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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 3 Annual Progress Report

August 1, 2021-July 31, 2022

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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, University of Vermont, and most recently, Alabama A&M University to construct a digital framework to better assess, understand, and forecast this complex forest at a resolution relevant to scientists, land managers, and policymakers.

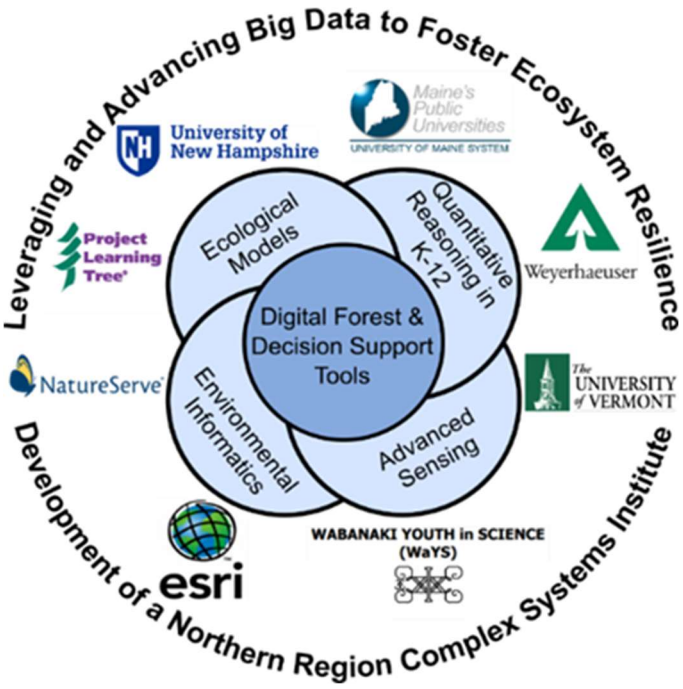


Figure 1. INSPIRES Digital Forest Research and Workforce Development Framework

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).

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.

Year 3 Goals

Undeterred by roadblocks from COVID-19, INSPIRES team members have been successful in developing strategies to enhance effective team building and support interjurisdictional research collaboration (details of Years 1 and 2 are available at https://bit.ly/InspiresForestResearch). The primary goals for Year 3 were to continue visiting field research sites, strategically deploying wireless sensors for climate data acquisition across the four jurisdictions, targeting remote sensing acquisitions, completing ecological model parameterization and calibration for predicting regional forest dynamics, and refining mentoring and student participation. Project leaders continue to directly engage stakeholders and project partners to gain input and feedback on research objectives, to identify opportunities for leveraging existing long-term data collections, and to develop collaborative relationships around the four INSPIRES research themes. In addition, an important focus of Year 3 was strategically evaluating project sustainability efforts and assessing key project wrap-up needs, particularly potential synthesis outcomes. This was mostly centered around focused efforts on synthesis publications, future proposals, and stakeholder engagement.

> *"Despite all the challenges created by the ongoing global pandemic, the INSPIRES team has remained dedicated to the effort and has continued to find very creative ways to continue collaboration. It is especially exciting to welcome Dr. Dawn Lemke and her team at Alabama A&M University to INSPIRES as I see numerous unique synergies between both individuals and organizations."*
>
> ***~Dr. Aaron Weiskittel, INSPIRES PI***

Institutional Roles

The participating institutions are the University of Maine (UM; lead), the University of New Hampshire (UNH; Co-PI), the University of Vermont (UVM; Co-PI), and Alabama A&M University (AAMU), which became part of the team in Year 3 through NSF Minority Serving Institution (MSI) supplemental funding. The PIs at these four institutions make up the Core Leadership Team (CLT; Table 1), a collaborative effort to continually re-assess project goals or objectives, strengthen cross-institutional cooperation, and support team members. In addition, upper administrative officials at these institutions compose the Tri-Jurisdictional Institutional Advisory Board (IAB). The INSPIRES team also includes several scientists and researchers from three additional academic institutions (Dartmouth College, Unity College, University of Maine at Fort Kent) and two non-profit organizations (Schoodic Institute at Acadia National Park, Appalachian Mountain Club).

Project Summary, Year 3

The INSPIRES project started August 1, 2019 and began as an interjurisdictional partnership between research and higher educational institutions in Maine, New Hampshire, and Vermont. In 2021, with $599,999 in new supplemental funding from NSF, the INSPIRES team began a strategic partnership with the Alabama Agricultural & Mechanical University (AAMU), an Historically Black College and University (HBCU). This partnership will add a diversified perspective as well as specific scientific expertise and talent to the multi-institution, multi-state endeavor.

AAMU has strong expertise and experience in the areas specifically related to INSPIRES, particularly forest ecology, ecological modelling, geoinformatics, and biometrics. It is also home to long-term ecological research sites that will provide invaluable data and insight on species spatial distribution in this hyper-diverse temperate forest; the recruitment, survival, and mortality of trees over time; the impacts of climate change and non-native invasive pathogens; and implications for sustainable forest management and conservation for the next century. This new collaboration is designed to mutually benefit both AAMU and the original INSPIRES partners through research collaboration opportunities, student exchange experiences, and hands-on learning opportunities across two transitional forest ecosystems (Figure 2). In particular, collaboration will focus on AAMU's long-term ForestGeo plot at Paint Rock Valley and work on building a strong, integrated forest research program there, especially through hiring current UM INSPIRES post-doc (Cen Chen).

In particular, the addition of AAMU has already resulted in new collaborations and tangible outcomes, including a joint UNH-AAMU proposal focusing on the ecological impacts of drought that was recently submitted to NSF's Organismal Response to Climate Change program and plans for several AAMU students to join the INSPIRES team in conducting field work in NH in the 2022 field season.

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
Dawn Lemke	Co-PI	Biological & Environmental Sciences	Alabama A&M University	AL

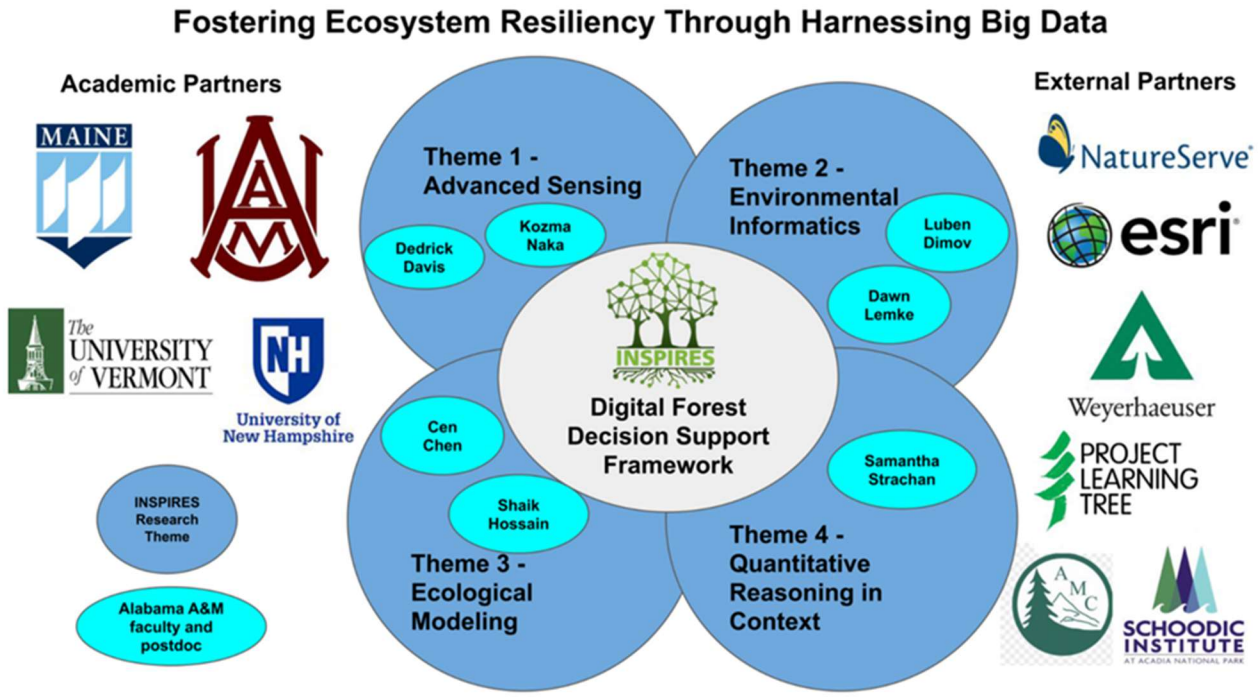


Figure 2. Integration of the AAMU team into the INSPIRES effort through the NSF MSI supplemental funding.

