%). As noted above, a primary focus on building research capacity in Years 1 and 2 of the effort has been addressed through ensuring successful inter-jurisdictional collaborations and providing significant workforce development opportunities, which will continue to be a focus in Years 3 and 4. Based on the Year 2 Data Outcome Portal, INSPIRES has already been successful at enhancing research capacity across the involved institutions by significantly leveraging the investment being made by NSF. INSPIRES researchers have been very active with proposal development and submission as 34 proposals have been submitted with 14 of them awarded and another 12 still pending. This has generated nearly $10 million in available new funding, which represents 63% of the requested funding and a current ratio of 3.19 for funding generated to amount of funding awarded by the NSF EPSCoR RII Track-2 grant. The majority (57.4%) of this additional research awards has been obtained through other NSF programs, while most the remainder (39.7%) is from other Federal programs. This suggests that INSPIRES researchers are being very effective and successful in their proposal development efforts despite the highly competitive nature of both NSF and other Federal funding programs. The Core Leadership attributes this success to the greater research capacity created by INSPIRES and the improved collaborations created by an expanded regional collaborative research network.

As noted by our external review assessment, the panel "found that integration across jurisdictions and institutions is an exceptionally strong aspect of INSPIRES. The PI noted that ~60-70% of participants were involved in new collaborations, and site visit presentations to the panel emphasized the number of new interactions and relationships. For example, the Theme 1 proposal focusing on winter and spring climate change involved researchers from all participating jurisdictions." Consequently, the new ideas and collaborations created by INSPIRES will further enhance research capacity in Years 3 and 4. Future research capacity in this area was discussed with the INSPIRES Tri-Jurisdictional Institutional Advisory Board in April and will be a focus in Year 3 and 4. Additional research capacity building efforts will be sought by better connecting and creating synergies with the other University of Maine Track 2 project (Award #2019470) led by Brian McGill and which involves University of Vermont researchers.

Jurisdictional Impacts

Maine

Within Maine, INSPIRES has brought 21 faculty, 3 undergraduates, 10 graduate students, a post-doctorate fellow, and 5 project staff from across several different institutions together. The INSPIRES team within Maine links several disciplines across 10 different academic units or research centers together. Most of the INSPIRES team members in Maine have not worked together previously and the project has been a rather effective means for enhancing collaborations. 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.

Several new team members in Maine were brought on in Year 2 to help strengthen team diversity and expertise. In particular, two new key staff members were added and include Stefania Marthakis and Leo Edmiston-Cyr. Stefania provides important project coordination and communications, particularly interfacing with undergraduate and graduate students across jurisdictions. Leo is an IT and programming specialist that leads the INSPIRES data sharing subcommittee and was the primary author of the INSPIRES data sharing plan. He has brought important computer science and data sharing expertise to INSPIRES. Leo also mentored a summer undergraduate INSPIRES intern (Jack Prior) who developed a prototype mapping interface for the ForEST online application. Both Stefania and Leo are cost-

shared with the other University of Maine Track 2 project (Award #2019470) led by Brian McGill to help create synergies across projects. In addition, an early-career female faculty member (Katherine Crowley) at Unity College and adjunct faculty at the University of Maine was recruited for her expertise on soil nutrient modeling and joined Theme 3 discussion. Maine INSPIRES team members participated in several important state events including Maine's Forest Climate Change Initiative's Science and Practice monthly webinar series, Maine's Chapter of the Society of American Foresters annual meeting, and Maine's Climate Council.

New Hampshire

Within New Hampshire, the team was composed of 9 faculty, 3 project staff, and 3 graduate students with representation from two institutions and five research centers or academic units. Most of the faculty had little prior collaboration, so team building and collaborative planning continued to be an emphasis in Year 2. 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 all-team meetings. Additional planning activities included the Theme 3 meetings to discuss new approaches to integration of the PnET and LANDIS models. This, in part, was brought about by a reduction in field data collection (a result of the Covid-19 pandemic) and a decision to expand effort in modeling and data analysis.

Activities and plans through Year 2 resulting from these discussions and plans made at the end of Year 1 include coordination of inter-jurisdictional Theme 1 meetings (by A. Contosta), deployment of a first wave of Mayfly sensors at sites in all three jurisdictions, integration of eddy covariance data and soil sensor date (Theme 1) with modeling and remote sensing data sets (Theme 3), collection of tree physiology measurements involving canopy access with a bucket lift to enable parameterization and testing of the PnET ecosystem model (Theme 3), analysis of winter-to-spring carbon balances using eddy covariance data at the Thompson Farm research site, recruiting of one new MS student, refinement of machine learning methods for predicting forest condition response to silvicultural activities, and development of the first preliminary map of foliar nitrogen concentrations across northern New England using remote and synthesis of existing field data. Preliminary results from activities described above were presented at the American Geophysical Union's Fall Meeting (December 8 and 9, 2020), and the Harvard Forest Annual Ecology symposium (March 16, 2021).

Vermont

The researchers based out of the University of Vermont have grown into a team of 6 faculty, 1 post-doc, 3 graduate students, and 3 research technicians. These participants span three academic units within the University of Vermont. Aimee Classen has since shifted to a faculty position at the University of Michigan department of Ecology and Evolutionary Biology but she remains engaged as part of our team. Dave Lutz and his student Emma Hazard, both from Dartmouth College, are also an integral part of our UVM based team. With the onset of Covid-19, as well as the existing geographical spread of the team, it was a priority to continue communication in person and virtually so that every member of the team continued to be welcomed and supported in their roles in Year 2. As such, the UVM team continued monthly meetings to share university-specific successes and challenges as well as discuss cross-theme connections and were able to organize an in-person visit in July 2020 to the newly-established INSPIRES sensor site in Corinth, VT for all team members.

Members of the UVM INSPIRES team at the Clements Woodlot in Corinth, Vermont (July 2020).

Considerable effort in Year 2 was put into developing COVID-related safety protocols for the summer 2020 field season to ensure research capacity was built and sustained surrounding advanced sensoring deployment for quantifying the impacts of changing climate and the increasing prevalence of non-native insects on northern New England forests. To this end, summer field crews, largely composed of undergraduate research technicians supported by the INSPIRES project, were able to established and measure forest inventory and sensoring plots at the Corinth (VT) and Second College Grant (NH) INPSIRES sensor sites. A portion of this data was shared with Theme 2 collaborators from the University of Maine (Salimeh Yasaei Sekeh) to assist with machine learning algorithms for detecting white ash in mixed northern hardwood forests. Building from this data, early career female faculty member (Foster) led the initialization of numerous forested landscapes in VT and NH to allow for inter-jurisdictional evaluations of future forest dynamics in these locations using ecosystem and landscape simulation models.

Members of Theme 1 and Theme 4 scouting a new site for sensor suite deployment that will be accessible to students and teachers.

UVM team members involved in Theme 1 worked closely UNH Theme 1 members to finish developing low-cost high frequency sensor system nodes. This culminated with the UVM/Dartmouth team deploying two sensor nodes in Corinth which have been operating smoothly all winter. Seven more sensor suites will be deployed by the same team in summer 2021. This work has led to the current development of a field campaign for a regional cold air pooling assessment led by UVM team members integrating skillsets across Themes 1 and 3 (Adair, Classen, Foster, Pastore) and including early career scientists from the other two jurisdictions (Contosta-UNH; Nelson-UMaine). Theme 4 has also been able to successfully recruit 9 teachers, an increase from the targeted 7, to partake in leveraging INSPIRES work for education of grades 5-12 (Toolin). UVM team members also regularly contributed to the cross-theme collaboration meetings, most notably by helping to develop an interactive interface for data sharing within the project (Foster). Finally, INSPIRES-supported undergraduate student Olivia Vought successfully completed and defended her honors thesis in April 2021 on controls over litter decomposition and soil carbon and has been accepted into a PhD program at the University of Michigan for fall 2021.

Overall Project Integration

A key focus in Year 2 was helping to further sustain and enhance the integration of cross-theme, inter-jurisdictional opportunities given the focus on team-building and overall project as well as theme-specific strategic planning in Year 1. This was primarily accomplished through the formal formation and regular meetings of two committees, namely the Collaborative Research Committee (CRC) and the Data Sharing Subcommittee (DSS) that were previously described in detail above. Both committees had a diverse membership of researchers, trainees, and professional staff that were

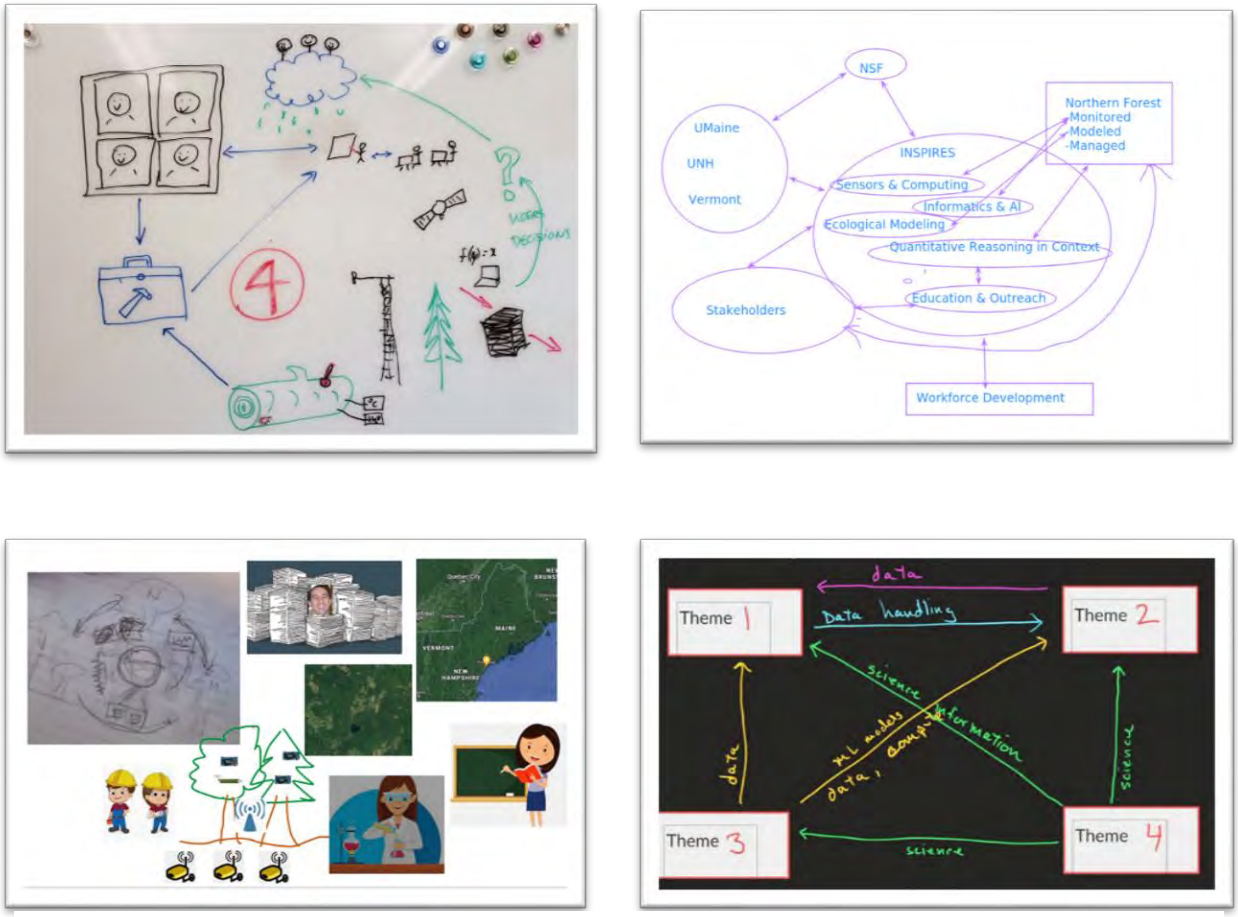


Figure 19. Contrasting team perspectives on overall project integration created by a facilitated cross-theme, inter-jurisdictional activity at the December 2020 all-team meeting

cross-theme and inter-jurisdictional in nature. The focus of both themes was on cross-theme opportunities and creating key synergies to help maximize collaboration. Both committees will continue to regularly meet and formulate adaptative strategies in Year 3. In addition, each quarterly all-team meeting involved cross-theme, inter-jurisdictional activities to enhance overall project integration efforts. This often involved the use of small breakout rooms that allowed open interactions between project participants and quite frequently resulted in identifying new collaborative opportunities created by INSPIRES, as well as areas of need as it related to training and support. Also in Year 2, a specific project integration activity was undertaken during the December 2020 all-team meeting and was led by an external facilitator (Dr. Pips Veazy). Like the quarterly all-team meeting activities, the facilitated activity was cross-theme, inter-jurisdictional and focused on small groups diagraming their shared vision of the INSPIRES effort with particular emphasis on integration opportunities. This resulted in numerous contrasting diagrams (Figure 19. Contrasting team perspectives on overall project integration created by a facilitated cross-theme, inter-jurisdictional activity at the December 2020 all-team meeting) that promoted a broader discussion on better defining a shared team vision and will be revisited at future all-team events, particularly the planned in-person January 2022 retreat.

The success of these various efforts to create and enhance overall project integration is rather apparent even to individuals external to INSPIRES. As noted in our external evaluation report, the panel observed that “it was also apparent that team members involved in each INSPIRES theme have been successful in organizing themselves across the different institutions. This is manifest through team member’s support of each other in the development of data infrastructure and research. The health of these working relationships, both at the leadership and the research team scale, are particularly impressive – and valuable – given the challenges posed by the Covid-19 pandemic over the past

year. Specifically, these relationships appear to be promoted by an appropriate schedule of team meetings, cross-theme attendance at many of these meetings, a thorough Project Implementation Plan, coordination of administrative tasks by the co-PIs, and an environment in which all team members can express their perspectives." The Core Leadership Team has worked hard to create this type of environment and support overall project integration efforts. As noted in our Year 2 voluntary researcher assessment, most respondents believe (73.7% agree, 68.4% strongly agree) that INSPIRES has led to collaborations that have facilitated knowledge generation and transfer among researchers from different disciplines and allowed individuals to pursue new ideas, respectively. These collaborations primarily have happened across jurisdictions with early career scientists and have been actively encouraged by the Core Leadership Team. In fact, INSPIRES has already resulted in several cross-jurisdictional research proposals and publications as indicated by the recent Data Outcome Portal snapshot. These outcomes and additional metrics that quantify cross-jurisdictional collaborations will be actively tracked in Years 3 and 4. As noted in a recent anonymous comment from a project participant, "Collaboration across institutions has been great for me and I feel that our collaborative efforts are finally gaining momentum after a tough 12 months of pandemic." Continued efforts to sustain and enhance overall project integration will remain a primary focus in the years ahead.

BROADENING PARTICIPATION

Team Demographics

Significant focus in Year 2 was again on building and formalizing research teams, recruiting new research members, and inter-team collaboration, particularly with everyone primarily working remotely during the ongoing pandemic. Currently, the team comprises 41 faculty (21 early-career), 4 undergraduate students, 15 graduate students, 1 post-doc, and 8 professional staff across 6 different institutions over the 3 jurisdictions. According to the Data Outcomes Portal (DOP) for Year 2, of those who disclosed their gender, there is equal female-male representation (F=26, M=25) on the research team for both researchers and trainees. Furthermore, the DOP reported 1 senior researcher and 1 undergraduate student self-identified as underrepresented race, while 20 researchers and 5 trainees identified as an underrepresented group. Significant recruitment efforts are still underway for undergraduate and graduate students for Year 2 due to the ongoing influence of the pandemic. Continued engagement and support of early-career faculty as well as team diversity will remain a key priority for Year 3 and 4, which was further discussed with our inter-jurisdictional advisory board in April. A summary of current team member composition across the three jurisdictions is provided in Table 5, while a detailed list of all personnel is provided in Appendix 5. INSPIRES Team Roster

INSPIRES faculty composition still has strong representation of early-career investigators (50%) composed of a high percentage of those identifying as female (42.1%). In terms of race, 10%, 6%, and 14% of the early-career researchers, senior researchers, and trainees were from a non-white race with one individual Native American on the team. In addition, INSPIRES faculty are also highly diverse in terms of academic rank and the number of disciplines (15) represented that remains 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 5. Summary of INSPIRES team personnel by role and jurisdiction

Role	Jurisdiction			Total
	Maine	**New Hampshire**	**Vermont**	
Faculty (Early-career)	21 (12)	12 (7)	7 (2)	40 (21)
Staff (Professional, Post-doctorates, Support)	5	1	1	7
Students (Undergraduate/ graduates)	11	4	5	20
Total	37	17	13	67

Development/Recruitment of Diverse Early Career Faculty

Despite the ongoing pandemic, the benefits for early-career faculty through the project primarily stemming from the theme and institutional cross-collaborations, which are enhancing research and analytical skills for team members. There have been multiple opportunities for early career faculty, particularly with helping to identify and resolve problems as they arise within themes and projects. Currently, there are 21 early-career faculty in INSPIRES with equal representation in gender with continual recruitment of faculty ongoing. 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 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 led and submitted numerous research proposals in Year 2 with many as a direct result of emerging or ongoing collaborations formed from INSPIRES. A focus in Year 3 will be encouraging early-career faculty to lead high-impact synthesis publications.

As highlighted in our external review panel report, the ongoing impacts of the pandemic have been particularly challenging for early career faculty given the need to balance professional with personal demands and work entirely remotely with limited support. The external review panel applauded the "effective and collegial working environment during the project start-up phase", while commending "the leadership team for its commitment to reducing administrative burdens of the early career faculty." This strategy of minimizing administrative duties yet maximizing collaborative and scientific opportunities for early career faculty has paid significant dividends for the project. For example, several early-career faculty have started new collaborations and written joint proposals as a result of INSPRIES, while others have formed a writing support group that allows them to share progress and ideas on potential journal articles. Better supporting early-career faculty was noted in our external review panel report and discussed with the inter-jurisdictional advisory board in April.