The INSPIRES team currently involves 82 individuals with the majority being faculty from the four states (45; ME = 19, NH = 12, VT = 8, AL = 4), bolstered by undergraduate/graduate students (21), post-doctorate researchers (2), and professional staff (14). Despite the continued challenges imposed by the ongoing pandemic, the team has remained diverse (58% female), has built strong linkages across jurisdictions, and many of the faculty remain early career (55%). 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 (and now Southern Forest) with a focus on key ecological and socioeconomic drivers.

Despite the ongoing pandemic, Year 3 INSPIRES team members were successful in developing strategies to enhance team building, implementing suggestions from the external project panel review in Year 2, 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 (which continued to be virtual in Year 3, the third year of the Covid-19 pandemic), is essential for enriched teamwork and relationship-building. In January 2022 a planned in-person team retreat was pivoted to yet another Covid-imposed virtual retreat, where the CLT was joined by external facilitator Sarah Garlick of the Hubbard Brook Research Foundation. Ms. Garlick worked with INSPIRES project leadership and management teams to facilitate a discussion about team progress and overall team successes and goals in relation to the project. The goal of the all-team meeting was to help team members to develop shared goals and plans to achieve them for the remainder of the project. Discussions addressed specific challenges and pathways to the success of the project and promoted the communication of common goals and successful project outcomes.

The CLT continues to meet at regular intervals to re-assess priorities, discuss concerns, brainstorm contingencies for ongoing pandemic-related 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 continue to regularly interact to gain understanding of team member research interests, complete strategic materials, including collaborative research agendas, and outline key research milestones, which are essential to monitor project progress. Student-led meetings of INSPIRES graduate students continued in Year 3 and helped strengthen cohort connections, provided opportunities for mentoring with early-career scientists on the project, and built community and collaboration across disciplines and institutions. The Collaborative Research Committee (CRC) was 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. Likewise, the Mentoring, Engagement, and Education (MEE) committee developed materials to help facilitate effective mentorship for both the mentor and mentee. Both the CRC and MEE met regularly during Year 3 to review materials, discuss potential opportunities, and plan for the final year of the project. The Data Sharing Subcommittee also met regularly to review its materials and made the necessary revisions or updates, particularly with regard to developing easy to use templates for uploading data and metadata to the Environmental Data Initiative.

Travel and health safety concerns surrounding the pandemic continued to limit travel, although a majority of researchers were able to access field sites. The travel and access limitations forced the CLT to revise its plan for an external evaluation in-person research site visit in June. The Implementation Group (T.I.G.; external evaluator on the project) surveyed INSPIRES faculty and students as part of the evaluation process, and the survey results were formally summarized and evaluated (see Evaluation section of this report). In Year 3, the CLT also implemented some important changes based on prior recommendations from the multi-day remote external evaluation conducted in January 2021 and the Tri-Jurisdictional Internal Advisory Board in August 2021:

- Successful in pursuing and securing additional resources in support of the efforts initiated by INSPIRES: Awarded NSF supplemental funding ($599,999) to support a strategic partnership with AAMU to focus understanding of the transitional forest response to unique stressors when species are primarily at the southern extent of their biological ranges
- Project collaborative coordinator (Dr. Emily Uhrig) hired and is helping to build collaboration across research themes, particularly the integration of AAMU researchers and students
- PI Weiskittel attended the NSF EPSCoR PI virtual meeting May 17-19, 2022 to learn about potential future opportunities for INSPIRES and current best practices
- The core leadership team continued to strongly support integration across all jurisdictions and institutions
- The recruitment of post-docs, graduate students, and undergraduate students continued, despite some continued setbacks imposed by COVID-19
- Ongoing progress in advancing and implementing INSPIRES research and program development, particularly given the challenges posed by Covid-19
- Data Management Plan reviewed and revised
- Lead site continues prioritizing reducing administrative burdens for INSPIRES faculty

Photo 1. INSPIRES cross-institution field tour, Bartlett, NH, May 2022.

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 met again early in Year 3 of the project with a primary focus on helping to champion Federal support for a regional environmental monitoring network focused on snow cover and depth similar to the SnoTel network in western US. Project outputs grew in Year 3 and team personnel continue synergistic efforts to leverage the collaborations created through INSPIRES.

Overall, the INSPIRES team continues to make substantial forward progress and remains mostly on track as it heads into the final year 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

- Research activities in Year 3 focused on the refinement and deployment of environmental sensors at strategic locations throughout the region (Theme 1), providing regional estimates of key forest canopy traits (e.g. foliar nitrogen, photosynthetic capacity) at high resolution (30-m) using field collected data and remote sensing platforms (Theme 2), initiating the construction of a general digital framework for a multi-model comparison to understand model strengths and weaknesses (Theme 3), and continuation of engagement as well as recruitment of high school science teachers to better integrate project elements into hands-on curricular activities (Theme 4).

- The INSPIRES team began a strategic partnership with the Alabama Agricultural & Mechanical University (AAMU), an Historically Black College and University (HBCU). AAMU's long-term research field site at Paint Rock will be a key focal area of collaboration and leverage numerous ongoing INSPIRES efforts and has already led to a new collaborative proposal submitted to NSF.
- The INSPIRES team currently involves 82 individuals with the majority being faculty from the four states (45; ME = 19, NH = 12, VT = 8, AL = 4), bolstered by undergraduate/graduate students (21), post-doctorate researchers (2), and professional staff (14).
- Project semi-annual virtual retreat featured a team science facilitator who conducted team-building exercises to address specific challenges and pathways to the success of the project and promote the communication of common goals and successful project outcomes, particularly joint publications (Table 2) and proposals (Table 3).
- A 3-day INSPIRES in-person team retreat in May 2022 featured a field tour (Photo 1), informal group meetings, and all-team discussion to envision the future beyond the project end.
- Virtual quarterly all-team meetings foster team-building and highlight ongoing collaborations as well as project progress and provide opportunities for student flash talks. Regular graduate student meetings with non-academic professionals to discuss future opportunities and ongoing research.
- Data sharing document further refined 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 live and in use.
- Expanded partner and stakeholder engagement through webinars and field tours and workshops at INSPIRES research sites.
- 3-hour spatial machine learning workshop provided to INSPIRES by project partner ESRI in February 2022
- Continued recruitment and hiring of key project participants including several new graduate students across the four jurisdictions.
- 55% of the project's participating faculty are early career.
- 12 (8 published; 3 in press; 1 under review) peer-reviewed articles, 1 conference proceedings, 3 data/model/technology products, and 10 presentations (3 by early-career faculty, 2 by trainees).
- In Year 3 (through May 2022), 8 research proposals requesting $23,733,100 were submitted with 2 awarded ($818,197) and $22,714,987 pending.
- Ongoing updates to project jargon and acronym dictionary.
- Annual survey of project participants completed and analyzed.
- Twitter, Instagram, and YouTube accounts share and highlight team news and project developments.
- Ongoing development of INSPIRES team member profiles highlighting individual and project involvement along with the development and dissemination of a project e-newsletter.
- Theme 4 leaders convened teachers from Maine and Vermont at Acadia's Schoodic Institute with researchers Alix Contosta, Liz Burkowski and Peter Nelson.

Table 2. Identified ongoing and potential collaborative research publication proposals from the facilitated January 2022 all-team meeting.