At each institution, the Core Leadership Team has checked-in with team members, particularly early-career faculty, to ensure they have the resources needed to participate in the project. This has ranged from converting part-time graduate assistantships to full-time, hiring additional undergraduate student employees for project support, and covering workshop costs for early-career faculty. We will continue to check-in with team members to prevent potential unintended consequence of the pandemic. For several early-career faculty members, PI Weiskittel has written letters of support describing their involvement with the effort and nature of these collaboration for their annual evaluations, which have highlighted the significant impacts of the pandemic on the project. In addition, the inter-jurisdictional advisory board will work to support early-career faculty on this project at each institution by potentially offering additional seed grants, acknowledging their involvement in multi-institution EPSCoR grant, and ensuring they have the necessary resources for being productive despite the ongoing pandemic. A more effective mentorship of early career faculty will be pursued by the Core Leadership Team in Years 3 and 4.

Development/Recruitment of Diverse Students

Currently, there are 1 female post-doc, 4 undergraduate (2 female) and 15 (8 female) graduate students across the three institutions that are involved with the project, which reflects the significant recruitment efforts in Year 2 despite the ongoing pandemic. Both research technicians supported at UVM are female. In addition, 10% and 50% of the projects trainees currently identify as an underrepresented race and group, respectively. PI Weiskittel with Co-PIs D'Amato and Ollinger have continued to welcome all students on the INSPIRES project, which 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. In fact, during the December annual retreat, graduate students gave flash talks about their research and received input from other INSPIRES team members. Guidelines for effective collaboration for student mentors and mentees has been revised by the Mentoring, Education, & Engagement (MEE) Committee with input from INSPIRES team members. The MEE met monthly with graduate students in Year 2 where they were able to openly discuss challenges they were facing, network with fellow students, and hear from the other INSPIRES team members about their research as well as professional development. In addition, an informal graduate student journal club has been formed and has met regularly. INSPIRES graduate students oversee and manage the project's social media accounts, which has helped to build collaboration and networking across jurisdictions. Recruitment will continue in Year 3 and will continue to focus on underrepresented groups, particularly racial minorities and Native Americans.

As noted above for early-career faculty and by our external review panel, the pandemic has been especially difficult for graduate students due to the challenges of adjusting to new environments with limited support and high isolation. In Year 2, there were at least 3 trainees (2 from underrepresented groups) that had to withdraw from the projects due to complications and challenges created by the pandemic. The Core Leadership Team has fully acknowledged these challenges created by the pandemic and has worked to resolve hardships for both mentors and mentees. As noted in our Year 2 project survey, 71.4% of the respondents indicated using at least one of the project's developed documents (e.g., project implementation plan, mentoring guidelines) with their mentees, which indicates relative high adoption and use of these materials. Efforts in Year 3 will be continuing to focus on refining these materials and ensuring students have every opportunity to gain new professional experiences. For example, a summer field trip is being planned for late summer so students can visit new research sites being evaluated in this project and participate in training activities around collaborative science and a multi-day all-team retreat is scheduled for January 2022 with activities specifically focused on graduate student development.

Leadership and Governance

The Core Leadership Team (CLT) continues to regularly meet to assess project progress, potential issues, and team needs. Year 2 efforts specifically focused on pandemic-related adjustments, particularly the recruitment of diverse trainees such as post-doctoral associates and graduate students, overall project management in an entirely virtual environment, and selection of core research sites, which is a complex matter given the subject of this project. Recruitment efforts were generally successful in most cases, but retention remains a high concern for the CLT given the ongoing stress and high uncertainty created by the global pandemic. Specific efforts will be made in Year 3 to address these potential issues and boast overall team morale, particularly with trainees. As outlined in our original proposal and our current governance document, an additional key project element will be the formation of several important committees including an External Advisory Board (EAB), a Tri-Jurisdictional Institutional Advisory Board (IAB), and two project committees: 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 university upper administrators 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 2, the CLT helped to form these various committees including the CRC, MEE, and IAB as specifically described above, but felt the project was still too early especially with the ongoing impacts of the global pandemic to form an EAB. INSPIRES team members remain highly engaged with stakeholders as 68.4% and 84.2% of the Year 2 researcher survey participants indicated that they have engaged in the past year or plan to engage in the coming year with stakeholders, respectively. Consequently, the CLT feels well connected with stakeholders and a formal EAB would potentially be redundant at this stage of the project. Regardless, INSPIRES faculty and the CLT have formed a list of potential EAB members and will work on forming that in Year 3 given the future shift to project sustainability and outreach efforts. A particular focus of the CLT in Year 2 was preparing for, conducting, and responding to the external project review, which occurred in early January 2021. The panel's report was quite positive about project leadership with some specific recommendations for Years 3 and 4, which the CLT discussed and addressed in their detailed

response. As noted in the report, the external review panel indicated that it was observed "that the leadership team has developed an effective and collegial working environment during the project start-up phase, which is a crucial asset to the overall project. Managing a project this complex, involving multiple actors across three institutions and three states (n=54 individuals, including 38 faculty; ME = 28, NH = 13; VT = 13) is a challenge, and based on information provided, the panel concluded that the leadership team is doing an excellent job of managing the four core teams and the administrative requirements to implement an EPSCoR RII Track-2 project." To help sustain this positive and significant momentum, the CLT continued to revise and update the project implementation plan, particularly the overall project and theme-specific research milestones. In addition, the preparation and presentation of key project briefing materials for the IAB helped to identify key project strengths and potential opportunities that will be further explored in Years 3 and 4 of the effort. In particular, the CLT and IAB felt the key strengths were: (1) successfully interactions and collaboration among applied ecologists and data science experts; (2) the exceptional integration of education and outreach efforts into specific activities and objectives that enhance inter-institutional collaboration; and (3) the focus and support for developing an integrated entity that can produce convergent outcomes and products (e.g., the Digital Forest Framework). These specific core strengths will be sought to be fully leveraged by the CLT.

For the external review assessment, the CLT rigorously assessed the project status across the core focal areas and felt the project was largely on track despite the significant and highly unprecedented challenges created by the global pandemic (Table 6).

Table 6. INSPIRES Benchmarks and Accomplishments

Program Area	Output/Outcome/ Impact Indicators	Annual Project Benchmarks	Year 2 Accomplishments
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	1 post-doc, 15 graduate students, 5 research assistants, strategic plan developed & updated, Internal advisory board formed and engaged in April 2021
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 publicly available (25% being integrated)	Multi-institutional publications (5) and proposals (4), graduate student led presentations (6) and publications (3)
Education and Diversity	Student participation in project research activities; student participation in project professional and career development training events; student research and career development outcomes; diversity (participation of students from populations underrepresented in STEM; i.e. WaYS)	10 undergraduates involved, 5 undergraduate & graduate students enrolled in certificate programs, 3 training events, 35% of project participants from underrepresented groups, 1 inter-institutional graduate course	Undergraduates involved (4), 33% female trainees, and trainee participation from underrepresented groups (5), detailed plans developed for inter-institutional graduate course

Program Area	Output/Outcome/ Impact Indicators	Annual Project Benchmarks	Year 2 Accomplishments
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 2-4), 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	50% of faculty involved are early career (21), teachers recruited in Maine (8) and Vermont (9) with plans for recruitment in New Hampshire, teacher interviews on curriculum needs conducted and being currently analyzed
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	84.2% of researchers plan to engage stakeholders in the next year, several new partnerships formed, outreach events conducted, website as well as social media pages created and launched, 5 media features

EVALUATION Year 2

Overview

Pandemic: Due to safety regulations in response to the COVID-19 pandemic, travel, field research, and in-person contact were severely restricted for all project participants throughout Year 2. The formative strategic assessment site visit originally planned for the end of Year 1 had to be postponed to Year 2, then rescheduled/reformatted during Year 2 to a virtual site visit due to the ongoing pandemic limitations.

Change in Evaluators: At the outset of the project, a five-year agreement was signed with the American Association for the Advancement of Science (AAAS) Research Competitiveness Program (RCP) to serve as the external evaluator. The RCP used a hybrid approach that combined 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. AAAS discontinued the RCP on Oct. 13, 2020 with no prior notice to the Core Leadership Team or the University of Maine.

Evaluation activities in Year 2 before the termination date were limited to a survey of students and a report on those findings. However, an assessment site visit to be conducted by AAAS-RCP staff had been scheduled for January 2021, along with plans for a faculty survey and analysis of quantitative project data. In late December 2020, we signed a new evaluation agreement with The Implementation Group (TIG) to complete the Year 2 evaluation activities using the same hybrid approach and the same personnel who had served previously as our external evaluators, making it possible to complete all Year 2 evaluation tasks as originally planned. Evaluation reports will be emailed to our program officer. We plan to meet with the evaluators in July 2021 to prepare for Year 3 activities.

Faculty and Researcher Survey: During the gap in evaluator services, the Core Leadership Team developed a brief survey of faculty and other research personnel to gather data needed for the assessment visit in January. By shortening the survey instrument, we were being adaptive to the ongoing pandemic and responsive to team members who are struggling to manage the impacts of the pandemic response (e.g., teaching remotely, home schooling, loss of childcare, illness and caring for those who are ill) while simultaneously furthering project research. We limited questions to their role in the project, mentoring, and stakeholder engagement. We did not include questions on research collaborations, productivity, and professional development that were included in the baseline survey, as we were aware that the pandemic severely limited those activities. We intend to return to a more in-depth survey in Years 3 and 4 now that we have a full complement of evaluation services. In the meantime, the results of the brief survey provided valuable quantitative and qualitive data to the Core Leadership Team.

In response to specific concerns raised by team researchers, we added time to our all-team meetings for a team-building exercise and an open listening session about the impact of the pandemic. We sought guidance on how to assist early-career faculty in these difficult times from the assessment panel of experts and the Tri-Jurisdictional Institutional Advisory Board. We are planning to hold an in-person retreat in January 2022 that will allow us to come together as a team for the first time in two years, work together on publications, and develop strategies to achieve our long-term goals.

Outcomes

External Program Assessment

Heather McInnis, Ph.D., vice president of The Implementation Group, conducted a virtual site visit on January 6-7, 2021 by a panel of three experts for an external, formative assessment of the project. The panelists were:

- Dr. Jennifer Allen, Associate Professor, Department of Public Administration, Portland State University
- Dr. Ragan Callaway, Regents Professor, Division of Biological Sciences, University of Montana
- Dr. Christian Messier, Full Professor, Department of Biological Sciences at the University of Quebec in Montreal (UQAM) and in Outaouais (UQO).

The panel was charged with providing a formative assessment appropriate for the 50% point of this project in three specific areas:

1. Assess development of interdisciplinary research

   We are at approximately 50% point in this effort. We should have convincing evidence for our capacity for this type of work, and clear indications of what some of the resulting research outputs will be. What strategies might we employ to improve this?

2. Assess development of cross-jurisdictional research

   NSF EPSCoR awards RII Track-2 grants to build enduring cross-jurisdictional capacity. What evidence is there that these types of networks are being developed? What strategies might be employed to strengthen cross-jurisdictional relationships?

3. Assess the early career researcher development

   What additional steps could be taken to advance this goal, particularly given the ongoing challenges with COVID-19?

A final report from that site visit will be sent to our program officer with this report, and our responses to the each of the panel's specific recommendations. The following is an excerpt of the report:
"The External Review Panel observed that the leadership team has developed an effective and collegial working environment during the project start-up phase, which is a crucial asset to the overall project. Managing a project this complex, involving multiple actors across three institutions and three states (*N*=54 individuals, including 38 faculty; ME = 28, NH = 13; VT = 13) is a challenge, and based on information provided, the panel concluded that the leadership team is doing an excellent job of managing the four core teams and the administrative requirements to implement an EPSCoR RII Track-2 project. It was also apparent that team members involved in each INSPIRES theme have been successful in organizing themselves across the different institutions. This is manifest through team member's support of each other in the development of data infrastructure and research. The health of these working relationships, both at the leadership and the research team scale, are particularly impressive – and valuable – given the challenges posed by the COVID-19 pandemic over the past year. Specifically, these relationships appear to be promoted by an appropriate schedule of team meetings, cross-theme attendance at many of these meetings, a thorough Project Implementation Plan, coordination of administrative tasks by the co-PIs, and an environment in which all team members can express their perspectives."

Annual Formative Evaluation: Faculty and Non-Faculty Researchers and T-2 DOP Project Data

Maysaa Alobaidi, Ph.D., who conducted the baseline evaluation report for AAAS in Year 1, was retained by TIG to compile data from the faculty and researcher survey administered by the project leadership team, as well as data collected from the Data Outcomes Portal. Her report, which will be emailed to our program officer, noted the disparity in survey approaches, which did not enable to a year-to-year comparison with the baseline data. This disparity will be resolved by a return to a full survey in Year 3.

INSPIRES Student Surveys

Surveys of graduate and undergraduate students were administered by Dr. Alobaidi in her role as an evaluator for AAAS in September 2020. The response was low, which may be attributable to the timing of the survey in the first weeks of the semester and the fact that because of the pandemic, students were working remotely and had not yet formed a strong connection to the larger team. Our first all-team meeting of the semester was held in November. To address the lack of connection, the Core Leadership Team began conducting monthly Zoom meetings with all students on the project invited. These inter-institutional meetings provide an opportunity for the students to interact with each other, learn about the different research roles and projects students are involved with, and learn from invited early career team members. The timing and administration of future surveys will be discussed with the evaluators when we meet this summer.

Data Outcomes Portal Formative Feedback Report

A report prepared by Integrated Learning Innovations on Year 2 results entered in the Data Outcomes Portal has been included in evaluation materials sent to our program officer. In order for Dr. Alobaidi to include the DOP data in her report, it was necessary for the PI to download the data, send it to her separately, and summarize it manually. After noting errors in the initial ILI report received on April 18, 2021, the final ILI report was revised and received on April 21, which was after the evaluation report had already been completed.

Next Steps

The leadership team will meet with the evaluators in July 2021 to discuss Year 3 activities, including the scope and timing of surveys. Faculty and researchers will be surveyed, as well as students. Efforts to increase participation will be encouraged at team meetings and at the retreat, and promoted through team communications (e.g., Slack). A detailed survey of external stakeholders will be conducted in Year 3 and compared to the baseline survey conducted in Year 1.

PROGRESS ON SPECIFIC PROGRAM ELEMENTS

Committees & Subcommittees

Mentoring, Education, and Engagement (MEE)

The Mentoring, Education, and Engagement (MEE) committee led by Co-PI D'Amato met monthly with INSPIRES students to discuss strategies for successful research efforts, collaboration, and professional development. Each month the group was joined by an INSPIRES researcher, generally early career, from across the different themes and jurisdictions who gave an overview of their professional development, current research focus, and tips for professional success. The meetings were highly interactive with strong dialog between students and researchers, which has led to informal mentoring arrangements and additional discussions outside of MEE, including an informal INSPIRES student journal club. These MEE meetings are planned to continue in the coming months and years with training opportunities focused on graduate student-identified priorities around models for successful collaborative science and manuscript development.

Collaborative Research Committee (CRC)

The Collaborative Research Committee (CRC) led by Co-PI Ollinger also met monthly in Year 2 to discuss and explore cross-theme as well as cross-jurisdictional collaboration opportunities. This committee had representation from each theme and jurisdiction with several early-career faculty involved. Committee members generated and shared their project storylines (Table 7). These storylines have led to the creation of interactive online maps of INSPIRES study sites (Figure 20) and the research being conducted there to help facilitate potential collaboration and broader team understanding of available data. In addition, the Theme 4 representative on this committee has sought input on potential topics from INSPIRES projects that may be relevant for high school teachers and students. Like MEE, these CRC meetings are planned to continue in the coming months and years.

Table 7. CRC Storylines

Theme Member	Storyline
1	"INSPIRES seeks to combine ground-based measurements of snowpack and vegetation phenology (Theme 1) with data science tools to automate data processing (Theme 2) and process-based modeling (Theme 3) to understand how changing seasonality impacts ecosystem carbon cycling. I am also interested in training teachers and students to make ground-based observations of snow and vegetation phenology to both expand our regional network of observations and train the next generation in the theory and practice of studying climate change (Theme 4)"
2	"INSPIRES is working to use ground measurements of forest attributes scaled with remote sensing to inform mechanistic forest models that help educators and managers understand current and future forest conditions."
3	"INSPIRES is leveraging large-scale data like USFS FIA to identify emerging regional trends to help facilitate linkages across researcher and land managers to build the necessary monitoring infrastructure as well as guide management and policy."