Concepts for Publications				
Paper subject	**Expertise needed**	**Potential lead authors**	**Target journals**	**Next steps**
Determination and delineation of novel regional climate zones	Ecology, modeling	Sam Roy	Global Change Biology	Finalize and submit
Forest resilience to thirty years of cyclic mortality: Revisiting Sprugel's fir-waves with Landsat data	Spatial analysis, remote sensing, forest dynamics, open science	Jane Foster	Global Change Biology	Revise draft manuscript
Historical & projected changes in phenology (Maine)	Remote sensing, ecology, ecosystem ecology	Valeria Briones et al	ERL	Prepare for submission
Image processing for tree species using hyperspectral UAV data	Remote sensing, ecology, ecosystem ecology	Peter Nelson and Ken Bundy	Remote Sensing	Revise draft manuscript
New HSI Semantic Segmentation Model (CE U-NET)	Machine learning, deep learning, remote sensing	Salimeh Yasaei Sekeh and Nicholas Soucy	IEEE Remote Sensing	Submission
Drivers of forest productivity	Ecologists, modeling, data scientists	Andrew Ouimette et al.	Forest Ecology and Management	Outline draft
Adversarial Robustness of semantic segmentation models for hyperspectral data (e.g. seasonality, phenology)	Machine learning, deep learning, remote sensing	Salimeh Yasaei Sekeh and Nicholas Soucy	Potentially ICML or ICLR	Submission
Spatial-temporal Patterns of Cold-Air Pooling in the Northeastern US From MODIS	Remote sensing, ecology, ecosystem ecology	Jane Foster, Melissa Pastore, Tony D'Amato, Aimee Classen, Carol Adair, Dave King, et al.	Remote Sensing of Environment	Revise draft manuscript
Semantics of Forest Knowledge	Ecology, modeling	Torsten Hahmann, Kingsley Wiafe-Kwakye, Kate Beard	Current Forestry Research; Forest Ecology and Management	Revise draft manuscript
Review: Sensitivity of forest models to minimum Temperatures	Forest and ecological modeling	Jane Foster, Andrew Ouimette, Erin Simons-Legaard	Ecological Modeling	Revise draft manuscript
SBW & Decision-Making	Forest modeling	John Gunn	Ecosphere	Revise draft manuscript
Nutrient dynamics in forest dead wood	Ecologists modeling	Andrew Ouimette, Jane Foster, Mark Ducey, Scott Ollinger, Tony D'Amato, Jack Hastings	Ecological Applications	Revise draft manuscript

Table 3. Identified potential collaborative research proposals from the facilitated January 2022 all-team meeting.

Concepts for Proposals				
Topic/short title	**Expertise needed**	**Team members**	**Stakeholders**	**Next steps**
NSF AI	Open	All	Forest landowners	Submit preproposal
USDA SAS	Open	All	Forest landowners	Submit preproposal
NSF NRT	Open	All	Open	Outline concept
NSF Mid-Scale Infrastructure R1	Open	All	Open	Outline concept
NSF i-TEST	Open	All	Open	Outline concept
NSF Innovation for Undergraduate Teaching	Open	All	Open	Outline concept
Northeastern States Research Cooperative	Open	All	Open	Submit preproposal
NSF Partnerships for International Research	Open	Canadian partners?	Christian Messier of UQAL	Outline concept
NSF EAGER	Open	Melissa Pastore, Jane Foster	Open	Outline concept
NSF CAREER	Open	All	Open	Outline concept
NSF MRI	Purchase remote sensing hyperspectral & LiDAR	Peter Nelson, Dan Hayes	Ecosystem modeling, forest inventory, crop health	Submit full proposal
NSF GeoInformatics	Remote sensing	All	Open	Outline concept
NSF Growing Convergence	Open	All	Open	Outline concept
NSF Climate Change DCL	Open	All	Open	Outline concept
NSF START	Open	All	White Mountains Community College	Outline concept
NSF INTERN	Open	Current grad students can spend 6 months at a private company	Open	Outline concept
NASA Ecological Forecasting	Remote sensing and modeling	All	Open	Outline concept
NASA Biodiversity	Remote sensing and ecology	All	Open	Outline concept
NSF Mid-Career Advancement	Associate-level faculty	All	Open	https://beta.nsf.gov/funding/opportunities/mid-career-advancement-mca

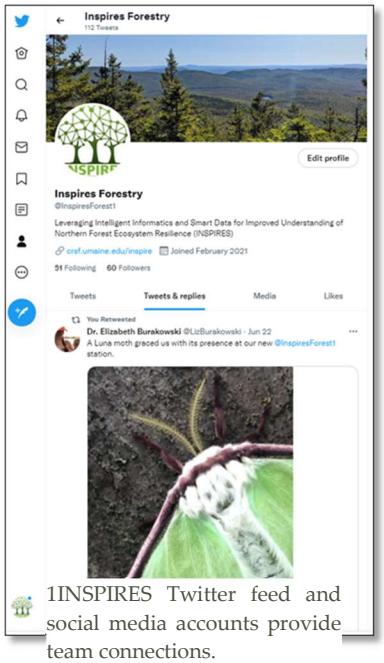
Intellectual Merit

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. With 2 months still to go in Year 3, this has included 8 submitted proposals (3 to NSF), 2 proposals funded (1 from NSF), 12 peer-reviewed publications, 1 conference proceedings, and 10 presentations. The funded proposals include awards from NSF, NASA, and Northeastern States Research Cooperative. In addition, early-career Senior Personnel submitted several grants to NSF, USDA, and Northeast Climate Adaptation Science Center including a $20M NSF AI research institute proposal led by INSPIRES Co-PI Abedi with Weiskittel and Yasaei Sekeh as Co-PIs. INSPIRES outcomes achieved in Year 3 (thus far) include 8 peer-reviewed publications with an additional 1 accepted, 3 awaiting publication, and 1 under review.

Overall, the strong intellectual merit outcomes highlight the level and strength of current collaborations within INSPIRES. As we approach the final year of the project, emphasis will continue to be placed on inter-jurisdictional outcomes, particularly publications. Support and professional development of early-career faculty members will remain a high priority. As identified from the Year 3 all-team meeting in January 2022, key synthesis products that assess the current state of knowledge and outline strategies for future research will be prioritized in Year 4 of the project.

Broader Impacts

Effective stakeholder engagement remains a high priority for INSPIRES. In Year 3, virtual and in-person outreach events featured INSPIRES participants and highlighted ongoing research. In particular, Theme 4 continues to unite teachers and INSPIRES researchers to foster forest research and data acquisition partnerships. In July 2021, Theme 4 hosted numerous high school science teachers from around the region for a field visit to support integration of Quantitative Reasoning in Context (QRC) using forestry science and research at the Schoodic Institute in Maine (short videos highlighting the workshop available on YouTube). INSPIRES researchers furthered their association during the 2021 Maine Stem Partnership Annual Summit focused on strengthening research-guided STEM teaching and learning. A public website for educators is maintained to support collaboration between teachers and researchers to work together to develop lessons for the classroom focused on forestry and QRC (https://www.mainestempartnership.org/ index.php/track-ii-inspires).



1INSPIRES Twitter feed and social media accounts provide team connections.

Science and practice webinars related to forest climate change in Maine (https://crsf.umaine.edu/fcci-webinars/) continued for a second year and were enhanced by field tours that provide opportunities for scientists, conservationists, land managers and operations to learn and discuss climate change impacts on forest types found in Maine. The interactive webinars were very well attended (60-80 participants), highlighted some ongoing research efforts from INSPIRES, and were recorded for future viewing on the Science and Practice YouTube playlist, along with video

highlights from each field tour. Similarly, a workshop and field tour for 45 foresters and other stakeholders occurred at the Corinth, VT INSPIRES site in September 2021 to demonstrate adaptation strategies to address invasive insects and climate change impacts and the novel insights provided by advanced sensing technologies.

The project's external website and social media (Instagram and Twitter) accounts, in conjunction with the Team Slack channel and INSPIRES website, continue to showcase the project's research successes (Appendix 5. INSPIRES Communications and Resources).

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, team members on medical leave), demands on project participants, and high uncertainty for future planning. A recent survey of the INSPIRES team in January 2022 indicated that over 70% of the participants were either "Struggling" (14.7%) or "Surviving" (55.8%) due to the unique and ongoing challenges created by the global pandemic. Nearly half of the participants (44%) indicated that the primary challenge created by the pandemic were related to workload issues, while others suggested isolation, work-family balance, and availability of time to be additional challenges.

A variety 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, 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 adapted, rescheduled, and revised field and lab work in response to reduced restrictions on travel and expenses and were able to ramp-up field/lab work for summer 2021.

In January 2022, a planned in-person retreat and field tour for the entire team had to be cancelled and restructured to a virtual experience in response to surging variants of the coronavirus. Using a facilitator from the Hubbard Brook Research Institute, team members met cross-institutionally and cross-themes to discuss current research, short-term goals, collaborative projects, and goals after EPSCoR support ends. With restrictions being lifted in spring 2022, the CLT quickly rescheduled the in-person retreat for mid-May. This was the first in-person INSPIRES all-team event since the original kick-off meeting in December 2019.

Novel Opportunities

With the supplemental funding received for AAMU joining INSPIRES, several important and highly unique opportunities emerged in Year 3. AAMU faculty and students participated in numerous INSPIRES events and areas of potential collaboration were established across all project research themes. In particular, AAMU's long-term research field site at Paint Rock will be a key focal area of collaboration and leverage numerous ongoing INSPIRES efforts and has already led to a new collaborative proposal submitted to NSF. For example, Theme 1 will send two University of Maine INSPIRES graduate students to participate in a summer student workshop to showcase and deploy a wireless soil moisture sensor that has been developed over the course

of the project. AAMU faculty and students will build additional wireless soil moisture sensors that will also be deployed at the Paint Rock field site. Theme 2 will send a researcher and student in the summer to acquire unique high-resolution hyperspectral imagery for the Paint Rock field site, which will be aligned with foliar nitrogen samples simultaneously taken and used to create a map of canopy traits. Theme 3 has identified key input variables and developed a common framework for ecological modeling initialization with efforts to include Paint Rock as selected site for model evaluation and refinement. Finally, efforts are currently underway to recruit Alabama high school science teachers to participate in Theme 4 meetings and summer events. The current plan is to have high school teachers who are already part of the project mentor the incoming teachers to help facilitate collaboration and build teams across jurisdictions. These collaborative cross-institution and multi-jurisdictional efforts will be highlighted prominently at the planned NSF National EPSCoR meeting in November being organized and hosted by the Maine EPSCoR Office.

Changes in Strategy

Due to the ongoing challenges created by the pandemic and the difficulties of arranging in-person meetings, virtual meetings were kept to a minimum and teams encouraged to communicate directly via Slack or other means. A new Collaborative Project Coordinator at the University of Maine, Dr. Emily Uhrig, was hired in Year 3 and she has made several key efforts to help facilitate team member participation and satisfaction. In particular, this has largely meant personalized one-on-one meetings with various team members, which led to follow-up meetings or identifying potential collaborative opportunities for the team. Through these meetings and reviewing project materials, she has developed a team collaborative network diagram (Figure 3), which was presented to the full team and used to facilitate additional collaboration, particularly across research themes and jurisdictions. Dr. Uhrig has also coordinated monthly INSPIRES student meetings where relevant guest speakers are identified and invited to discuss their professional journey. Finally, Dr. Uhrig has attended and helped facilitate the regular research theme as well as the Collaborative Research Committee monthly meetings, which has been helpful for identifying potential synergies between research themes and project participants. Dr. Uhrig will be an important project asset as INSPIRES moves into its final year and the focus shifts to sustaining ongoing collaborations.

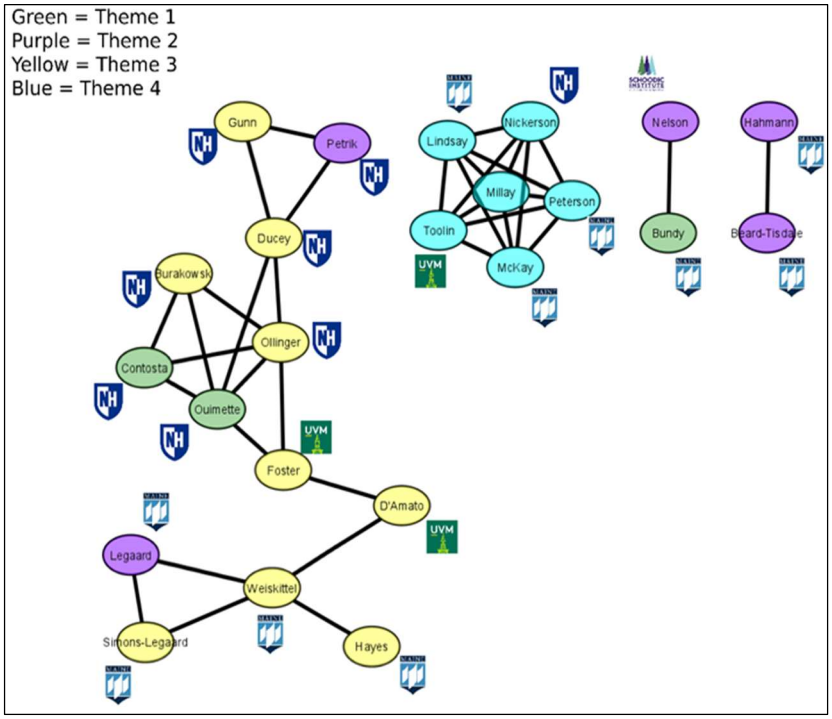


Figure 3. INSPIRES collaboration network based on project outcomes reported in the Data Outcome Portal (DOP) after Year 3. Additional cross-theme collaborations not captured by the DOP have also occurred, including work by L. Burakowski with Theme 4, which will result in her playing a greater role in Theme 4 going forward.

RESEARCH PROGRAM

Background

Photo 2. INSPIRES field tour attendees learn about soil sampling.

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 multi-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 4) 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 3, the CLT now meets quarterly 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 4. 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 machine learning for link quality improvement and efficient resource utilization in addition to data mining.
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

A key accomplishment in Year 3 was bringing in AAMU as a partner in the project under a supplemental grant, which has created new collaboration opportunities and research directions for the project. Primary Year 3 research activities of the INSPIRES project focused on the continued refinement and deployment of environmental sensors at strategic locations throughout the region (Theme 1), providing regional estimates of key forest canopy traits (e.g. foliar nitrogen, photosynthetic capacity) at high resolution (30-m) using field collected data and remote sensing platforms (Theme 2), initiating the construction of a general digital framework for a multi-model comparison to understand model strengths and weaknesses (Theme 3), and continuation of engagement as well as recruitment of high school science teachers to better integrate project elements into hands-on curricular activities (Theme 4). INSPIRES graduate student projects continue to progress with summer field seasons planned and new students being recruited. To enhance collaboration, researchers have actively participated in quarterly all-team discussions and team-building exercises with a project collaboration network diagram formulated and presented to the team.

Research themes continued 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 included detailed planning (incorporating pandemic-related restrictions) for field research activities and analytical techniques for summer 2022, such as wireless sensor deployment, remote sensing acquisitions, and model parameterization and calibration for predicting regional forest dynamics. Cross-theme coordination with the Theme 4 team led to a Quantitative Reasoning in Context (QCR) teacher training and workshop held at the Schoodic Institute in Maine with teachers from Vermont and Maine as well as researchers from all three jurisdictions. An additional Theme 4 teacher summer workshop is planned for July 2022 and would include additional new participants from Alabama.

The INSPIRES team continues to engage 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. Our key project stakeholders remain Federal partners like the US Forest Service, NGOs like the Appalachian Mountain Club, Schoodic Institute, or Second College Grant, and private forest landowners like The Nature Conservancy, Seven Islands Land Company, and Weyerhaeuser Company.