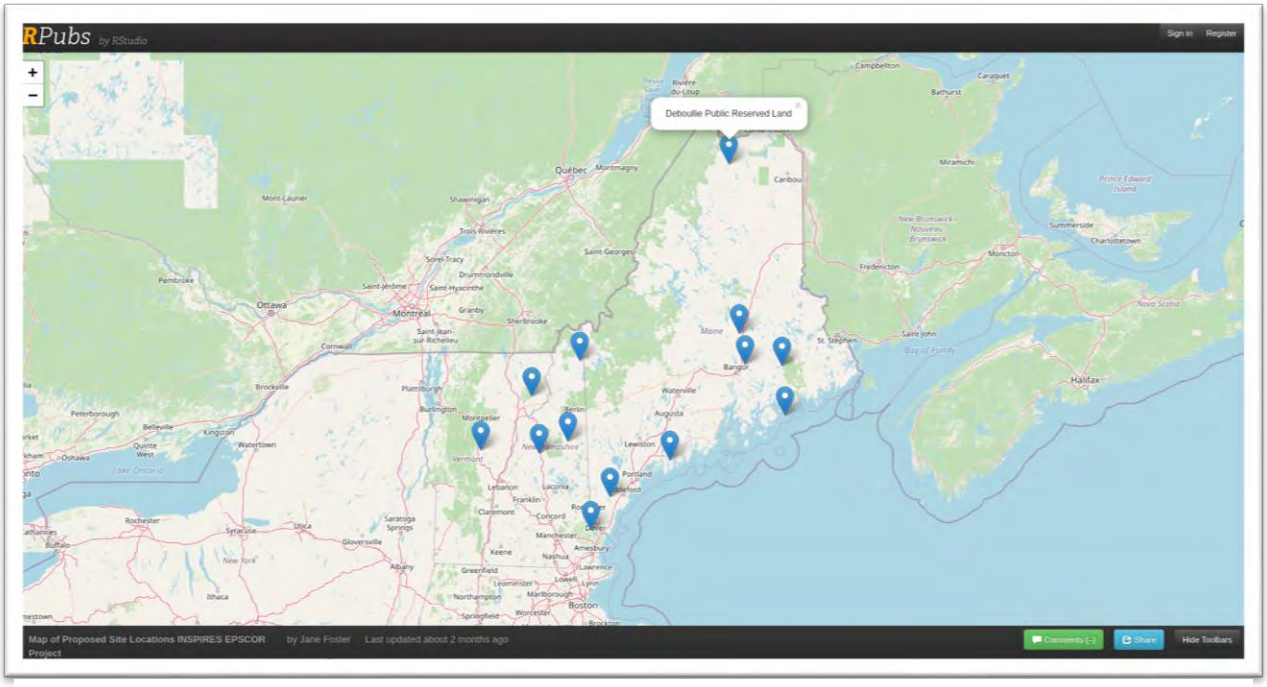


Figure 20. Online and interactive map of current INSPIRES study sites across the three jurisdictions to increase cross-theme collaboration. Available at: rpubs.com/onetreetwotrees/INSPIRES_test_site_map_from_R_leaflet

Data Sharing Subcommittee (DSS)

A cross-theme/cross-institutional committee convened to create a concise document that would provide a foundational data sharing implementation plan. The DSS met weekly for two months to provide a thorough introduction to publishing datasets to the NSF-supported Environmental Data Initiative (EDI) repository and gathered input to strengthen the organization, naming, and metadata standards to be offered to all INSPIRES members. Theme representatives used questionnaires to identify their theme's specific data sharing outputs to both the public and other themes as well as a schedule for that sharing. The DSS work culminated in

- A data sharing document for all INSPIRES team members guiding them on best practices for sharing inside INSPIRES and identifying each theme's outputs and estimated schedule (Appendix 4. INSPIRES Data Sharing Plan)
- A newly organized OneDrive to house all shared documents and files
- A presentation to the INSPIRES all-team meeting in March to raise awareness of the new plan, delivered by Leo Edmiston-Cyr (subcommittee goals and outcomes with a highlight on the data sharing plan), Ami Gaspar (OneDrive), and Mary Martin (Metadata).

Inter-jurisdictional Advisory Board (IAB)

The Inter-jurisdictional Advisory Board (IAB) was successfully formed in Year 2 and formally met for the first time in April 2021. The IAB consists of Jason Charland (UMaine), Director of the Office of Research Development; Shane Moeykens (UMaine), State EPSCoR Director; Anthony Davis (UNH), Dean of College of Life Sciences and Agriculture; Mark Milutinovich (UNH), Director of Research and Large Center Development; Nancy Mathews (UVM), Dean of Rubenstein School of Environment and Natural Resources; and Arne Bomblies, State Director of Vermont EPSCoR. The IAB met with the CLT on April 30, 2021 and discussed project progress to date, particularly items raised by the external review panel. Specific topics included cross-jurisdictional collaboration opportunities, sustainability of Northern Forest Digital Forest, potential availability of seed funding, creation of Regional Complex Systems Consortium, broader value of INSPIRES to each institution and the larger region, potential international collaborations (e.g., Finland MOU, Artic Initiative) and finally, the structure as well as function of the IAB. Specific outcomes of the meeting were a focus on cross-jurisdictional

collaboration issues at the next National EPSCoR meeting, linking the INSPIRES Theme 4 education and outreach efforts to key EPSCoR representatives, each jurisdiction encouraging INSPIRES early-career faculty to pursue available seed funding, and plans for the IAB to meet formally twice a year as well as when informal opportunities present themselves. Each IAB member was planning to communicate the INSPIRES effort and plans for the future with key university administrators such as Provosts and Vice Presidents of research at each of the primary institutions.

Collaborative Research Development

The INSPIRES project started August 1, 2019 and is a relatively large multi-jurisdictional, multi-disciplinary effort with over 60 team members now. Over the last two years, the project has primarily 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, particularly with the ongoing challenges created by the current pandemic. The CLT has relied heavily on the effective team-building strategies outlined in *Strategies for Team Science Success* (edited by Hall et al., 2019) and sought the input of a team science expert (Dr. Pips Veazey) in Year to work directly with CLT as well as conduct a team-building exercise with the full team in December 2002. This activity was highly productive and future facilitated team-building exercise will be employed in the future, especially at the planned multi-day retreat in January 2022. In addition, these efforts resulted in the incorporation of various integrative practices such as highly interactive virtual team meetings with a mixed format approach, use of cloud-based collaborative tools such as Slack and OneDrive, and regular electronic team updates. Finally, the key online documents and resources to help foster team collaboration have been created in Year 1 have been maintained and expanded in Year 2. This has included a team website, shared project calendar, project jargon or acronym dictionary, summary of project resources, anonymous feedback form, and now, several social media sites.

A primary focus during Year 2 has been on the initiation of cross-theme, inter-jurisdictional research efforts as outlined in this annual report. 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 openly discussed; individual research theme meetings to explore team member research interests, complete strategic materials, and outline key research milestones by project year; and 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 developed in Year 1 has continued to provide the necessary structure, governance, strategic assessment, and plans for research, communications, and evaluation. In Year 2, the project implementation plan was regularly revisited to ensure successful project progress, intra-jurisdictional collaboration, and stakeholder engagement. The primary focus in Year 2 was the development and implementation of a detailed data sharing implementation plan. In addition, INSPIRES team members have been asked to review and digitally sign the governance agreement, which sets forth guidelines for roles and responsibilities, conflict resolution, data sharing, authorship of publications, and mentoring. In addition, the project implementation plan was used by research theme leads, the CLT, and our external evaluators to assess progress against our initial motivating project goals and objectives. In particular, the research milestone maps continue to be used for the basis of project evaluation and reporting and provides each INSPIRES team member with a comprehensive summary of important project information to help guide their work. This document was the basis of an orientation package for our project's external review panel and internal advisory board. As further outlined below, future plans are specifically focused on furthering the collaborative research development created by INSPIRES.

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 2 Progress Report. Despite some delays and significant challenges, the project remains largely on track and various next steps have been well identified by each of the research themes. Year 3 will continue to harness the ongoing strong momentum from Year 2 and work to leverage existing synergies with specific focus on the milestones and desired project outcomes identified in the project's detailed implementation plan. Key Year 3 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 January 2022
- Work with the project's external evaluator and internal advisory board to develop refined survey instruments to collect data from project constituencies
- Implement a more detailed annual survey of the INSPIRES team and assess project progress, particularly with respect to better improving research capacity and inter-jurisdictional collaborations
- Continue to address the recommendations as identified by the project's external evaluator's assessment report
- Continue to engage and support a Tri-Jurisdictional Institutional Advisory Board (IAB), and three project committees or subcommittee: Collaborative Research Committee (CRC), Mentoring, Education, & Engagement (MEE) Committee, and Data Sharing Subcommittee (DSS)
- Continue to update project social media, while further develop certain project 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 in August of 2021 to visit specific research sites, 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
- Further 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
- Work with the Tri-Jurisdictional Institutional Advisory Board (IAB) to improve project mentoring strategy for early career faculty
- Identify strategies for better quantifying the potential impacts of the ongoing pandemic on project efforts
- Form an external advisory board and seek input on desired project outcomes and future sustainability

EXPENDITURES AND UNOBLIGATED FUNDS

Year 2 Financial Plan

Although Year 2 of the project remains quite productive and has resulted in numerous successes, the continued direct of impacts of the COVID-19 epidemic have caused us to shift effort and refocus activities. As a result, spending of Year 2 funds was reduced to approximately 78% of planned expenditures. Specific details and a future plan for spending are outlined below.

Our Year 2 efforts primarily focused on continual recruitment of staff, graduate students and postdoctoral researchers, team building, re-assessing core research objectives, and the selection of extensive as well as intensive research sites. Total expenditures for Year 2 were $1,164,057.92 or 77.6% of the total allocation, which is below the 80% threshold (Table 8). Personnel costs and tuition comprised the majority of the proposal budget. Recruitment efforts remain a challenge with the ongoing pandemic, particularly for graduate students, and will remain a focus in Year 3. In addition, the ongoing university-wide travel restrictions have caused a significant portion of funding to be reallocated.

All-team meetings and retreats have been virtual in Year 2, while the planned field work planned for the 2021 summer season has been significantly reduced from original plans due to the pandemic. We have planned an all-team field tour for late August and a facilitated in-person, multi-day retreat is planned for January 2022. Although several graduate students, post-docs, and professional staff have been hired and have assumed their positions in Year 2, we also had numerous project participants that needed to reduce their time on the project or completely withdraw, which included at least one part-time undergraduate student, one full-time summer trainee internship, and two full-time graduate students. Consequently, we propose to distribute the Year 2 surplus over the next year of the project to primarily support additional research personnel (Table 9). In particular, 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 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 for expenses not incurred in Year 2, which will primarily be for the completion of planned summer field work in the fall of 2022. The University of Vermont plans to distribute surplus faculty salary, add an additional post-doctoral associate, increase support for graduate students, and provide additional support for research supplies and communication.

Table 8. Total project spending and allocation in Year 2 by university and overall by specific NSF budget categories

Item	Spent	Allocated	Variance	% Variance
University of Maine (Project Lead)				
Salary	$209,687.45	$203,374.00	$6,313.45	103.10%
Fringe Benefits	$47,382.85	$38,350.00	$9,032.85	123.55%
Travel	$-	$13,000.00	$13,000.00	0.00%
Materials and Supplies	$3,381.19	$2,694.00	$687.19	125.51%
Professional Services	$68,963.00	$14,527.00	$54,436.00	474.72%
Computer Services	$749.00	$10,000.00	$9,251.00	7.49%

Item	Spent	Allocated	Variance	% Variance
Other costs	$17,994.00	$67,874.00	$49,880.00	26.51%
Indirect	$151,875.21	$149,467.00	$2,408.21	101.61%
Total	$500,032.70	$499,286.00	$746.70	100.15%
University of New Hampshire				
Salary	$167,388.33	$222,433.00	$110,089.34	75.25%
Fringe Benefits	$49,497.24	$52,097.50	$5,200.53	95.01%
Travel	$2,257.37	$13,050.00	$21,585.26	17.30%
Materials and Supplies	$9,040.02	$7,814.50	$(2,451.04)	115.68%
Professional Services	$-	$-	$-	-
Computer Services	$-	$2,200.00	$4,400.00	0.00%
Other costs	$10,335.13	$37,822.50	$54,974.75	27.33%
Indirect	$115,232.52	$150,285.50	$70,105.96	76.68%
Total	$353,750.60	$485,703.00	$131,952.40	72.83%
University of Vermont				
Salary	$176,987.00	$192,679.00	$15,692.00	91.86%
Fringe Benefits	$60,054.00	$65,880.00	$5,826.00	91.16%
Travel	$14,760.00	$16,000.00	$1,240.00	92.25%
Materials and Supplies	$9,479.95	$13,178.00	$3,698.05	71.94%
Professional Services	$-	$-	$-	-
Computer Services	$-	$4,060.00	$4,060.00	0.00%
Other costs	$38,280.00	$38,280.00	$-	100.00%
Indirect	$142,291.45	$163,406.00	$21,114.55	87.08%
Total	$441,852.40	$493,483.00	$51,630.60	89.54%
Overall Project				
Item	**Spent**	**Allocated**	**Variance**	**% Variance**
Salary	$554,062.78	$618,486.00	$132,094.79	89.58%
Fringe Benefits	$156,934.09	$156,327.50	$20,059.38	100.39%
Travel	$17,017.37	$42,050.00	$35,825.26	40.47%
Materials and Supplies	$21,901.16	$23,686.50	$1,934.20	92.46%

Item	Spent	Allocated	Variance	% Variance
Professional Services	$68,963.00	$14,527.00	$54,436.00	474.72%
Computer Services	$749.00	$16,260.00	$17,711.00	4.61%
Other costs	$66,609.13	$143,976.50	$104,854.75	46.26%
Indirect	$409,399.18	$463,158.50	$93,628.72	88.39%
Total	$1,295,635.70	$1,478,472.00	$184,329.70	87.63%

Table 9. Proposed reallocation of Year 2 projects funds by university and the overall project

Item	UM	UNH	UVM	Total
Salary	$313.12	$62,437.47	$20,680.99	$83,431.58
Fringe Benefits	$70.76	$18,462.95	$7,017.33	$25,551.03
Travel	$-	$842.02	$1,724.71	$2,566.73
Materials and Supplies	$5.05	$3,372.02	$1,107.74	$4,484.80
Professional Services	$102.98	$-	$-	$102.98
Computer Services	$1.12	$-	$-	$1.12
Other costs	$26.87	$3,855.10	$4,473.03	$8,355.00
Indirect	$226.79	$42,982.85	$16,626.80	$59,836.44
Total	$746.70	$131,952.40	$51,630.60	$184,329.70

APPENDICES

Appendix 1. Products Year 2

Appendix 2. Student Survey

Appendix 2. INSPIRES Student Profiles

Appendix 4. INSPIRES Data Sharing Plan

Appendix 5. INSPIRES Team Roster

Appendix 6. INSPIRES Communications and Resources

Appendix 7. Regeneration of Northern Hardwoods in the Northern Forest Roundtable

Appendix 1. Products Year 2

Journal or Juried Conference Papers (16 published; 3 in press; and 2 under review)

Other Conference Presentation/Paper (14)

Database/Model/Technology Products (3)

Related Publications (26)

Journal or Juried Conference Papers *(**Bold** indicates project participants)* (21)

Bose, A.K., Wagner, R.G., **Weiskittel, A.R.,** & **D'Amato, A.W.** (2021). Effect magnitudes of operational-scale partial harvesting on residual tree growth and mortality of ten major tree species in Maine USA. Forest Ecology and Management, 484. https://doi.org/10.1016/j.foreco.2021.118953

Chen, C., Rahimzadeh-Bajgiran, P., & **Weiskittel, A.** (2021). Assessing spatial and temporal dynamics of a spruce budworm outbreak across the complex forested landscape of Maine, USA. Annals of Forest Science, 78. https://doi.org/10.1007/s13595-021-01059-y

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

Hastings, J.H., Ollinger, S.V., Ouimette, A.P., Sanders-DeMott, R., Palace, M.W., **Ducey, M.J.,** Sullivan, F.B., Basler, D., & Orwig, D.A. (2020). Tree Species Traits Determine the Success of LiDAR-Based Crown Mapping in a Mixed Temperate Forest. Remote Sensing, 12. https://doi.org/10.3390/rs12020309

Javed, A., Lee, B.S., & **Rizzo, D.M.** (2020). A benchmark study on time series clustering. Machine Learning with Applications, 1. https://doi.org/10.1016/j.mlwa.2020.100001

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Javed, A., Lee, B.S., & **Rizzo, D.M.** (2020). A benchmark study on time series clustering. Machine Learning with Applications, 1. https://doi.org/10.1016/j.mlwa.2020.100001

Kern, C.C., Kenefic, L.S., Kuehne, C., **Weiskittel, A.R.**, Kaschmitter, S.J., **D'Amato, A.W.,** Dey, D.C., Kabrick, J.M., Palik, B.J., & Schuler, T.M. (2021). Relative influence of stand and site factors on aboveground live-tree carbon sequestration and mortality in managed and unmanaged forests. Forest Ecology and Management, 493: 119-266. https://doi.org/10.1016/j.foreco.2021.119266

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Meisner, A., Snoek, B.L., Nesme, J., Dent, E., Jacquiod, S., **Classen, A.T.,** & Priemé, A. (2021). Soil microbial legacies differ following drying-rewetting and freezing-thawing cycles. ISME J., 15(4):1207-1221. http://doi.org/10.1038/s41396-020-00844-3.

Nevins, M.T., **D'Amato, A.W.,** & **Foster, J.R.** (2021). Future forest composition under a changing climate and adaptive forest management in southeastern Vermont, USA. Forest Ecology and Management, 479. https://doi.org/10.1016/j.foreco.2020.118527

Puhlick, J.J., **Weiskittel, A.R.,** Kenefic, L.S., **Woodall, C.W.,** & Fernandez, I.J. (2020). Strategies for enhancing long-term carbon sequestration in mixed-species, naturally regenerated Northern temperate forests. Carbon Management, 11. https://doi.org/10.1080/17583004.2020.1795599

Rahimzadeh-Bajgiran, P., Hennigar, C., **Weiskittel, A.,** & Lamb, S. (2020). Forest potential productivity mapping by linking remote-sensing-derived metrics to site variables. Remote Sensing, 12. https://doi.org/10.3390/rs12122056

Ranco, D. (2021). People have shaped most of terrestrial nature for at least 12,000 years. Proceedings of the National

Academy of Science. In press.

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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. https://doi.org/10.1111/gcb.14850

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Teitelbaum, C.S., Sirén, A.P., Coffel, E., **Foster, J.R.,** Frair, J.L., Hinton, J.W., Horton, R.M., Kramer, D.W., Lesk, C., Raymond, C., Wattles, D.W., Zeller, K.A., & Morelli, T.L. (2021). Habitat use as indicator of adaptive capacity to climate change. Diversity and Distributions, 27 (4). https://doi.org/10.1111/ddi.13223

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Other Conference Presentation/Paper (14)

D'Amato, A.W. (2020). *Silviculture for adaptation in north temperate forest systems*. Michigan State University, Hanover Forest Science Seminar Series. East Lansing, MI, USA. https://www.canr.msu.edu/for/events/hanover

Daigneault, A., & **Simons-Legaard, E.** (2021). *Benefits and Costs of Maine's Natural Climate Solutions Part 2: Forestry*. Northeast Climate Hub Webinar Series. Online. https://www.climatehubs.usda.gov/hubs/northeast/events/benefits-and-costs-natural-climate-solutions-maine-part-2-forestry

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Millay, L. (2020). *UMaine Arctic Broader Impacts Discussion*. UMaine Arctic Broader Impacts Seminar. Orono, Maine, United States. https://umaine.edu/arctic/event/strengthening-the-impact-of-your-arctic-research/

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 Association Annual Conference and Research Symposium. Belfast, Maine, United States. https://www.meeassociation.org/programs/researchandevaluation

Ollinger, S. (2021). *Forest ecosystems and the winds of change: Forests as a cog in the Earth's climate system*.

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Wiafe-Kwayke, K., Beard-Tisdale, K., & **Hahmann, T.** (2021). *Creation of a Digital Forest*. All-Hands Team Meeting. Online.

Database/Model/Technology Products (3)

Hahmann, T., Beard-Tisdale, K., & **Wiafe-Kwakye, K.** First Prototype OWL/RDF Knowledgebase for the Digital Forest; stored as a GraphDB database; not yet publically shared.

Nelson, P., Bundy, K., Smith, K., Soucy, N., **Wiafe-Kwakye, K.,** & **Hastings, J.** Laboratory of ecological spectroscopy (lecospec) is composed of people, hardware and code for processing imaging spectroscopy data for mapping plants. This NSF funding has helped with some recent development on the code component of lecospec. https://github.com/nelsopet/lecospec

Zhang, Z., Miranda, B., & Gustafson, E. (2021). We developed modeling functions of N cycling processes in the LANDIS-II PnET-Succession model. The preliminary model is shared on GitHub as a branch of the LANDIS-II PnET-Succession model.

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Akresh, M., King, D., Lott, C., Larkin, J., & **D'Amato, A.** (2021). A meta-analysis of the effects of tree retention on shrubland birds. Forest Ecology and Management, Volume 483, 118730. doi.org/10.1016/j.foreco.2020.118730

Bibaud, H., **Ducey, M.,** Simmons, M., McCarthy, H., Bibaud, R., & Lee, T. (2020). Factors limiting the success of invasive glossy buckthorn (Frangula alnus) in New Hampshire's eastern white pine – hardwood forests. Forest Ecology and Management. Volume 474, 118345. doi.org/10.1016/j.foreco.2020.118345

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D'Amato, A., & Palik, B. (2020). Building on the last "new" thing: exploring the compatibility of ecological and adaptation silviculture. Canadian Journal of Forest Research. doi.org/10.1139/cjfr-2020-0306

Dean, T., **D'Amato, A.,** Palik, B., Battaglia, M., & Harrington, C. (2021). A direct measure of stand density based on stand growth. Forest Science, Volume 67, pages 103–115. doi.org/10.1093/forsci/fxaa038

Finzi, A., … **Ollinger, S.,** et al. (2020). Carbon budget of the Harvard Forest Long-Term Ecological Research site: pattern,

process, and response to global change. Ecological Monographs. doi.org/10.1002/ecm.1423

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Stephen, S. & **Hahmann, T.** (2020). Model-Finding for Externally Verifying FOL Ontologies: A Study of Spatial Ontologies. Formal Ontology in Information Systems: Proceedings of the 11th International Conference.

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Teacher Education Programs for Preservice and In-service Teachers. Journal of Computational Science Education. doi.org/10.22369/issn.2153-4136/12/1/1

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Appendix 2. Student Survey

INSPIRES Student Surveys

Graduate and Undergraduate Students

OCTOBER 29, 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 Institute 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."

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, three surveys were conducted - one targeting faculty and non-faculty researchers and the others targeting graduate and undergraduate students. This report summarizes key findings from the INSPIRES Graduate and Undergraduate Baseline Surveys.

The goal of the Graduate and Undergraduate Baseline Surveys was to collect baseline information about the project's education 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.

Methodology

The AAAS Evaluator developed two separate survey instruments for graduate and undergraduate students. The draft instruments were sent to INSPIRES Principle Investigator (PI) and Co-Investigators (Co-PIs) for review and input. The 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 SurveyMonkeyTM software (SurveyMonkey, San Mateo, CA, USA). A link for each of the survey instruments was forwarded to the INSPIRES PI and project manager. The link was sent to graduate and undergraduate students affiliated with the INSPIRES project via email on September 1st, 2020. The students 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 September 23rd, 2020.

Graduate Student Survey

The development of the INSPIRES Graduate Student Baseline Survey instrument was informed by a review of project documents, discussions with the project leadership, and a review of existing literature and instruments.[1–4]

The final version of the survey instrument had 29 questions/items, which included a participant background section and six domains:

- Participants Background (13 items): name, institution, department, training year, academic advisor/mentor, affiliation with project themes and related research projects, anticipated graduation date, gender, race/ethnicity, reason for joining the project and expected outcomes.
- The INSPIRES Project (4 items): participation in project kick-off and all-team meetings, understanding of different aspects of the project and how student contributions fit into the project, and aspects of the graduate training experience perceived to be most valuable.
- Knowledge and Research Skills (2 items): students were asked to rate the level of their ability on a scale from 1 to 10 for 12 knowledge and research skill areas and the extent to which the INSPIRES project has contributed to the improvement of their multidisciplinary research knowledge and skills.
- Mentoring (3 items): whether students have other mentors (besides their primary academic advisor), whether they use an individual development plan or a mentoring compact when working with their mentor, and academic and professional areas discussed with the mentor(s).
- Professional Development (2 items): professional development opportunities pursued and barriers to pursuing professional development in the previous year.
- Research Productivity (4 items): number of articles, presentations, grant applications submitted and awarded, and other research and education activities/products completed in 2020.
- Post-graduation Plans (1 item): plans after completing graduate training.

Undergraduate Student Survey

The development of the INSPIRES Undergraduate Student Baseline Survey instrument was informed by a review of project documents, discussions with the project leadership, and a review of existing literature and instruments.[5–7]

The final version of the survey instrument had 25 questions/items, which included a participant background section and six domains:

- Participants Background (11 items): name, institution, major, classification in college, start date with INSPIRES, affiliation with project themes and related research projects, anticipated graduation date, gender, race/ethnicity, previous undergraduate research experiences.
- The INSPIRES Project (3 items): understanding of different aspects of the project and how student contributions fit into the project, and aspects of the summer undergraduate research experience perceived to be most valuable.
- INSPIRES-supported Undergraduate Research Training Experience (5 items): how did learn about INSPIRES' undergraduate research experience opportunity, reason for choosing to participate in the project, expected outcome, amount of time spent with different project personnel and areas of engagement.
- Knowledge and Research Skills (1 items): students were asked to rate the extent of confidence in their ability in 9 knowledge and research skill areas.
- Science Communication (1 item): students were asked to rate the extent of confidence in their ability along 6 science communication skill areas.
- Research Productivity (1 item): number of articles, presentations, and other research activities/products completed in 2020.
- Overall Impression about the INSPIRE S undergraduate research experience (1 item): perception of the extent to which the project contributed to improvements in research skills and attitudes towards STEM training and related careers.
- Post-graduation Plans (2 items): intention to seek another research undergraduate experience and plans after completing undergraduate education.

Results

Based on the INSPIRES project team roster in October 2020, the 15 graduate students and 4 undergraduate students are/were directly involved in INSPIRES-related research activities. A total of 4 graduate students responded to the survey, representing a response rate of 26.7%. Of the four undergraduate students who received an invitation to participate in the survey, 2 responded representing a response rate of 50%.

The Participants

All three different jurisdictions (Maine, New Hampshire, and Vermont) were represented in survey responses (Table A1). Respondents indicated involvement in the following research projects:

Theme 1: Advanced Sensing and Computing Technologies

- 1.1 Wireless sensor research and development

Theme 2: Smart Environmental Informatics

- 2.2b Provide spatial datasets for theme 3 objectives (LAI, tree height/stature, foliar nitrogen, tree/forest age, historic disturbances)

Theme 3: Integrated Ecological Modeling

- 3.1 Inverse parameterization of ecological models
- 3.2 Model integration and application

Table A2 demonstrate the list of proposed activities for supporting graduate students. One of the INSPIRES project's goals is to have approximately 12 graduate students directly involved in the project research. During the first year of the project, a total of 15 graduate students were directly involved in project research activities and supported by the INSPIRES project.

Table A1: INSPIRES Project Graduate Students - Year 1

Jurisdiction/Institution	No. Graduate Students Enrolled	No. Graduate Students Responded to the Survey	Discipline(s) Represented	Project Themes	Research Projects
Maine					
University of Maine	7	1	Electrical and Computer Engineering	Theme 1	1.1
New Hampshire					
University of New Hampshire	4	2	Natural Resources and Earth System Science	Theme 2, Theme 3	2.2b, 3.1, 3.2
Vermont					
University of Vermont	4	1	Natural Resources	Theme 1	-

Table A2: INSPIRES Workforce Development Strategy-Graduate Training

Activities	Y1	Y2	Y3	Y4
Graduate students directly involved in research projects across all three jurisdictions and teams *as cohorts*	√*			
Science communication graduate courses developed				
Graduate students offered opportunities for cross-disciplinary interactions	√			
Graduate students offered opportunities to gain experience in supporting teachers and K-12 students				
Certificate in environmental informatics and analytics				
Recruitment of Native American graduate students				

* As this is a baseline survey, the formation of a cohort was not assessed.

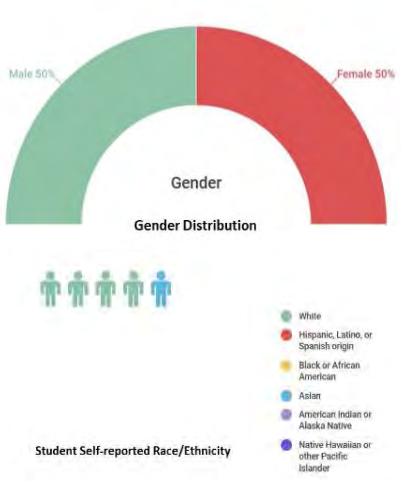


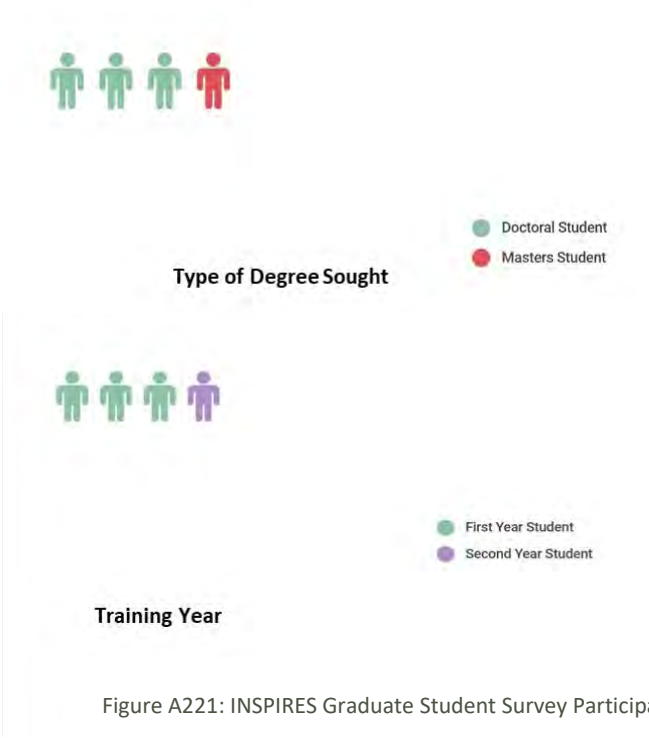
Figure A1: INSPIRES Graduate Student Survey Participants Characteristics -A

INSPIRES Workforce Development Goals:

One of main workforce development goals for the INSPIRES project is to increase the diversity of the STEM workforce by attracting women and underrepresented minorities.

Based on responses from the INSPIRES Graduate Student Survey:

- 50% of respondents identified as female (Figure A1).



INSPIRES Workforce Development Goals:

Another workforce development goal for the INSPIRES project is to have approximately 12 graduate students (4 PhD and 8 MS) directly involved in the project research.

Based on responses from the INSPIRES Graduate Student Survey:

- 3 out of the 4 respondents identified as Doctoral students and 1 identified as Masters student (Figure A2).
- 3 out of the 4 respondents were first year students and 1 (PhD) student was a second-year student.

Figure A221: INSPIRES Graduate Student Survey Participants Characteristics -B

What motivated you to be part of the INSPIRES project?

Graduate students were asked about their motivation to join the INSPIRES project. The following responses were provided:

- Interest in building cross-institutional collaborations and to be part of an important scientific research in the northeastern U.S.
- The project's mission and goals match research interests
- Research interest in nutrient cycling
- Interest in computer science/programming
- Interest in learning more about biogeochemical cycles

What do you expect to get out of the INSPIRES project?

Graduate students were asked to outline their expected outcome from joining the INSPIRES project, in addition to earning a graduate degree. The following responses were provided:

- Build strong connections with researchers and organizations in the northeastern U.S.
- Write and publish papers
- Develop professional skills and explore career options
- Learn about ecological modeling and to build connections with researches in that field across three jurisdictions involved.

The INSPIRES Project

Graduate students are fully integrated into the project and expected to attend quarterly all-team meetings (Figure A3) to:

- Learn and stay informed about the various aspects of the project.
- Provide updates about their research activities as needed.

Project meetings can provide opportunities for graduate students to identify potential resources, mentors, and collaborators to enhance their training experiences.

Figure A3: Number of Graduate Student Attending Quarterly All-team Meetings

Based on responses from the INSPIRES Graduate Student Survey, all respondents indicated having a clear understanding of the project's goal and priorities (Figure A4). Most respondents also indicated having a clear understanding of how their contribution fits into the project as a whole. This lends further support to the effectiveness of project leadership effort to fully integrate students into the project.

Figure A422: INSPIRES Graduate Students Understanding of the Project and the Scope of their Contribution

Knowledge and Research Skills

INSPIRES graduate students were asked indicate the level of their ability for 12 knowledge and skill areas by selecting a number on a scale from 1 to 10 (where 1= 'I have very little or no ability and 10 = 'I have advanced ability):

- Explain basic concepts of their discipline to someone outside of it **(7.3; 6-10)**[1]
- Apply research techniques commonly used within their field/discipline **(7.8; 6-10)**
- Design research that meets the standards of credible work in their discipline **(7.0; 5-10)**
- Apply ethical standards of practice in their discipline **(9.0; 7-10)**
- Formulate an interdisciplinary research question **(7.3; 6-10)**
- Apply concepts and methods from multiple disciplines to address a research problem **(6.5; 4-10)**
- Collaborate with researchers trained in different disciplines **(6.5; 5-10)**
- Communicate their research to researchers trained in other disciplines **(6.8; 5-10)**
- Communicate their research to non-academic audience **(7.3; 5-10)**
- Translate their research into practice **(6.8; 5-10)**
- Explain how their research connects to issues that are important to society **(7.3; 5-10)**
- Design and teach a course in their field/discipline **(6.5; 3-10)**

Figure A5 illustrates the median and interquartile range of ability level for each of the knowledge and research skills areas. While average ratings in all areas were in the uper range, areas involving mutlidiciplinary collaborations, interdisciplinary communication, translation of research, and teaching received lower ratings. The figure also show skewness in the survey data. One respondent rated themselves at 10 on all of the knowledge/skill areas. A more normally distributed boxplot was obtained after eliminating data from this respondent. Survey findings also show that students rated their ability very highly in the areas of ethical standards aplication. The way the question is worded may be leading and conducive to social desirability bias. One suggestion is to break down the concept of "applying ethical standards" into its individual components (e.g., data management, authorship, conflict of interest, etc.)

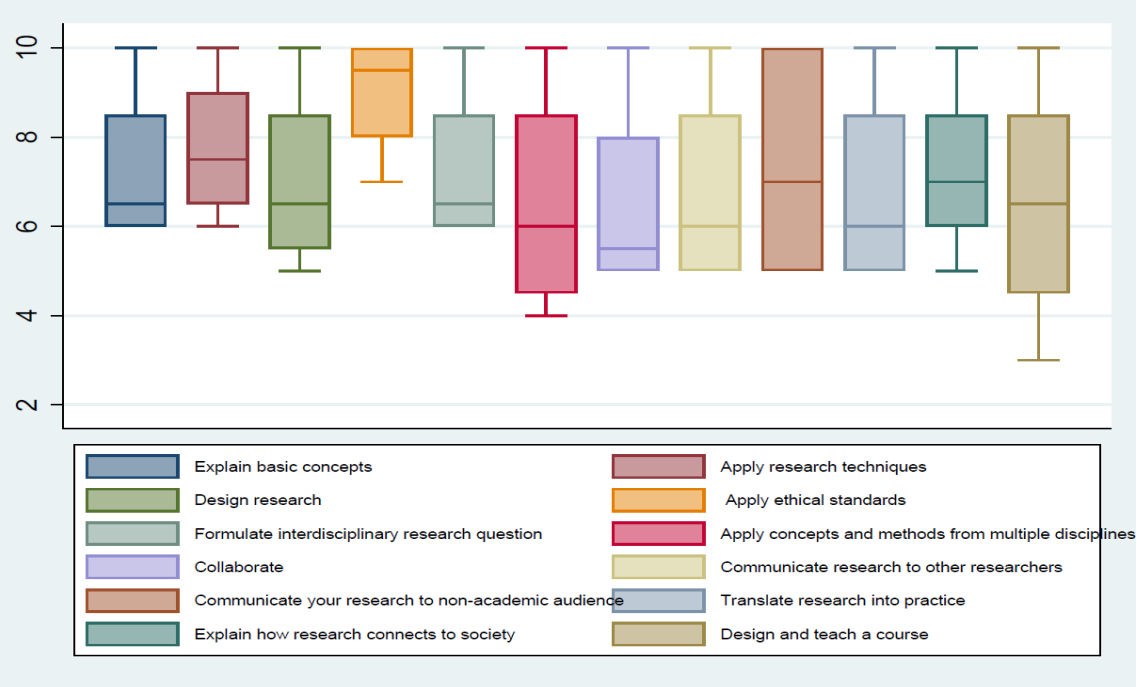


Figure A5: Graduate Students Knowledge and Research Skills - Ability Level

[1] Average rating and range (min-max).