As detailed in the following pages, the project has continued to make considerable progress despite the ongoing challenges created by the global pandemic. With this current momentum and new partnership with collaborators in Alabama, the project is well positioned for its final year and will effectively deliver on the key outputs originally identified in the proposal.

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. Year 2 focused on deciding what ecosystem parameters would be measured at specific sites and how the system would be built. To best accomplish this, theme members split into two related subgroups: the UMaine group completed the design phase of the wireless soil moisture probe and began field comparisons with more standard research-grade sensors, while the Dartmouth/UNH/UVM team focused on building a sensor suite (measuring Photosynthetically Active Radiation (PAR), snow depth, atmospheric temperature and relative humidity, soil temperature and volumetric water content, soil matric potential) with existing low-cost sensors. The focus in Year 3 was to deploy the developed sensors across the region, which was done with great success as the team established 48 plots across 9 transects in New England.

Theme 1 continues to meet once a month to report progress and work through challenges, and have joined members of Theme 3 to work on cross-theme collaboration and data management planning. Extraordinarily strong synergies have been identified with new collaborators from Alabama in Theme 1, particularly Dr. Dedrick Davis and his students. Key research goals, questions, and motivating hypotheses from the proposal were refined and are outlined below from the initial proposal.

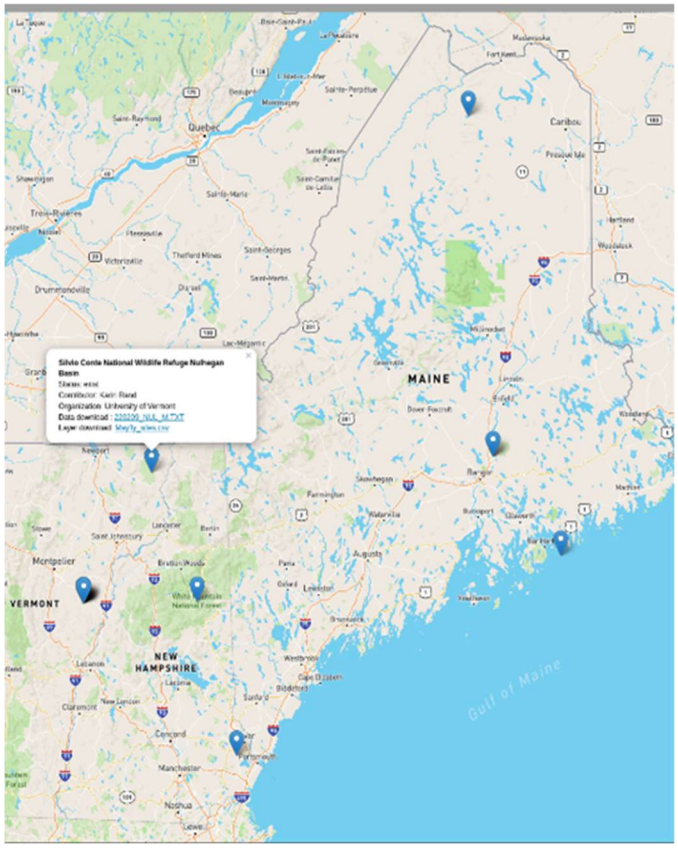


Figure 4. Location of 7 new environmental monitoring sensor sites established in Year 3 of INSPIRES across the three New England jurisdictions.

Highlights

- Data from the plots will help better understand variation in environmental conditions and its relationship to vegetation attributes.
- Established seven new environmental monitoring sensor sites using technology developed by Theme 1 researchers (Figure 4).
- The IWiN system-designed and developed under the leadership of Dr. Ali Abedi at UMaine
- Wireless Sensor Networks Laboratory (WiSe-Net Lab). System modules were implemented and refined in Year 3.
- Took key ecosystem measurements and samples, installed continuous in-situ temperature and soil moisture sensors; lab processing/analyses are ongoing.
- Provided research opportunities for undergraduate interns.

Photo 3. (*Left*) Theme 3/UNH faculty researcher Alix Contosta establishing a new sensor site with UMaine Cooperative Forestry Research Unit coordinator Regina Smith at Appalachian Mountain Club forest research site in Maine. (*Right*) Prototype wireless tree dendrometer sensor being developed by University of Maine INSPIRES team member Leo Edmiston-Cyr that will be tested at other sites in Year 4 of the project.

- Published a related concept paper in *Ecology* (in press).
- Extended stakeholder engagement with new collaboration for sensor site locations with UMaine's Cooperative Forestry Research Unit (Photo 3).

Team Members

8 Faculty (6 Early Career), 4 Research Staff, 1 Post-doc, 6 Graduate Students, and 3 Undergraduate Students; 10 VT, 7 ME, 5 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

Name	Affiliation	Jurisdiction	Institution	Early Career	Role
Apryl Perry	Earth Systems Research Center	NH	UNH	N	Research Staff
Bruce Segee	Advanced Computing Group	ME	UMO	N	Faculty
Carol Adair	Rubenstein School of Environment and Natural Resources	VT	UVM	Y	Faculty
Dave Lutz	Environmental Studies	NH	Dartmouth	Y	Faculty
Emma Hazard	Environmental Studies	NH	Dartmouth	N	Grad Student
Karin Rand	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Research Staff
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 Staff
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 3 Milestones	Milestone Progress
1.1	1.1 Wireless sensor research and development	Abedi, Contosta, Adair, Naderi	Deploy prototype sensors at selected field sites Strategically expand network of sensors using appropriate methods	Deployed alternative prototype sensors at numerous field sites throughout each of the jurisdictions Compiled list of strategic field sites with contact info and location to help future site selection
1.2	1.2 Wireless sensor network design	Abedi, Contosta, Adair, Lutz, Whitney	Field test alternative network designs at selected field locations	At a few locations, alternative network arrangements have been evaluated and used to refine current designs
1.3	1.3 Cyber-based big data harmonization, ML & interface	Abedi, Bundy	Implement machine learning approaches to ecological sensor collection, storage, and processing	Testing alternative AI-driven smart sensing that allows both dynamic and highly flexible data acquisition depending on current conditions, projected weather patterns, and available battery power
2.1	1.4 Implications of cold-air pooling to forest vegetation composition and soil carbon storage across the north-eastern US	Pastore, Adair, Classen, D'Amato, Foster, Rand, Engish	Advance temporal and spatial understanding of buffering and decoupling between cold-air pooling microclimates and the overlying free atmosphere	Sensor data offloaded thus far is being processed and visualized and R code is being written to automate future processing. We have identified general characteristics/ patterns of cold-air pooling across a subset of sites.

Significant Problems/Unexpected Results/Novel Opportunities

- Continued challenges created by covid have created restrictions that adversely impact travel and field work.
- Supply chain issues causing equipment shortages and delays as well as increases in costs.

Future Plans

- Deployment of wireless environmental sensors in Alabama
- Development of training materials for sensor construction and deployment
- Expansion of wireless sensor development for other key forest ecosystem attributes such as tree growth
- INdendro, a Band Dendrometer with networked data logging of LoRa network which measures changes in tree diameter by measuring the change in tension of a sprung non-elastic band wrapped around the girth of the tree. This first prototype has been installed on a white pine in an open area

(Photo 3). Data collection commenced during the installation process and continues to the present moment (Figure 5).