Graduate students were also asked to indicate the extent to which their participation in the INSPIRES project has led to competence gains in eight practical skill areas. As shown in Figure A6, areas where significant gains have been made were:

- Developing knowledge and/or skills in one or more new disciplines.
- Learning to use disciplinary knowledge and skills to address a complex research question that requires multidisciplinary expertise.
- Learning to use instrumentation or techniques that are not typically used in the student's own discipline.These findings demonstrate the project's contribution to promoting interdisciplinary graduate training, which is another key workforce development goal for the INSPIRES project. Competence gains in the other areas are likely to be seen in the coming years as student progress through their graduate training.

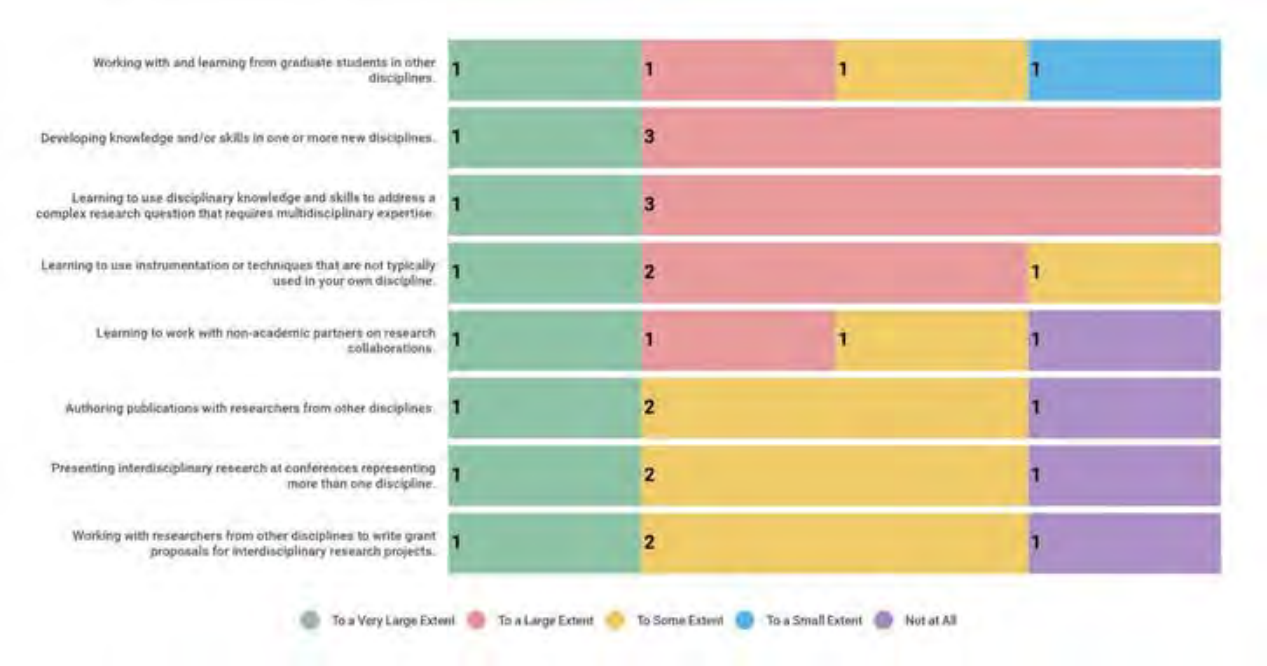
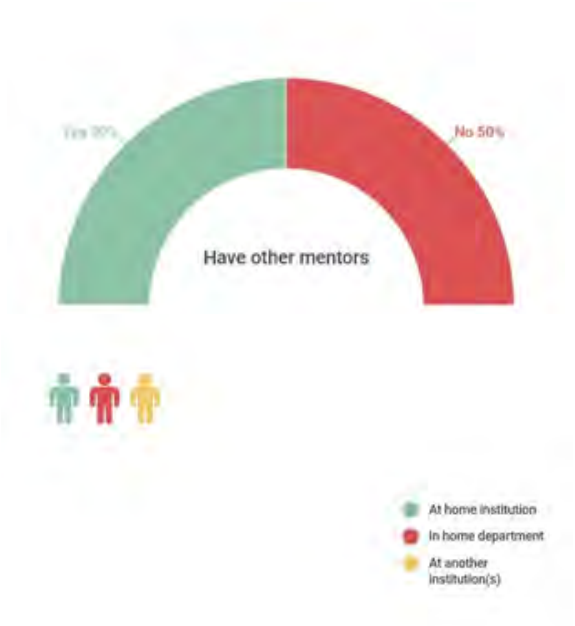


Figure A6: Competency Gains Achieved through the INSPIRES Project

Mentoring



Graduate students were asked to indicate if they have other mentors besides their primary mentor/academic advisor.

- 50% indicated that they have other mentors besides their primary mentor/academic advisor (Figure A7).
- Of the two students who indicated having other mentors, one is working with another mentor at their home institution, and the other is working with two other mentors (at their home department and at another institution).

None of the respondents indicated using an Individual Development Plan (IDP) or mentoring compact when working with mentors.

Figure A7: Working with Multiple Mentors

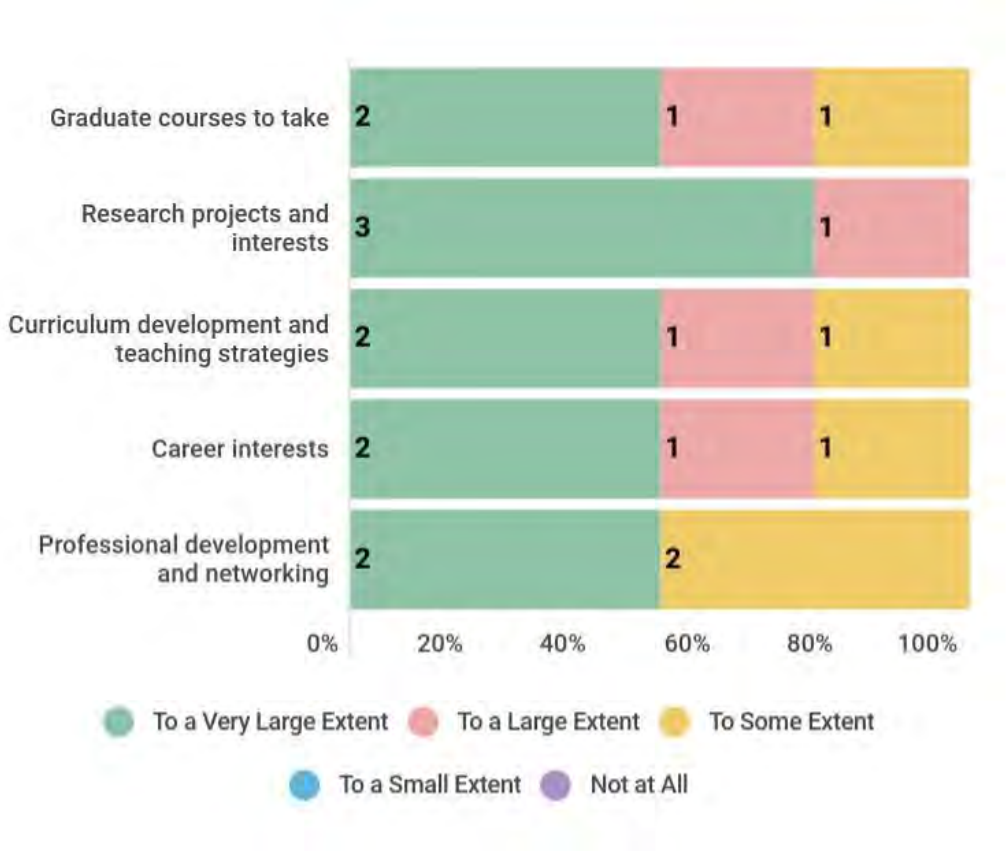


Figure A8: Topics Discussed with Mentors

Graduate students indicated discussing various topics with their mentors including which classes to take, research projects, teaching, and career interests (Figure A8).

Professional Development

Graduate students were asked to indicate if they have pursued professional development opportunities during the past year. As illustrated in Table A3, only one student pursed professional development activities in 2020. Professional development activities focused on functional training to equip the student with the skills necessary for advancing their research competitiveness such as grant writing, publishing, and communication.

Graduate students were also asked about the reasons for not pursuing professional development opportunities during the past year. Being a new student who have just began their graduate training was provided as the main reason.

Table A3: Professional Development Activities Pursued by INSPIRES Graduate Students

Activities	Y1	Y2	Y3	Y4
Career guidance				
Communication/organizational skills development	√ **(1) ***			
Leadership skills development				
Training to enhance grant writing skills	√ **(1)**			
Training to enhance mentoring skills				
Training to enhance publishing skills	√ **(1)**			
Training to improve research or teaching skills	√ **(1)**			
Professional networking				
Conferences or professional meetings	√ **(1)**			

* The number in parentheses refers to the number of students

Productivity

Graduate students were asked to indicate whether they have engaged in several research, education, and mentoring activities, and whether they have produced scholarly output in the past year (Table A4). Two students provided responses for this question. One student (second year graduate student) reported giving 1-3 research presentations, authoring/co-authoring 3 research papers, and submitted/received 2 grant proposals in the past year. The other student (Masters) reported teaching as a graduate teaching assistant.

Post-graduation Plans

Graduate students were asked about their plan after graduation. The following responses were provided:

- Seek a tenure-track faculty appointment at a research-intensive institution (1)
- Undecided (1)
- Seek a PhD (1)

Aspects of Graduate Training Experience Perceived as Most Valuable

Graduate students were asked about aspects of their graduate training experience they find most valuable. Access to a network of professional individuals who can be approached for advice, assistance, or guidance on academic and professional development was considered as the most valuable aspect of the graduate training experience as part of the INSPIRES project.

Table A410: Productivity of INSPIRES Graduate Students

Activities	Y1	Y2	Y3	Y4
Number of research presentations at your home institutions				
Number of research presentations at regional or national meetings/conferences	√ (1); 1-3*			
Number of research papers authored or co-authored	√ (1); 3			
Number of grant proposals submitted and/or received	√ (1); 2			
Completed a certificate course/program				
Prepared a syllabus				
Conducted field or laboratory research as a research assistant				
Taught a course as a graduate teaching assistant	√ (1)			
Mentored undergraduate students in conducting scientific research				
Organized a seminar, workshop, or symposium				
Participated in an academic committee or working group				
Helped others develop a research or funding proposal				
Independently developed a proposal for a research grant or fellowship				
Took part in an educational event aimed for K-12 students				
Took part in an educational event aimed at the public				
Gave a formal talk about my research to an audience of people outside of my discipline				

* The number in parentheses refers to the number of students. The number following the semicolon represents

The Participants

Two out of the three jurisdictions (Maine and Vermont) were represented in survey responses (Table A5). Respondents indicated involvement in the following research projects:

Theme 1: Advanced Sensing and Computing Technologies

- 1.3 Cyber-based big data harmonization, ML & interface

Theme 2: Smart Environmental Informatics

- Other- Interactive Display of Data

Theme 3: Integrated Ecological Modeling

- 3.1 Inverse parameterization of ecological models

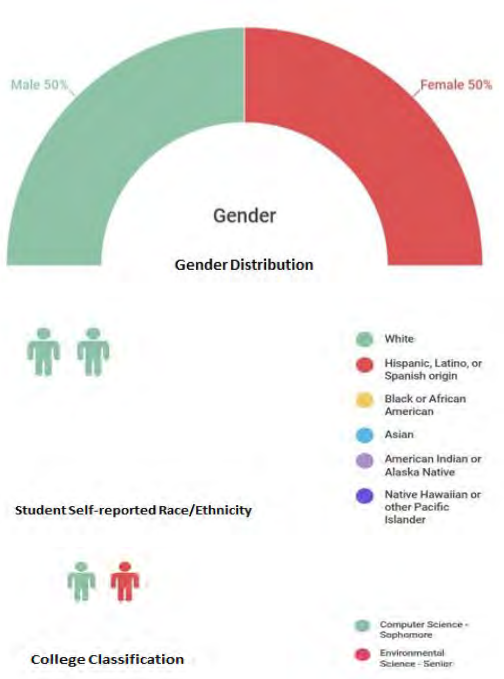
Table A5: Participants on the INSPIRES Undergraduate Research Experience – Year1

Jurisdiction/Institution	No. Undergraduate Students Offered SURE	No. Undergraduate Students Responded to the Survey (Response Rate)	Discipline(s) Represented	Project Themes	Research Projects
Maine					
University of Maine	3	1 (33.3%)	Computer Science	Theme 2	Other
New Hampshire					
University of New Hampshire	-	-	-	-	-
Vermont					
University of Vermont	1	1 (100%)	Environmental Science	Theme 1, Theme 3	1.3, 3.1

Table A6 demonstrate the list of proposed activities for supporting undergraduate students. One of the INSPIRES project's goals is to have approximately 15-20 undergraduate students directly involved in the project research and education activities. A total of 4 undergraduate students were recruited to join the project's Summer research experience.

Table A6: INSPIRES Workforce Development Strategy-Undergraduate Education

Activities	Y1	Y2	Y3	Y4
Summer research experience	√			
Professional Internships				
Research opportunities for Native American Students				
Enrollment in classes that integrate project data				
Certificate in environmental informatics and analytics				



INSPIRES Workforce Development Goals:

One of main workforce development goals for the INSPIRES project is to increase the diversity of the STEM workforce by attracting women and underrepresented minorities.

Based on responses from the INSPIRES Undergraduate Student Survey:

- 50% of respondents identified as female (Figure A9).
- All (100%) respondents identified as white.
- Of the 2 respondents to the survey, one identified as Sophomore Computer Science major and the other as Senior Environmental Science major.

Figure A9: Characteristics of Participants in the INSPIRES Undergraduate Research Experience

Both respondents reported having prior undergraduate research experience:

- University of Maine, Department of Electrical Engineering: A novel non-invasive radar to monitor honeybee colony health, 06/17, 08/19.
- University of Vermont, Rubenstein School of Environment and Natural Resources: assisted with PhD students research investigating how soil texture influences soil carbon, 09/18- ongoing.
- University of Vermont, Rubenstein School of Environment and Natural Resources: conducted basic lab work and participated in lab meeting, 09/18- ongoing.
- Cary Institute of Ecosystem Studies: REU student and conducted research on stream moss at Hubbard Brook, 06/19-08/2019.

INSPIRES-supported Undergraduate Research Training Experience

Participants in the Undergraduate Research Training Experience were asked about how they learned about the research training opportunity offered through the INSPIRES project. Both respondents indicated learning about the opportunity through word of mouth:

- One student worked previously at Cooperative Forestry Research Unit (CFRU)
- One student was approached by faculty members affiliated with the project

The students were also asked about the reasons for deciding to participate in the INSPIRES Summer Research Experience. The following responses were provided:

	1 Respondent – decided to participate to help prepare for graduate school
	2 Respondents – thought the project sounded interesting
	2 Respondents – thought the experience will enhance their resume
	2 Respondents – saw an opportunity to develop a mentoring relationship with a faculty member
	2 Respondents – indicated a faculty/staff member approached them about the opportunity
	2 Respondents – thought the experience will help them gain practical experience for a future career
	2 Respondents - decided to participate because it was a paid position

The students were also asked about what they had hoped to gain through the INSPIRES undergraduate research training experience. The following responses were provided:

- Gain more knowledge of programming, specifically javascript
- Gain more skills in data collection and analysis, and make progress on senior thesis

When asked to indicate the average number of hours per week they spent during the summer on research-related activities with different project personnel, both reported spending 0-4 hours per week on average with:

- Faculty mentor
- Other faculty mentors
- Graduate students and postdoctoral fellows Other undergraduate students
- Other Lab personnel/staff

These findings suggest that the INSPIRES project has provided both students with opportunities to expand their professional network and learn from mentors, peers, and other professional on the project team.

As shown in Figure A10, the faculty mentor plays a key role in mentoring and advising undergraduate students on research methods, scientific background underlying the research project, and future career options and learning opportunities.

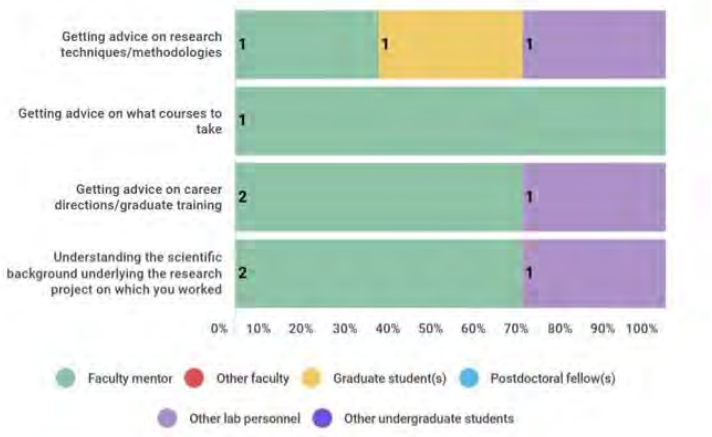


Figure A10. Undergraduate Students Engagement with INSPIRES Project Personnel

Figure A11: INSPIRES Undergraduate Students Understanding of the Project

Unlike graduate students, undergraduate students who responded to the survey had a less clear understanding of the project's goal and priorities (Figure A11). They also had a less clear understanding of how their contribution fits into the project as a whole.