- Continual monitoring of wireless sensors at specific study locations throughout the region
- Synthesis of key trends and integration with Themes 2 & 3
- Development of online interface for data access and trend assessment

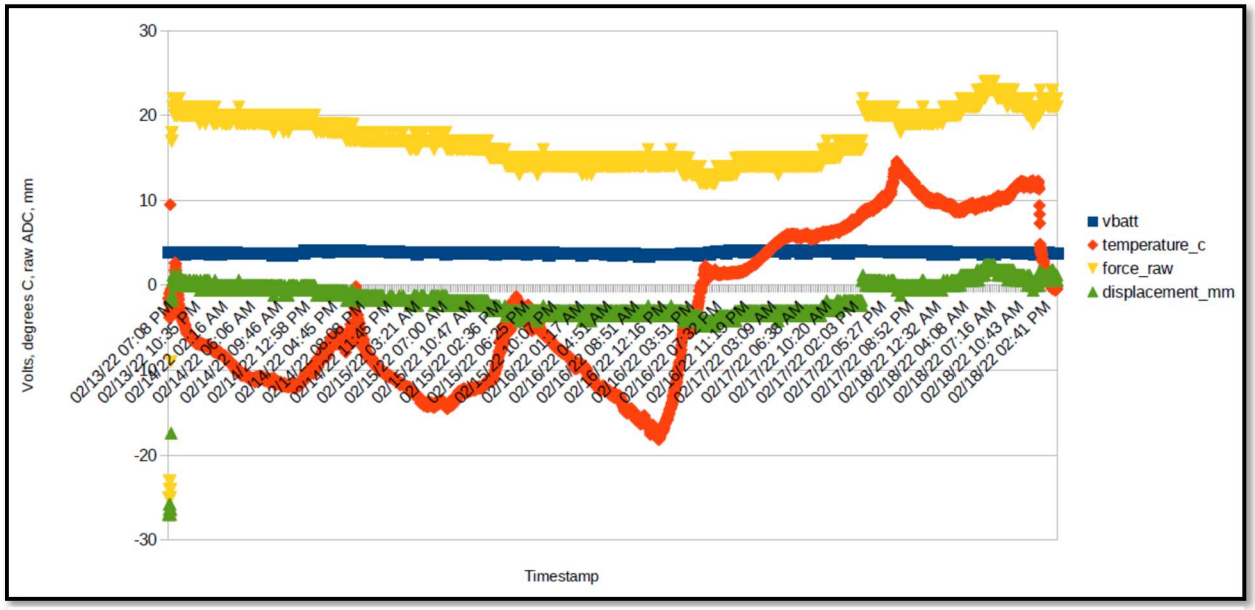
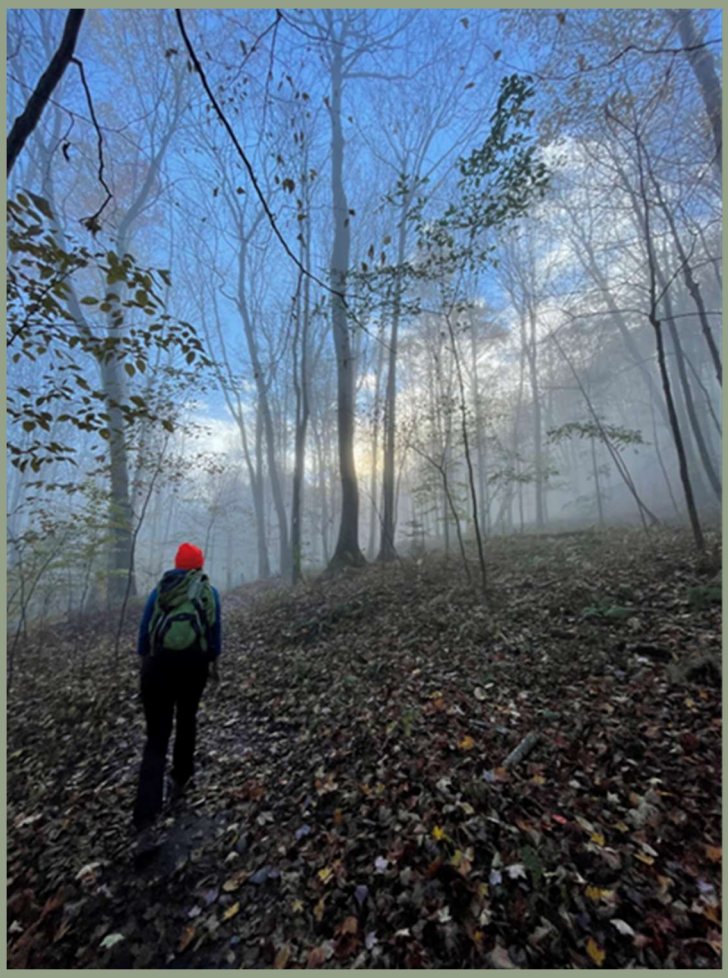


Figure 5. Pre-post installation data collection (four days of operational data).

Special Project Report

Determining the Implications of Cold-Air Pooling to Forest Vegetation Composition and Soil Carbon Storage Across the Northeastern US



Karin Rand hiking up the Duxbury Window Trail in VT as a cold-air pooling event was destabilizing fall morning. We were prepping our project's transects for winter. (Photo credit: Melissa Pastore)

In several regions across New England, we are establishing targeted elevational transects spanning cold-air pooling gradients (i.e., strong to absent cold-air pooling dynamics) identified using remotely sensed land surface temperatures. Each transect consists of 5-6 large radial plots (11.3 m radius) positioned at different elevations beginning at the valley bottom. Forest tree composition and tree sizes are measured in each large plot and understory species are identified in each nested subplot (5.65 m radius) and classified by life stage. These data will be used to calculate a 'community temperature index' for each plot's overstory and understory community, a method to assess nonlinearities in warm- vs. cold-adapted species along slopes. We are collecting soil and litter in each plot to measure carbon and nitrogen pools of the organic layer and mineral soil. We are measuring other key factors to use in multiple regression analyses, such as slope, aspect, and soil pH. We are also measuring canopy cover, ground layer species % cover, soil inorganic nitrogen (via resin strips), and decomposition (via the in-situ teabag method) in each plot. During plot establishment, we place a TMS-4 datalogger centrally in each plot to continuously measure soil moisture and temperature at 6 cm depth and air temperature at 2 and 15 cm above the surface. We also place iButton sensors that continuously measure air temperature 1.5 m above the surface.

Karin Rand and Melissa Pastore near the highest plot of a transect along the Duxbury Window Trail in VT, overlooking valley fog breaking up after a cold-air pooling event. (Photo credit: Melissa Pastore)

Research Objectives & Progress

Objective 1: Determine the effects of nonlinear temperature gradients generated by cold-air pooling on forest composition across tree life stages and implications for ecosystem function.

Progress: 48 plots established so far with key measurements taken and sensors deployed. Vegetation data has been visualized and preliminary patterns identified. Soil samples have been processed and will be analyzed soon.

Objective 2: Advance temporal and spatial understanding of buffering and decoupling between cold-air pooling microclimates and the overlying free atmosphere.

Progress: Sensor data offloaded thus far is being processed and visualized and R code is being written to automate future processing. We have identified general characteristics/patterns of cold-air pooling across a subset of sites.

Key Accomplishments

We began establishing sites for the project and will finish establishing our core New England sites this summer, although we are interested in expanding this work and have discussed applying for NSF funding to do so. In conjunction with site establishment, we

Marie English and Melissa Pastore sampling soils in a plot. (Photo credit: taken by Karin Rand; M. Pastore's phone)

made several ecosystem measurements focused on plants and soils, and we deployed continuous sensors that will allow us to assess cold-air pooling dynamics at fine spatiotemporal scales. We published a concept paper related to this work and mentored an under-graduate intern who was heavily involved in the field and lab work last summer.

Team Synergies & Interjurisdictional Collaborations

We have briefly connected with Theme 4 about potentially using these transects for educational activities. We are also connecting with other themes (primarily via Jane Foster) about integrating remote sensing approaches with our in-situ approaches to characterize cold-air pooling extent and dynamics.

Intellectual Merit

The most important and novel result of this project will be demonstrating that cold-air pooling can impact soil carbon and generate biogeochemical hotspots through forest composition-function linkages, thereby serving as microrefugia for species and ecosystem functions in the face of climate change. More broadly, we need a foundational understanding of these nonlinear systems to accurately model climate change and predict its impacts. We expect at least three publications to result from these efforts: (1) An in-depth study of how nonlinearities in temperature with elevation influence forest composition across tree life stages, (2) A study uniquely linking the influence of cold-air pooling on forest composition to soil carbon patterns, (3) Spatial and temporal characterization of buffering and decoupling between the overlying free atmosphere and cold-air pooling microclimates. A related concept paper in press at *Ecology*. Current considerations include applying for NSF funding to expand this work.