Knowledge and Research Skills

Figure A12 shows the level of confidence students have in their ability to perform a variety of research-related tasks, such as developing research questions or hypotheses, search literature and databases, perform statistical analysis, and work effectively

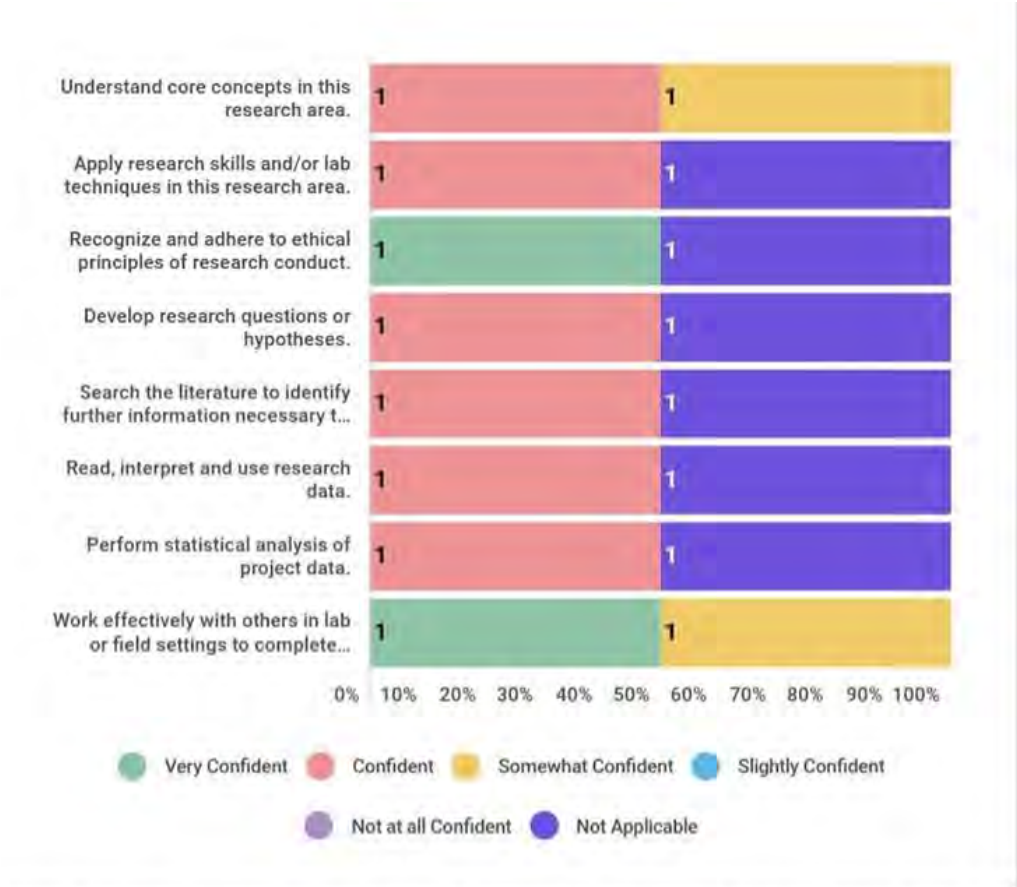


Figure A12. Undergraduate Students Research Knowledge and Skills – Level of Confidence in Ability

with others in lab settings. Even though the survey received two responses only, the differences in the goals and scope of the two summer research experiences is clear and can be explained by differences in disciplinary background and student classification in college (e.g., learning a coding language rather than research seemed to be the focus of the experience for the respondent with a computer science major, as a result, a "not applicable" response was selected for most of the items under this survey question).

Science Communication

Responses to the questions asking students to indicate the level of confidence in their ability to perform various science communication activities were varied (Figure A13). Given the low number of responses, it is difficult to explain these results (e.g., based on disciplinary background and student classification in college). A follow-up interview with the respondents may help shed more light on the nature of these responses and help identify potential strategies to better address undergraduate students' science communication needs.

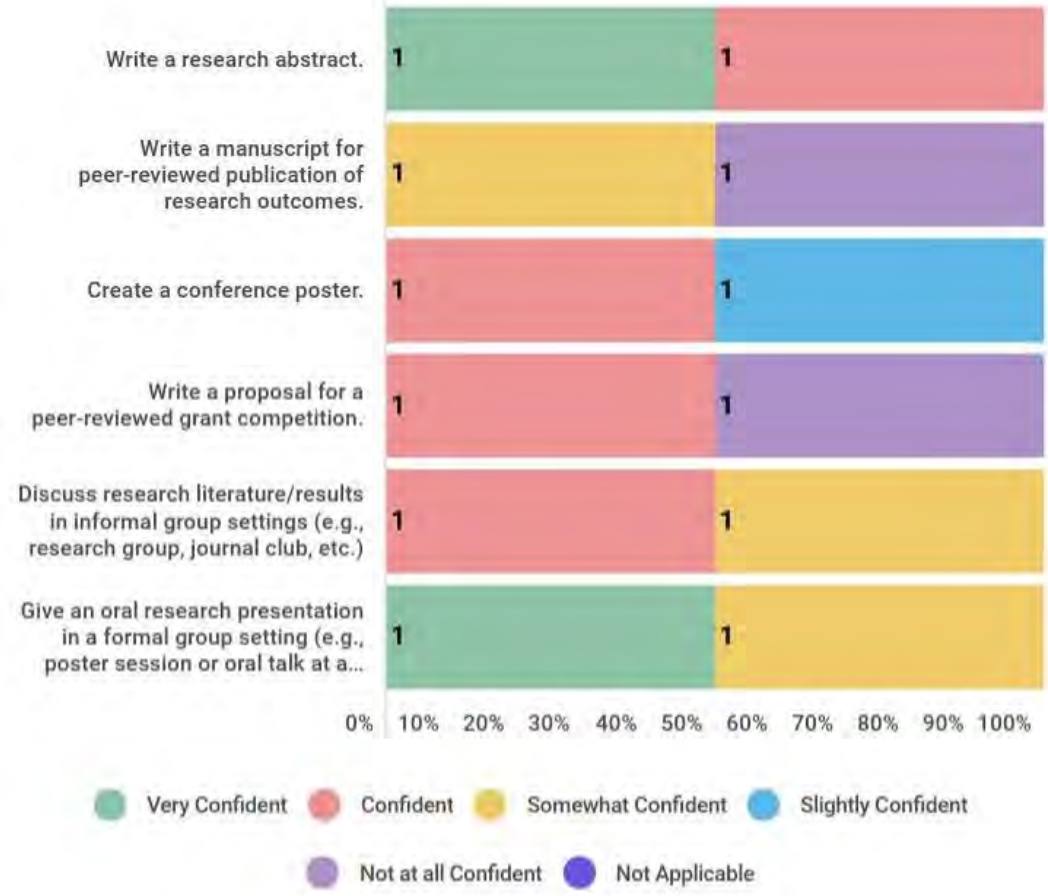


Figure A13. Undergraduate Students Communication Skills – Level of Confidence in Ability

Productivity

The students were asked about the number of times they have engaged in each of the activities listed in Table A7 in the past year. One respondent reported attending a national scientific conference and presenting a poster while the other reported co-authoring an article submitted to a peer-reviewed journal.

Table A7: Undergraduate Students Productivity

	Total Number in 2020	Number Associated with INSPIRES	List
• Number of times presented (poster or talk) at a seminar or symposium at your institution.			
• Number of times attended a regional or national scientific meeting/conference.	√ (1)	-	Ecological Society of America Annual Meeting
• Number of times presented (poster or talk) at a regional or national scientific meeting/conference.	√ (1)	-	Moss distribution in streams at Hubbard Brook Experimental Forest O Vought, AN Thellman, E Bernhardt, SK Hamilton, E Rosi. 2020 ESA Annual Meeting (August 3-6).
• Number of times contributed to writing a grant proposal.			
• Number of times been an author on an article submitted to a peer-reviewed journal.	√ (1)	-	Cunha, A.S., Rose, J., Prior, J., Aumann, H., Emanetoglu, N.W., & Drummond, F. (2020). A novel non-invasive radar to monitor honey bee colony health. Comput. Electron. Agric., 170, 105241.

Overall Impression

The students' overall impression of the INSPIRES Summer Research Experience was positive (Figure A14). Depending on the student's goals and reasons for participating in the project, both respondents seem to have met their objectives. Where research was the primary focus, the respondent strongly agreed that the INSPIRES Summer Research Experience:

- Improved the student's research skills
- Helped prepare the student for graduate school
- Increased the student's interest in STEM-related postgraduate training

Where technology development was the primary focus, the respondent strongly agreed that the INSPIRES Summer Research Experience:

- Increased the student's interest in STEM-related career fields
- Helped the student identify potential career options

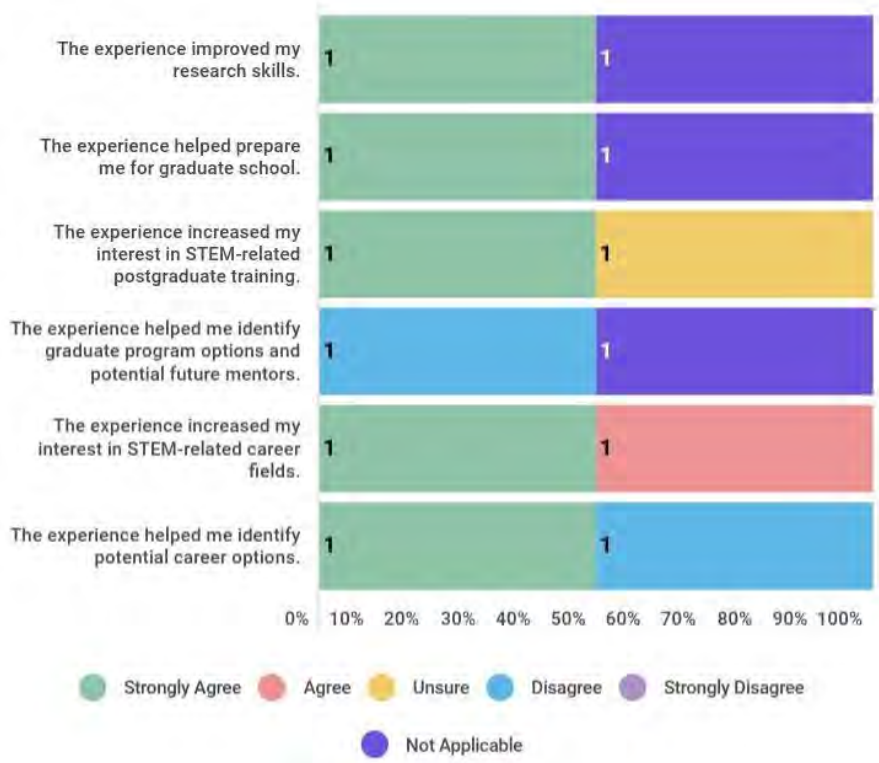


Figure A14: Overall Impressions of INSPIRES Undergraduate Research Experience

Post-graduation Plans

Undergraduate students were asked if they intend to pursue another undergraduate research experience and about their plan after graduation. Responses from the survey are provided in Figure A15.

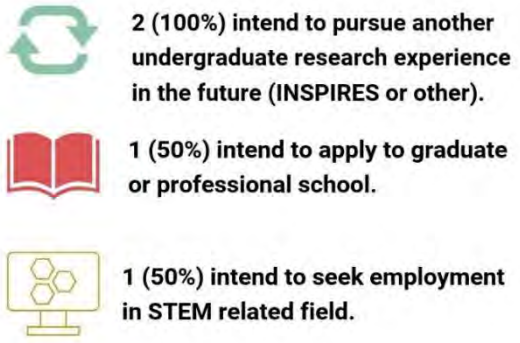


Figure A15: Post-graduate Plans – Undergraduate Students

Aspects of the Undergraduate Research Experience Perceived as Most Valuable

Undergraduate students were asked about aspects of their Summer Undergraduate Research Experience they found most valuable. The following responses were provided:

- Having a mentor who could help students to learn javascript
- The opportunity to gain programming knowledge in javascript
- Mining the literature to find data contributed to improved ability to find relevant information in databases

Discussion and Recommendations

Based on the results of the surveys, the INSPIRES project seems to be on track relative to its proposed benchmarks and targets for graduate and undergraduate training. Considering these findings, the following is suggested:

Future Surveys

Given the relatively low response rate, the project leadership might want to consider alternative mechanisms for survey administration (e.g. have the invitation to participate in the surveys comes from the evaluator or project coordinator). Considering additional measures to motivate students to participate in the surveys is also recommended (e.g., emphasize the importance of their participation in project meetings). Enhanced participation is critical to the validity of survey findings, for example, the low response rate in the Graduate Student Survey raise concerns about non-response bias. This can partially be addressed for the current round of surveys by providing a comprehensive description of the whole group of students (e.g., demographics, institutional affiliation and discipline, training year, etc.)

Graduate Students Survey

Generally, the graduate students who responded to the survey were positive about training experience. They reported good understanding of the project goals and how their contributions fit in the project as a whole, which indicates effective integration of graduate students into project teams. In terms of research knowledge and skills, the project seems to be addressing the students' learning needs (e.g., the students provided lower average ratings of ability in areas of interdisciplinary research, collaboration, and communication). The graduate students who responded to the survey provided positive responses regarding the INSPIRES project contribution to enhancing their competence in engaging in multidisciplinary research. More meaningful data about student productivity, in terms of publication and presentations of research, will be possible in future surveys since most of the respondents in the baseline survey just started their graduate training. The same argument can be applied to mentoring and the engagement of students in various professional development activities.

Undergraduate Students Survey

Similar to Graduate Students Survey, undergraduate students were generally positive about the INSPIRES Summer Research Experience. Since "broadening the participation of undergraduate students and students from groups underrepresented in STEM" is one of the INSPIRES project's workforce development goals, the project leadership might want to consider providing a description of their outreach, recruitment, application, and enrollment approach for the Summer Undergraduate Research Experience. Additionally, the project leadership might want to consider ways for the integration of undergraduate students into project activities so they can develop a better contextual understanding of their involvement in the project.

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Appendix 3. INSPIRES Student Profiles

Profiles by Stefania Irene Marthakis

Sonia Naderi

Sonia Naderi is a third-year Ph.D. candidate in Electrical and Computer Engineering (ECE) at the University of Maine, using her knowledge and research within multiple fields of study (e.g., forestry). As a graduate research assistant, advised by Ali Abedi, she works in WiSe-NET Lab, building wireless sensors for forest ecosystem monitoring as part of the NSF-funded INSPIRES project.

Naderi is also chair of IEEE Women in Engineering (WIE) Maine Section and President of the Iranian Graduate Student Association as well as ECE Senator of the Graduate Student Government, where she represents fellow ECE graduate students' interests and concerns.

With a bachelor's and master's degree in electrical engineering from her home country of Iran, she began studying the research papers of Abedi, whose work inspired her—along with her interest in sensors and wireless communications as well as a strong background in mathematics—to join the University of Maine's electrical engineering program and WiSe-NET Lab.

While she is very interested in reading and writing papers, the lab gives her the opportunity to work with cutting-edge sensors and collect data. Since 2018, Naderi has worked on several projects with Abedi at WiSe-NET Lab, including the wireless energy transfer project as well as different projects involving sensors. Through Abedi, Naderi was introduced to INSPIRES.

"Since it's an interdisciplinary project," states Naderi. "I had this opportunity to work with the University of Maine, University of New Hampshire, and University of Vermont with students and faculties from different majors."

To build a low-cost and low-power sensor suite for INSPIRES, Naderi leads a team of two undergraduate students in the ECE department, Victoria Nicholas and Thayer Whitney.

"These low-cost sensors enable large scale deployment, providing much needed data points in places that no data has been collected in the past," explains Abedi.

Naderi is currently working on soil moisture sensors for forest ecosystem monitoring as well as wireless sensing of forest ecosystem using artificial intelligence and machine learning developed by researcher Kenneth Bundy.

Soil moisture sensors and data acquisition system at Old Town site.

Although COVID has presented challenges, Naderi and project team members are working from home with their equipment, periodically meeting via Zoom. Recently, Naderi and team members have deployed a couple of soil moisture sensors and data acquisition system at the Old Town, ME site.

Teamwork is an important aspect of Naderi's work. "What I'm most excited about is this is the first time that I'm working with a large group of students and faculty from different

majors, from different schools," said Naderi. "And also we meet every month and I learn a lot about their work, especially forestry."

Kingsley Wiafe-Kwakye

With a background in Geographic Information Science (GIS), data processing, and data analysis, Kingsley Wiafe-Kwakye has found a graduate program that perfectly aligns with his interests. Wiafe-Kwakye is a second-year Ph.D. candidate in Spatial Information Science and Engineering at the University of Maine, as well as a graduate teaching assistant in the School of Computing and Information Science.

Co-advised by Kate Beard-Tisdale and Torsten Hahmann, Wiafe-Kwakye has been a research assistant in Beard-Tisdale's GIS Lab for the past two years as well as Hahmann's Spatial Knowledge and Artificial Intelligence Lab (SKAI) for the past year.

Through the NSF-funded INSPIRES project, Wiafe-Kwakye is part of a team that's creating a Digital Forest, which is a resource for integrating forest data from diverse sources to enable complex analyses as well as to support forest domain hypothesis formulation and testing. Wiafe-Kwakye is developing the ontology, in other words, the terminology to represent the forest data such as the terrain and bioclimatic conditions for different tree species, for this Digital Forest.

Wiafe-Kwakye explains, "I'm forming clusters of forest regions so we could find out if similar clusters have similar characteristics—what are the variables they have in common and what variables correlate with which phenomenon—in terms of forest composition based on observations. For instance, Theme 1 of INSPIRES is producing sensors which will be deployed into various places, the aim is to see if we're able to identify places with similar characteristics to maximize data collection efforts."

By maximizing the deployment of sensors, the researchers ensure that the sensors capture all the various types of clusters available in the forest regions, each representing a unique place for sampling data. Wiafe-Kwakye and project team members will then use this data from the "original" forest in order to create the Digital Forest.

Beard-Tisdale adds, "The aim of the Digital Forest is an integrated digital view of several variables that influence forest characteristics and distribution of species. Kingsley has integrated terrain, soil, geological, and climate characteristics represented as an ontology. So essentially what we have are what might be called eco_units covering the landscape. With these, the intent is to support questions/analyses such as are certain species more prevalent, are certain types of eco_units."

Wiafe-Kwakye's true interest is working with data, and INSPIRES provides him the opportunity to work with large volumes of data bases in Hahmann's SKAI Lab, especially graph data bases. The main challenge for Wiafe-Kwakye is data and data sharing, since data comes in different forms and different formats. That's where ontology methods can be used to handle Big Data, allowing the data to be shared and to make sense for people of diverse backgrounds.

Hahmann clarifies, "The aim of the Digital Forest is to use an ontology and knowledge graph as tools to automatically compute data-driven descriptions of different tree species that will be easily understandable by people. For example, we want to compute descriptions of what kind of terrain and bioclimatic conditions makes a good location for a specific tree species, such as ash or red spruce. Once the computational basis for the Digital Forest has been laid, it would allow a wide variety of uses: generating knowledge about where a species is likely to be found (and could be sampled), what species are most suitable for planting now in a specific location, or to identify locations with similar forest composition or with gaps in sampling."

Apart from Wiafe-Kwakye's direct role in INSPIRES, he likes the team science aspect of the project. "I get to interact with people of different backgrounds and also with students from two other universities: New Hampshire and Vermont, which is really an enlightening experience," said Wiafe-Kwakye.

"I like the structure of the whole INSPIRES theme: accomplished professors with early career, and then students. It's like information flow; I think it's really exciting."

Paulina Murray

Paulina Murray has begun her graduate career on an ambitious yet uncommon path. As a first-year Ph.D. student at the University of Vermont (UVM), Rubenstein School of Environment and Natural Resources, she works as a graduate research assistant in three different labs as part of the NSF-funded INSPIRES project. Murray is co-advised by E. Carol Adair, Anthony D'Amato, and Aimée Classen of Biogeochemistry and Global Change Lab, Silviculture and Applied Forest Ecology Lab, and Ecosystem Ecology Lab, respectively.

Also, Murray is a Quantitative Evolutionary STEM Trainee (QuEST), an NSF-funded UVM program, where she's learning how to be a data scientist as well as incorporating critical conversations on diversity, equity, inclusion, and justice.

Murray recently moved to Vermont to attend UVM, with a background in natural science, conservation, and invasive species management, specifically plants. She also gained valuable research experience in biogeochemistry at the Cary Institute, which led her to choose UVM and the following three labs.

Each of the labs provides a different element: Adair's lab focuses on terrestrial biogeochemistry, while D'Amato's lab focuses on sustainable forestry methods—a new field of study for Murray—and Classen's lab works to understand and model complex ecosystems. When taken together, this interdisciplinary approach fuels the INSPIRES project.

Through her co-advisor Adair, Murray was introduced to INSPIRES. "Murray has been a truly excellent addition to our INSPIRES team—her interests and research have already taken off in exciting directions, first looking at the contribution of fungal community composition and activity to wood decomposition and carbon storage in forests," said Adair.

Murray was drawn to INSPIRES because of its mission. **"**Considering my interests in Big Data and forest ecology, I was immediately drawn to the project and its supporting network of professionals. The multi-regional collaborative aspect of the project was especially enticing because I knew I'd have access to a wealth of knowledge and a diversity of professionals with unique experiences and interests that could support me on my own academic journey," states Murray.

Students deploying sensors at UVM Corinth site.

Murray is part of a team that's working with the Mayfly sensors, which measure soil VWC (moisture), air temperature, humidity, soil water potential, and PAR. Since fall 2021, two Mayfly sensors have been collecting data in Corinth, VT. Potential new sites in Corinth are also being identified as well as the building of the remaining sensors for deployment this summer.

Also, this summer, Murray is looking forward to processing and analyzing decay stakes—which have been deployed and

decaying for three summers—for changes in nutrient contents (e.g., carbon, nitrogen, phosphorous) as well as working with the Frankenlog sensing network, similar to the Mayfly's technology. INSPIRES has created both opportunities for Murray within and outside the project.

Forestry and working with sensors are new fields of study for Murray. "While I did not actively study forestry, I've always been curious about forest ecology and have become increasingly interested in understanding how wood-decay fungi drive wood decomposition in Northeastern forests," explains Murray.

"I'm also interested in the sensors because I've always enjoyed learning about and working with Big Data. Joining Theme 1 of the INSPIRES project seemed like a very natural step in the process of understanding how environmental monitoring and Big Data contribute to the scientific process."

Melissa Pastore

Melissa Pastore is a first-year postdoctoral associate in the Rubenstein School of Environment and Natural Resources and with the Gund Institute at the University of Vermont. Co-advised by E. Carol Adair (Biogeochemistry and Global Change Lab) and Aimée Classen (Ecosystem Ecology Lab), Pastore has been a research assistant in their labs since September 2020, where she joined the NSF-funded INSPIRES project.

As a global change ecologist, Pastore tackles big global change issues (e.g., elevated CO_2, warming, rainfall change, nitrogen pollution) and how they affect the functionality of ecosystems, especially the ecosystem services that humans rely on, for instance, carbon storage.

Although Pastore has worked mostly in coastal marsh and grassland ecosystems, she grew up in the northeast and has always loved temperate forests. Pastore has also studied the effects of winter climate change on ecosystems like changes in snowpack and soil freeze-thaw cycles.

While working in the forest is new for Pastore, she finds herself asking similar questions. What are the drivers of carbon storage? How will climate change affect carbon cycling?

From identifying large scale patterns across landscapes (e.g., carbon storage) to exploring the underlying plant mechanics (e.g., leaf level physiology) and microbial processes (e.g., microbial respiration), Pastore brings her integrated, cross-scale research approach to INSPIRES. With this approach, Pastore hopes to improve model predictions of future carbon storage by providing process-level knowledge that researchers don't understand well enough yet to incorporate into models. These underlying plant and microbial mechanisms often operate at smaller scales and over different time scales than the observed patterns in carbon storage.

As part of Theme 1 of INSPIRES, which focuses on advanced sensing, Pastore and project team members are planning a big project this summer.

"It's all about how microclimate can effect carbon storage in these mountainous regions that have really complex topography. Usually, when you go upslope, if you're hiking up a mountain, you think of temperatures getting colder as you move up the mountain. In contrast, in these regions at nighttime after sunset, there is radiative cooling of the earth's surface which forms this dense cold air that actually drains down slopes into valleys, creating temperature inversions where the bottom of these depressions is actually the coldest. There's been a lot of interest in whether these cold air pools can act as microrefugia for species in the face of climate change because their climate is so decoupled from the broader landscape," explains Pastore.

Project team members will set up high frequency sensors, monitor, and take measurements in Vermont, New Hampshire, and Maine this summer in these different valleys where cold air pooling is happening across New England.

"How do the climate patterns differ from the broader region, what species are present, and what does this mean for ecosystem function? In addition to being able to preserve species, can these cold air pools actually preserve carbon in the face of climate change?" Pastore asks.

Also, Pastore will be mentoring an intern this summer with this cold air pooling project. Pastore loves working with students and derives energy from the experience, which is her focus as she actively looks for a tenure track position. INSPIRES has given her a glimpse of what that job will look like, as she collaborates with researchers from different institutions with different approaches and has the space to design her own projects and research program within INSPIRES' broader framework.

"It's so exciting to hear all these different perspectives, and people with different areas of expertise coming together to work on these shared problems," states Pastore. "I think that's really powerful."

Melissa Pastore collecting soil for a laboratory freeze-thaw experiment and putting out soil and air temperature sensors

Appendix 4. INSPIRES Data Sharing Plan

Data Sharing Subcommittee

- Alix Contosta, Theme 1, UNH
- Ami Gaspar, ACG, UMaine
- Daniel Hayes, Theme 3, UMaine
- Franziska Peterson, Theme 4, UMaine
- Ken Bundy, Theme 1, UMaine
- Leo Edmiston-Cyr (lead), CRSF, UMaine
- Mary Martin, NSF EDI, UNH
- Peter Nelson, Theme 2, Schoodic Institute

Organization, naming, and metadata sections by Leo Edmiston-Cyr, CRSF UMaine, with invaluable review and feedback from Mary Martin, Ami Gaspar, and the whole data sharing subcommittee.

Overview

The data sharing plan provides guidance on where data is stored, naming conventions, and how metadata is recorded to ensure sufficient quality to meet NSF and publishing requirements. This is a pipeline from raw data to data and documents that are ready for publishing. Each theme has provided its own section of this plan, which includes a declaration of the data and document products they will share along with an estimated timeline.

Platform

All INSPIRES members will be added to the newly created OneDrive shared folder inside a dedicated “Shared Library. This is separate from the links that have previously been shared. All of the original documents have been consolidated into this new shared structure alongside the new organizational elements for each theme. Using this new, shared library will help keep the clutter down in our personal OneDrives as our IT departments roll them out and we use them more. This does not prevent you from using other platforms and systems to meet the needs of your work. This merely defines a stable platform which is well defined and accessible to all.

Naming Standards: Directories and Files

- Spaces in file or folder names often cause problems later. All file and directory names should contain only letters, numbers, dashes (-), and underscores (_).
- It is strongly recommended to avoid the use of dots (.), spaces, and other non-alphanumeric characters because they will cause problems for some software, steps, and people.
- There are two widely used conventions to write multi-word names. Those are:
    - camelCaseName
    - underscores_as_spaces_name
- You choose -- either way works. It is a good idea to always use one or the other inside a theme or project directory.
- All of the examples provided in this document follow these rules to provide a useful set of examples.

Organization

The number of files and folders at the top level, or root, of the file system will be limited. This will help to keep everyone’s shared workspace easy to navigate and well organized. Remember, there are many situations where members of one theme will do work inside or refer to work in other theme’s folders. All files and directories should be

created inside one of the existing top level directories. If you believe a new, top-level directory is needed this should be discussed in a special meeting of the data sharing subcommittee before creation.

OneDrive Directory Hierarchy

theme1/ ← Top level (Theme 2, 3, 4 - same for all)

incoming/ ← Unverified, freshly recorded, needs review

processing/ ← Data which is shared for review and cleaning

release/ ← Data packages; ready for general release

theme2/ ...

theme3/ ...

theme4/ ...

theme5/ ... ← Administrative workspace

cross-theme-research ← Use this for work that does not fit neatly inside a specific theme

Note: Any or all of incoming, processing, and release directories may be deleted if your theme does not require them.

Ad Hoc Directory Creation

To keep documents and data sets in order inside the theme or cross-theme top level directories over the coming years, it is recommended that you create a directory to hold different types of files instead of placing individual documents and files inside one of the existing top level directories. You are free to identify what file types you will lump in a single directory and which will be split into separate directories. Bottom line: you can make a directory for any purpose you see fit if you believe it will help you organize your work. Just keep these suggestions in mind.

Temporally Related Documents and Data

When you have a bundle of data or files that were finalized, captured, or created at a certain point in time you will be well served by creating a directory name with the date at the start of the name. This will have the effect of making it easy to sort your files by date. Here is an example of a sub-directory to store temporally related documents and/or data file(s):

<YYYYMMDD>-<data_name>-<contributor_name>/

Tip*:* Each theme should standardize what <data_name> they use and if the contributor name is needed.

Data names are used every time that type of data is stored. Over time, you will build a vocabulary of names that are easy to pick from and find files inside. Here is a more concrete example:

Theme1/incoming/20201217-example_sensor_log-leo_edmiston-cyr/

Topically Related Documents and Data

When the files you want to share are related by a topic, technique, researcher, etc and are from different points in time you probably want to drop the date prefix <YYYYMMDD>. Examples of situations where you want to drop the date prefix: a single date does not help place nor summarize the files or files will be added to the directory over time. In such a case, create a sub-directory that looks like:

<data_name>-<contributor_name>/

Example: theme_1/incoming/orono_location_xyz--leo_edmiston-cyr/data_name contributor

Multiple <data_name>s

If needed, use more than one <data_name> in a file or directory name.

Example 1: <data_name1>-<data_name2>-...-<data_nameN>-<contributor>/

Example 2: example_sensor_log-soil_and_sun-latitude_longitude-leo_edmiston-cyr/

If you need high temporal resolution buckets, here's an idea:

Example 3: yyyymmdd[hhmmss][mmmuuu]-<data_name>-...-<data_name>-<contributor>/

Vocabularies for <data_name>s

The big deal here is consistency. Here's the logic to apply when storing a file or set of files: Do you already have a data_name in your vocabulary for this kind of document or data?

- **Yes**: Use the same the exact name every time it applies
  - The easy way to know if you already have a name for a type of file is to look inside your directories and see!
- **No**: Check with collaborators before creating a new <data_name> vocabulary word
  - Aside from the limited characters that should be used, just be descriptive.

Tip: This stuff is easy to overthink. Try not to go there. Just bounce it off some colleagues before making new words and know that a little care goes a long way.

Metadata

While good filenames and formats that encode some metadata automatically are helpful, they do not tell the whole story. To clearly communicate the contents of directories and files to all stakeholders into the future, metadata must be added alongside the files.

Folder Contents

A README files should be created inside every directory to identify its contents. It should be updated over time to reflect changes, updates, file format usage, etc. Ideally, it would be in a simple, universal text format like .txt or .md.

Data Collection Metadata

There is an "EDI INSPIRES Metadata Template" spreadsheet template in every theme's top level directory. This is a well established pattern and tool for collecting metadata which is provided by Mary Martin from UNH. It will work for ANY data you are recording. If you decide to publish your data to the EDI repository when it is ready for publication, that completed spreadsheet will make your life easy.

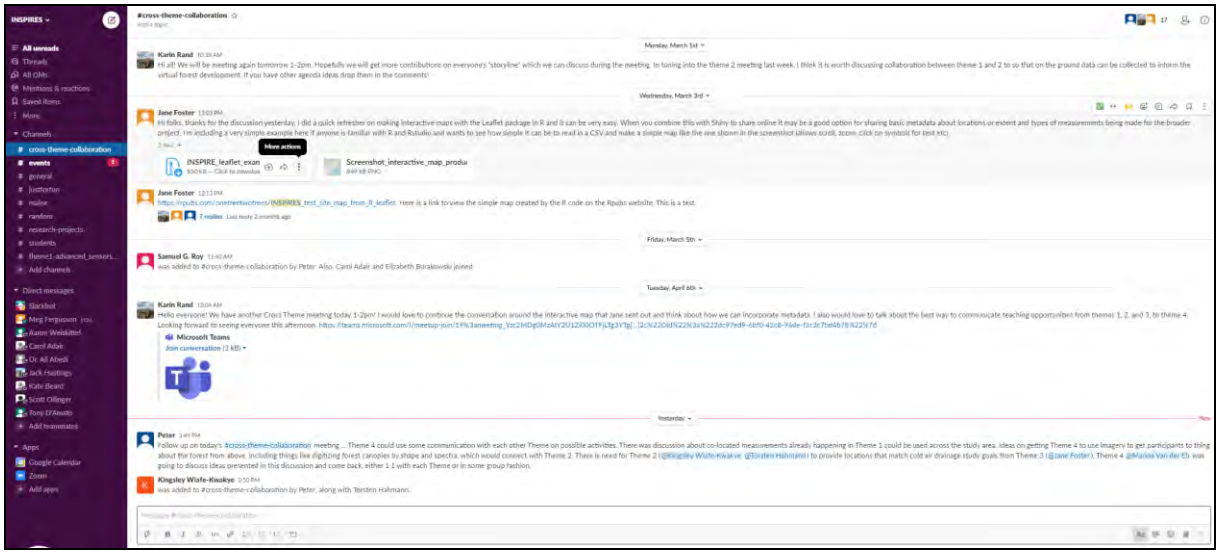
Appendix 5. INSPIRES Team Roster

Name	Theme	Jurisdiction-Affiliation	Role
Aaron Weiskittel	3	UMaine, Center for Research on Sustainable Forests	Faculty
Aimee Classen	1	UVM, Gund Institute for Environment/Rubenstein School of Environment and Natural Resources	Faculty
Ali Abedi	1	UMaine, Department of Electrical and Computer Engineering	Faculty
Alix Contosta	1	UNH, Earth Systems Research Center	Faculty
Andrew Ouimette	2	UNH, Earth Systems Research Center	Faculty
Anthony D'Amato	3	UVM, Rubenstein School of Environment and Natural Resources	Faculty
Anupam Raj	4	UMaine, Center for Research in STEM Education	Grad Student
Bruce Segee	1	UMaine, Advanced Computing Group	Faculty
Carol Adair	1	UVM, Rubenstein School of Environment and Natural Resources	Faculty
Daniel Hayes	3	UMaine, School of Forest Resources	Faculty
Darren Ranco	2	UMaine, Department of Anthropology	Faculty
Dave Lutz	1	Dartmouth College (NH), Environmental Studies	Faculty
Donna Rizzo	2	Department of Civil & Environmental Engineering	Faculty
Elizabeth Burakowski	3	UNH, Institute for the Study of Earth Oceans and Space	Faculty
Erin Nason	4	UMaine, Center for Research in STEM Education	Grad Student
Erin Simons-Legaard	3	UMaine, School of Forest Resources	Faculty
Franziska Peterson	4	UMaine, Center for Research in STEM Education	Faculty
Gavin Briske	1	UVM, Rubenstein School of Environment and Natural Resources	Grad Student
Hazel Cashman	4	UMaine, Center for Research in STEM Education	Grad Student
Heather McInnis		TIG	Evaluator
Jack Prior	2	UMaine, Center for Research on Sustainable Forests	Undergrad
Jane Foster	1,3	UVM, Rubenstein School of Environment and Natural Resources	Faculty
Jane Pettit	2	UMaine, Center for Research on Sustainable Forests	Professional Staff
Jing Yuan	2	UMaine, School of Computing and Information Science	Post-doc
John Gunn	3	UNH, Department of Natural Resources and the Environment	Faculty
John Hastings	2	UNH, Earth Systems Research Center	Grad Student
Karin Rand	1,2,3	UVM, Rubenstein School of Environment and Natural Resources	Professional Staff
Kasey Legaard	2	UMaine, Center for Research on Sustainable Forests	Faculty
Kate Beard-Tisdale	2	UMaine, School of Computing and Information Science	Faculty
Kathy Crowley	3	Unity College (ME)	Faculty
Keegan Feero	3	UNH, Earth Systems Research Center	Grad Student
Kenneth Bundy	1	UMaine at Augusta, College of Professional Studies	Faculty
Kevaughan Smith	2	UMaine, School of Forest Resources	Grad Student
Kingsley Wiafe-Kwakye	2	UMaine, Department of Spatial Information Sciences and Engineering	Grad Student
Larry Whitsel	2	UMaine, Advanced Computing Group	Faculty
Laura Millay	4	UMaine, Center for Research in STEM Education	Professional Staff