Recruiting/Training of Faculty and/or Students

- We recruited one undergraduate intern (Anna Sherman) from UVM last summer who was trained in field and lab methods for this project, and we are in the process of hiring another student (Carissa Finnerty) for this summer.
- Post-doc Pastore completed comprehensive exams and defended her PhD project proposal (identifying impacts of forest management practices on decomposition and fungal community composition) at UVM this year.

Karin Rand inspecting the soil organic horizon of a plot. (Photo credit: Melissa Pastore)

Broader Impacts

- The established network of monitoring plots will enhance research infrastructure for future projects. This project contributes unique datasets, such as fine spatiotemporal environmental data and forest composition/size-structure data that can serve as a baseline for detecting temporal trends in future studies.
- This work has fostered collaborations between institutions and stakeholders, creating a new multi-disciplinary network that can build upon these studies. (UVM, UNH, UMaine, UMichigan, AMC, USFWS, VT Forests Parks and Rec, VT Fish and Wildlife, Dartmouth College Woodlands, Bartlett Experimental Forest)
- This work has created opportunities for 2 undergraduate interns dedicated to this project and other interns that transiently helped with field and lab work.

Preliminary Findings

- Cold-air pooling occurs about 20-50% of the time depending on transect at our sites at Second College Grant, NH, and in the Camel's Hump/Little River area, VT, based on continuous air temperature sensor measurements at 1.5 m above the ground surface.
- Some of our sites with substantial cold-air pooling show an inverted forest composition transition from low to high elevation, with cold-preference species dominant at low elevation and warm-preference species dominant at high elevations.

Next Steps

Inspires Years 3-4

- Re-visit sites to offload sensor data and harvest tea bags (for decomposition measurements) and resin strips (for soil N availability measurements).
- Continue processing/analyzing samples in the lab (e.g., carbon and nitrogen stocks of soil and litter).
- We are establishing 9 more transects across 3 new regions, including Bartlett Experimental Forest, NH, AMC's Maine Woods Initiative property, ME, and possibly the Bigelow Preserve, ME.

Future Plans & Opportunities

Short-Term (1-2 years)

- Publish and present work at meetings
- Expand network of transects, co-locate with Mayfly sensor stations or add other key sensors
- Continue collecting temperature and soil moisture sensor data, building up a longer-term dataset

Long-Term (3-5 years)

- Re-inventory plots for vegetation composition/size-structure, measure tree mortality, coarse woody debris
- Make plant physiological and trait measurements (e.g., leaf-level photosynthesis, water-use efficiency, water potential, foliar nitrogen concentration)
- Assess long-term patterns in cold-air pooling temperature dynamics and buffering/decoupling
- Reciprocal seedling transplant study across transects

Theme 2. Environmental Informatics and Analytics

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, the team 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; identified new regional climatic zones based on project future conditions (which show significant departures from the USDA plant hardiness zones); refined machine learning classifier algorithms to detect individual tree crowns from high-resolution remote sensing images; and developed a streamlined and novel workflow for querying of multiple available spatial datasets to be deployed in the Digital Forest framework. The emphasis for Year 3 efforts was to continue evaluating key relationships between remote sensing variables and various ecosystem attributes, harmonizing various regional spatial layers within a unified digital framework for assessing key spatiotemporal trends, and understanding the primary drivers of forest productivity that can be leveraged in Theme 3 for future ecological forecasting.

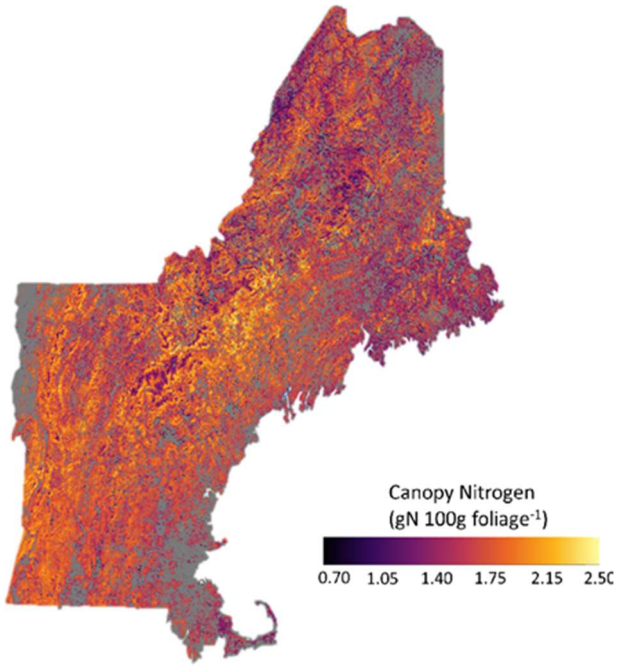


Figure 6. Preliminary estimates of mass-based canopy nitrogen concentration across the Northeast USA derived from Landsat-8 near infrared reflectance. Grey areas are non-forested regions.

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

- Updates and significant refinement to the software system for processing remote sensing data, lecospec (https://github.com/nelsopet/lecospec), happened through collaborations across themes.
- A R package (lecospectR) for hyperspectral and geospatial machine learning inference was developed and released in Year 3, which achieved a 93% reduction in processing time and is now able to process images larger than 10GB.
- A prototype for a Digital Forest Web Interface was developed to query the database.
- Machine learning classifiers were used to identify tree species characteristics based on hyperspectral imagery.

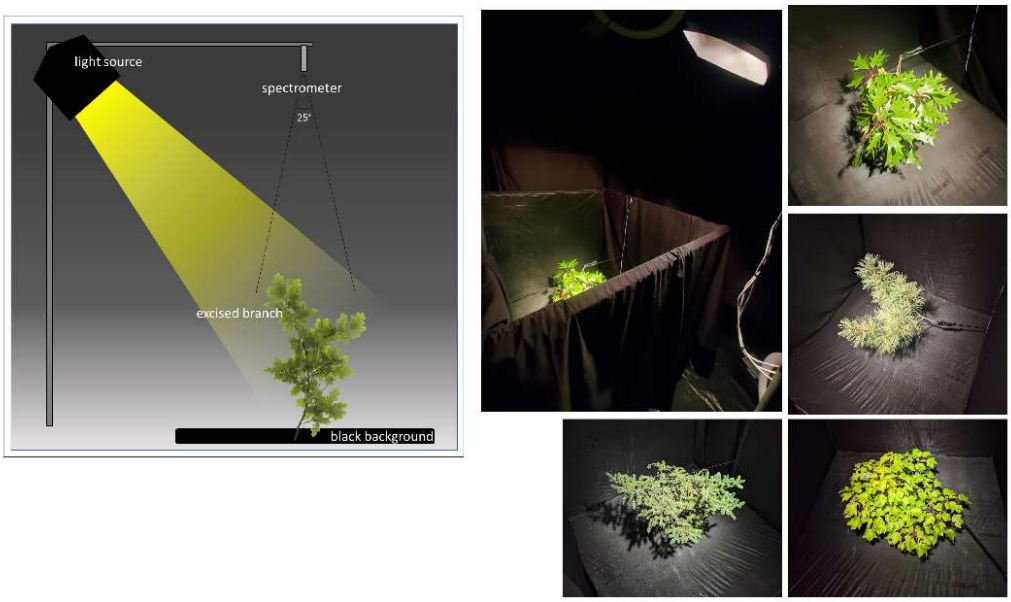


Figure 7. Diagram showing darkroom setup developed to measure the reflectance of individual branches (left). Photo of darkroom setup and examples of branches prior to measurement (right).

- A data-driven ontology for classification of species habitat characteristics based on abundance, slope, and aspect was developed and refined.
- Refined understanding of the response of temperate forest tree species to climate change by measuring their response to drought using sensors developed in Theme 1.
- Provided estimates of key forest canopy functional traits (e.g., foliar nitrogen, photosynthetic capacity) at high resolution (30-m) across regional scales using field collected data and remote sensing platforms (Figure 6). These regional estimates of canopy traits will serve as input parameters to drive regional modeling efforts in Theme 3.
- Improved understanding of species-specific strategies for intercepting and using photosynthetically active radiation (Figure 7), particularly its influence on forest productivity.