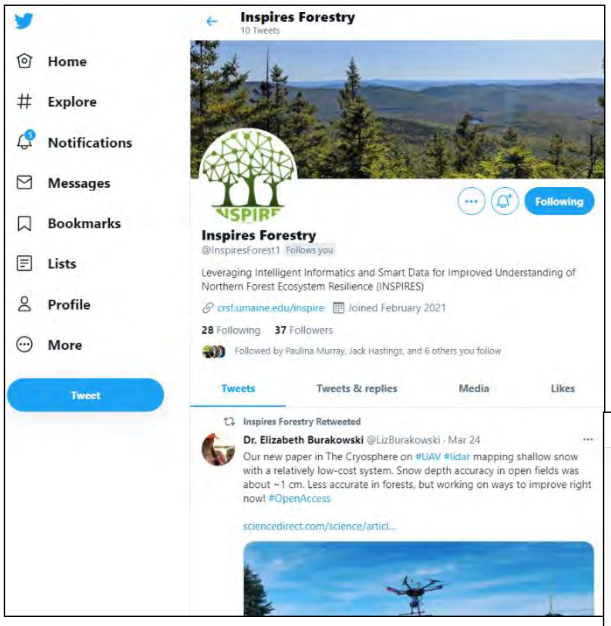
Laura Nickerson	4	UNH, Leitzel Center for Mathematics, Science, and Engineering Education	Faculty
Leo Edmiston-Cyr	2	UMaine, Center for Research on Sustainable Forests	Professional Staff
Leslee Canty-Noles	ALL	UMaine, Center for Research on Sustainable Forests	Support Staff
Lindsay Barbieri	1	UVM, Rubenstein School of Environment and Natural Resources	Grad Student
Lisa Scott	3	UNH, Department of Natural Resources and the Environment	Grad Student
Marek Petrik	2	UNH, Department of Computer Science	Faculty
Marina Van der Eb	4	UMaine, Center for Research in STEM Education	Faculty
Mark Ducey	3	UNH, Department of Natural Resources and the Environment	Faculty
Mary Martin	2	UNH, Earth Systems Research Center	Faculty
Meg Fergusson	ALL	UMaine, Center for Research on Sustainable Forests	Professional Staff
Melissa Pastore	1	UVM, Rubenstein School of Environment and Natural Resources	Post-doc
Michell Gregoire		UNH, EPSCoR	Support
Nicholas Soucy	2	UNH, Department of Computer Science	Grad Student
Olivia Vought	1	UVM, Rubenstein School of Environment and Natural Resources	Undergrad
Paulina Murray	1, 2	UVM, Rubenstein School of Environment and Natural Resources	Grad Student
Peter Nelson	2	Schoodic Institute at Acadia National Park (ME)	Faculty
Regina Toolin	4	UVM, College of Education and Social Services	Faculty
Salimeh Yasaei Sekeh	2	UMaine, School of Computing and Information Science	Faculty
Sam Roy	2	UMaine, Mitchell Center for Sustainability Sciences	Faculty
Sara Lindsay	4	UMaine, School of Marine Sciences	Faculty
Sarah Nelson	1	Appalachian Mountain Club (ME)	Faculty
Scott Ollinger	3	UNH, Earth Systems Research Center	Faculty
Silvia Nittel	2	UMaine, School of Computing and Information Science	Faculty
Sonia Naderi	1	UMaine, Department of Electrical and Computer Engineering	Grad Student
Susan McKay	4	UMaine, Center for Research in STEM Education	Faculty
Thayer Whitney	1	UMaine, Dept. of Electrical & Computer Engineering	Undergrad
Torsten Hahmann	2	UMaine, School of Computing and Information Science	Faculty
Valeria Briones	3	UMaine, School of Forest Resources	Grad Student
Victoria Nicholas	1	UMaine, Dept. of Electrical & Computer Engineering	Undergrad
Zaixing Zhou	3	UNH, Earth Systems Research Center	Faculty

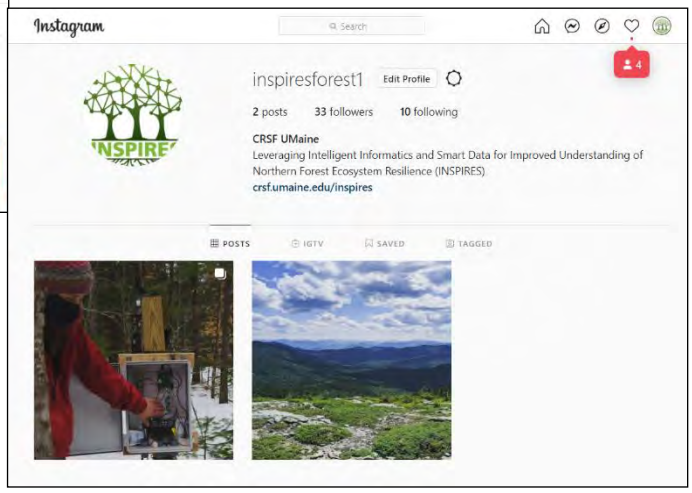
Appendix 6. INSPIRES Communications and Resources

The INSPIRES team uses a number of communications outlets to share project news and information.

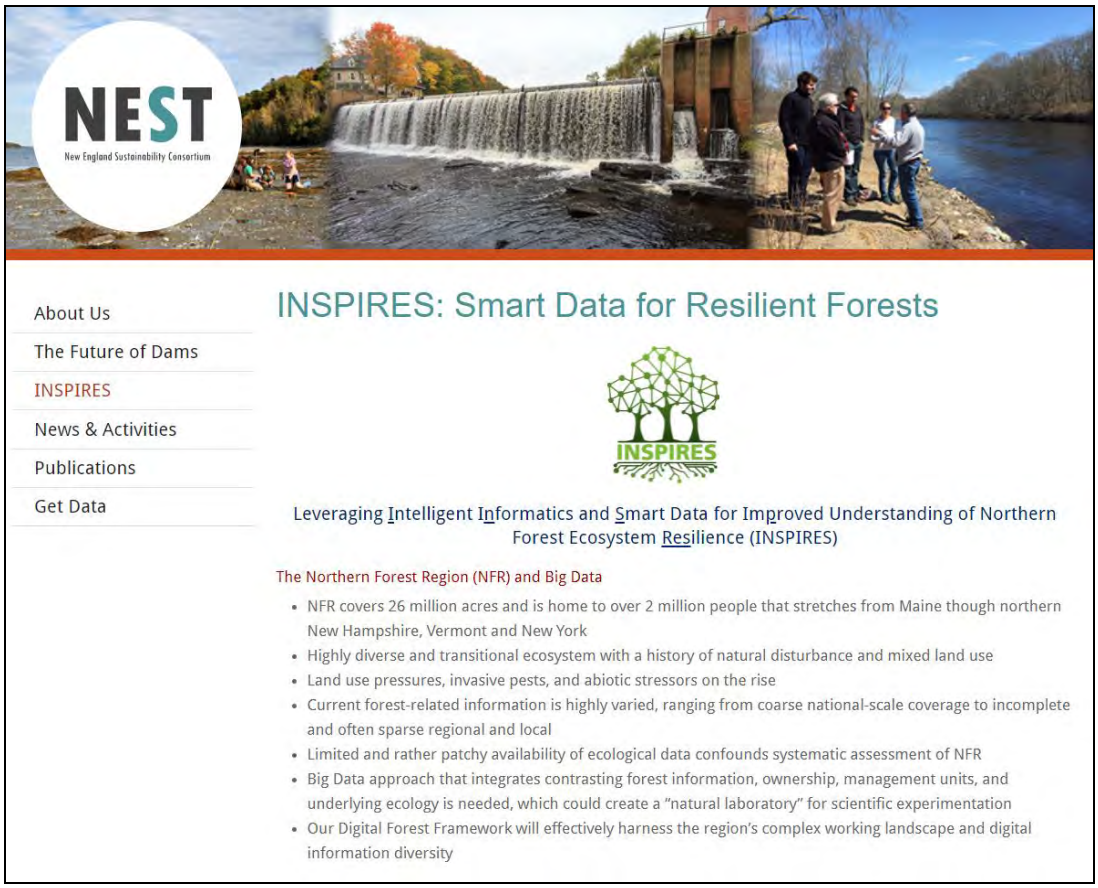


INSPIRES Slack Channel

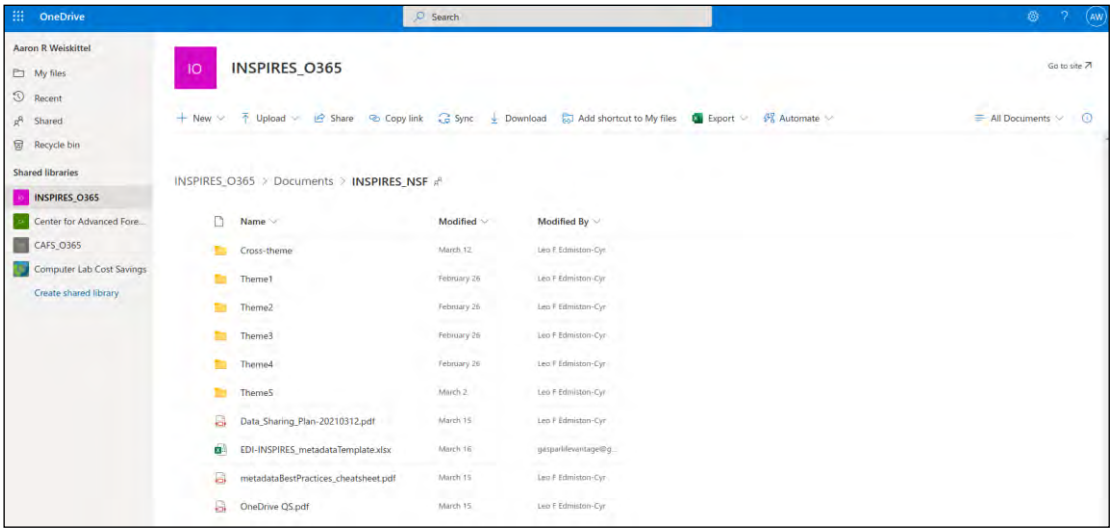




INSPIRES Twitter and Intagram accounts



INSPIRES Website: https://www.newenglandsustainabilityconsortium.org/inspires-smart-data-resilient-forests



Sharepoint folder in OneDrive accessible and shareable by all INSPIRES team members.

Appendix 7. Regeneration of Northern Hardwoods in the Northern Forest Roundtable

Regeneration of Northern Hardwoods in the Northern Forest:

A Hubbard Brook Roundtable

Draft Final Report
April 8, 2021

Prepared by Sarah Garlick[1], Alex Ding[2], Zoe Economos[2], Natalie Cleavitt[3], Raeana Kiss[2], and Isabella Kong[2]

[1]*Hubbard Brook Research Foundation*
[2]*Undergraduate Engagement Fellows, Cornell University*
[33]*Department of Natural Resources and the Environment, Cornell University*

Executive Summary

On March 25, 2021, the Hubbard Brook Research Foundation convened a three-hour online dialogue event with a group of 27 foresters, natural resource managers, scientists, and students to discuss the regeneration of northern hardwoods in the Northern Forest region. Prior to the meeting, 21 participants engaged in one-on-one, semi-structured interviews with a group of student leaders, the results of which were compiled and shared in a synthesis report. Following the roundtable, 12 participants joined an optional one-hour follow-up meeting to discuss next steps.

The following themes emerged during this roundtable process: (a) persistent and widespread challenges of managing beech competition; (b) concerns about deer herbivory and the social and political challenges of managing deer populations; (c) uncertainty about future forests under climate change and which tree species to encourage; (d) the importance of matching treatments to site-specific conditions, particularly soils; (e) interest in developing a common protocol for measuring and sharing data about regeneration; and (f) the importance of external factors in determining what happens on the landscape, particularly market forces in the forest products industry, and public perceptions of forests and active management. As these themes were discussed, the group converged on two main ideas: (1) a need to address the loss of what practitioners described as their "social license" to practice forestry as public perceptions and uses of forests in the region have shifted, and (2) the importance of opportunities for practitioners to interact with each other to share their knowledge, concerns, and approaches. Several participants expressed feelings of not wanting to "be alone" in figuring out how to manage for future forests in the face of increased public scrutiny, changing market pressures, and a multitude of ecological stressors including climate change, invasive species and diseases, and deer browse.

About the Roundtable Process

The goals of this Hubbard Brook Roundtable were: (1) to synthesize and share knowledge and perspectives across disciplines and institutions to inform forest-related research and practice; and (2) to foster new connections and collaborations among forest researchers and practitioners in the region. The roundtable focused on concerns from both the researcher and practitioner communities about the regeneration of northern hardwood forests and the complex and interacting stressors that affect forest regeneration, including climate change, recovery from acid rain, invasive pests and diseases, past management, and herbivory.

The roundtable agenda opened with three short presentations: Scott Bailey, a scientist from the USDA Forest Service, shared emerging research about soil classifications; Nat Cleavitt, a scientist from Cornell University, shared research findings related to American beech and beech bark disease; and Kevin Evans, Director of Woodland Operations at Dartmouth College, shared practical insights from decades of managing for northern hardwoods in northern New Hampshire. Following these presentations, the group engaged in two rounds of small-group dialogue: the first on the

future of the region and forestry practices related to regeneration, and the second focused on four individual topics: measuring regeneration, managing for beech, soils, and deer.

A week following the main dialogue event, a group of participants gathered via Zoom to talk about next steps. This one hour-long meeting opened with individuals sharing the topics they had been thinking about since the roundtable, followed by an open discussion of next steps. Please find summary notes from the small-group dialogues and the follow-up discussion in the appendices.

Next Steps

The group discussed a variety of possible actions to be taken on these issues, including:

- Developing and piloting a common protocol for measuring regeneration.
- Convening a working group of scientists and practitioners to create a management-relevant scientific synthesis about beech.
- Scientists and practitioners co-designing and piloting a tool that would make aerial LiDAR-based soil data and updated soil classification systems more accessible and useful.
- Convening a group of collaborating organizations to develop a public engagement strategy about the ecology of forest ecosystems and the important role of silviculture and active management.
- Developing an engagement strategy for landowners, publics, and decision makers about the impact of deer browse.
- Reconvening and growing this group for additional/ongoing knowledge exchange.
- Creating a collection of short essays or synthesis articles based on the topics raised in this roundtable.

Student Leader Reflections

Through support from the Office of Engagement Initiatives at Cornell University, four undergraduate students helped lead this Hubbard Brook Roundtable. Each student shared some of their reflections on this work in the statements below.

> *"This interview process allowed me a holistic perspective of the issues centered on and surrounding regeneration in the Northern forest, and I was surprised at how many interconnections I witnessed across different disciplines and backgrounds. Knowledge gaps (and equally important, communication gaps) have been unearthed during this process, which I think is vital in the process of creating actionable plans for regeneration beyond this roundtable. I hope that the Northern Forest gets the attention it demands and deserves, not just from the people here today but from the public. More specifically, I hope that people who may not notice their connection to the forest in their daily lives begin to feel drawn to it and compelled to pay attention."*

> *"This Roundtable has sparked discussion and contemplation about very important issues related to forest regeneration, and it is amazing to see that it all starts with some people who really care about the future of our forests. I also see that environmental change does not automatically manifest. Programs to catalyze such change like this Roundtable are thoughtfully organized and facilitated, and it has been a great experience to see positive environmental change happening in action."*

> *"My main takeaway from the interview process was the importance of communication between people who have a common goal, even if their roles in achieving that goal are different. Working together to attack major problems as a unified force is going to be much more effective than each individual trying to solve these problems on their own. Though regenerating the northern forest in the face of economic and climate changes is a daunting task, I believe that the knowledge shared in the roundtable can help its participants to explore new perspectives on the issue. I hope the participants have gained more appreciation for each other's work and felt a sense of unity through their common passion for the northern forest."*

Acknowledgments

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Note

Final reports from the Regeneration Roundtable are forthcoming. Please visit the **Hubbard Brook website** for updated information on the report and appendices.