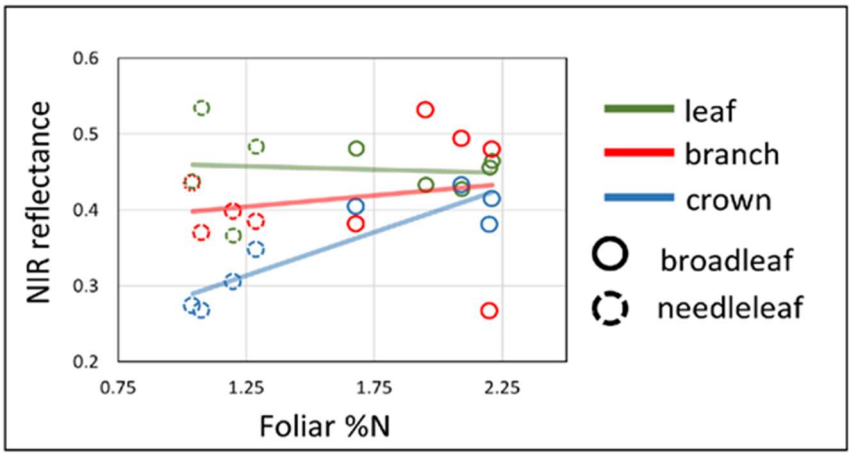


Figure 8. Preliminary patterns of near infrared (NIR) reflectance in relation to mass-based foliar nitrogen concentration across three different scales: leaf, branch, and tree crown. This figure shows species averages (4-6 individuals) for nine common tree species in the northeastern USA.

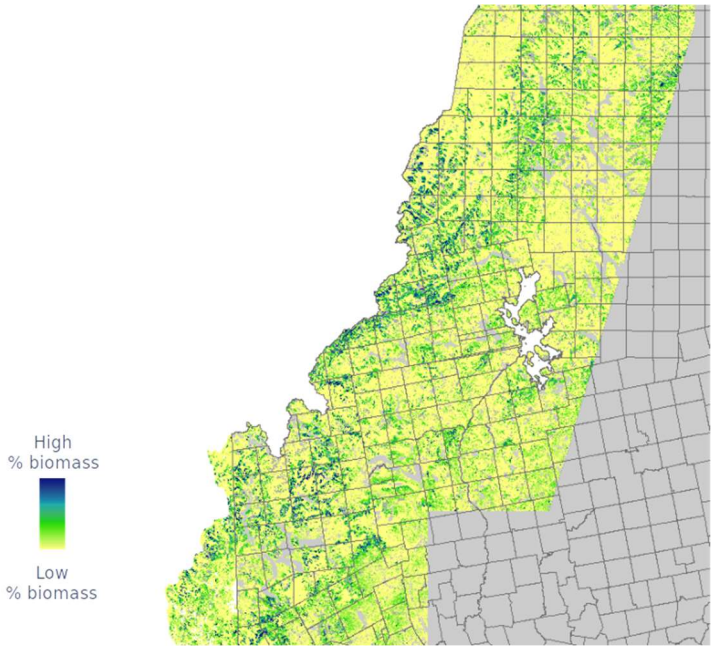


Figure 9. Map of sugar maple composition at a 20-m resolution for a portion of northern Maine using the developed multi-objective machine learning algorithm and available remote sensing imagery.

- The relationship between near infrared (NIR) reflectance to mass-based foliar nitrogen concentration was assessed across three different scales (leaf, branch, and tree crown) and species (Figure 8)
- Using observational data during two recent drought events (2016 and 2020) as well as an ongoing drought experiment, we looked at forest response to drought.
- During the severe drought events of 2016 and 2020 wood growth was reduced by 30% compared to average years and individual tree species responded differently to drought.
- In response to drought northern red oak doubled its fine root biomass, accessed water from deeper soil layers, and maintained near-optimum leaf temperatures for growth, while red maple showed a minimal root response and experienced growth inhibiting leaf temperatures of over 37°C.
- Distinct differences in the drought resistance across tree species and within tree species across sites that relate to mean site-level water availability.
- First Prototype OWL/RDF Knowledgebase for the Digital Forest stored as a GraphDB database.
- Data suggests intraspecific variation in drought resistance may be the result of long-term adaptation (genetic differences in populations across sites).
- Completion of species composition maps for over 4 million ha in northern Maine (Figure 9).
- Production of annual change detection using harmonized archive of Landsat and Sentinel remote sensing imagery (Figure 10).
- Grad students presented flash talks on project progress at May 2022 all-team retreat (Figure 11).

Figure 10. Map of annual change detection and identified disturbed polygons using harmonized Sentinel and Landsat archive with automated multi-objective machine learning algorithm.

Team Members

12 Faculty (6 Early Career), 2 Professional Staff, 4 Graduate Students, and 1 Research Assistant; 13 ME, 5 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
Emily Landry	Earth Systems Research Center	NH	UNH	N	Grad Student
Jane Pettit	Center for Research on Sustainable Forests	ME	UMO	N	Prof staff
John Hastings	Earth Systems Research Center	NH	UNH	N	Grad student
Kaitlyn Baillargeon	Earth Systems Research Center	NH	UNH	N	Research Assistant
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
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	Forest Ecology	ME	Schoodic Institute	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
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 3 Milestones	Milestone Progress
2.1	2.1 Extension of field model beyond in-situ sensors	Nittel, Petrik, Ranco	Extend methods for producing regional-scale spatial and better quantify uncertainty	Alternative methods of quantifying uncertainty have been evaluated and are currently being refined
2.2	2.2a Hybrid Semantic-statistical representation of forest places	Hahmann, Beard, Legaard, Martin	Formalize select semantics (land use/land cover, forest type, maturity, water availability) in an ontology using input from Theme 3 to seed the semantically- enabled representation	Digital Forest framework has been extended and used to begin analysis of key geospatial layers related to forest species composition
	2.2b Provide spatial datasets for Theme 3 objectives	Hahmann, Beard, Martin	Test AI/ML methods to produce necessary spatial layers at scale and incorporate uncertainty	Multi-objective ML method has been formalized through additional code refinement and is currently being used to produce regional spatial layers including annual disturbance history
	2.2c. Develop and evaluate alternative ML algorithms for analyzing spatio-temporal datasets	Legaard, Roy, Yasaei	Compare existing and newly developed ML algorithms on similar spatiotemporal datasets	Continued comparisons of multi-objective ML method highlights superiority over other commonly used ML algorithms like RandomForest or XGBoost
2.3	2.3 Analysis of forest place correlations and similarities	Beard, Legaard, Petrik, Hahmann, McGill, Roy, Ranco	Refine existing layers of regional climatic, forest type, disturbance, and potential productivity based on forecasted changes produced by Theme 3	Digital framework for harmonizing key regional spatial layers has been constructed and preliminary assessment of key spatiotemporal trends evaluated

Significant Problems/Unexpected Results/Novel Opportunities

- Ongoing restrictions on travel and fieldwork
- Availability of cloud- or haze-free remote sensing imagery for New England

Future Plans

- Refinements and necessary bug fixes needed to finalize the lecospectR's API and functionality.
- A web-based data labeling application, developed based on code developed by UMaine Software Engineer Chris Wilson, will be completed.
- Joint field season with AAMU graduate and undergraduate students planned.

- During mid-July to mid-August of 2022, UNH research group will host 2-4 students from AAMU to conduct research on how forest trees differ in their ability to intercept and diffuse light, their nutrient status and photosynthetic capacity, and resistance to drought.
- Senior research personnel, post-docs, graduate and undergraduate students from UNH will train and work with undergraduate and graduate students from AAMU on a variety of instruments, field techniques at 4-5 research sites, several of them with planned access to a canopy lift.

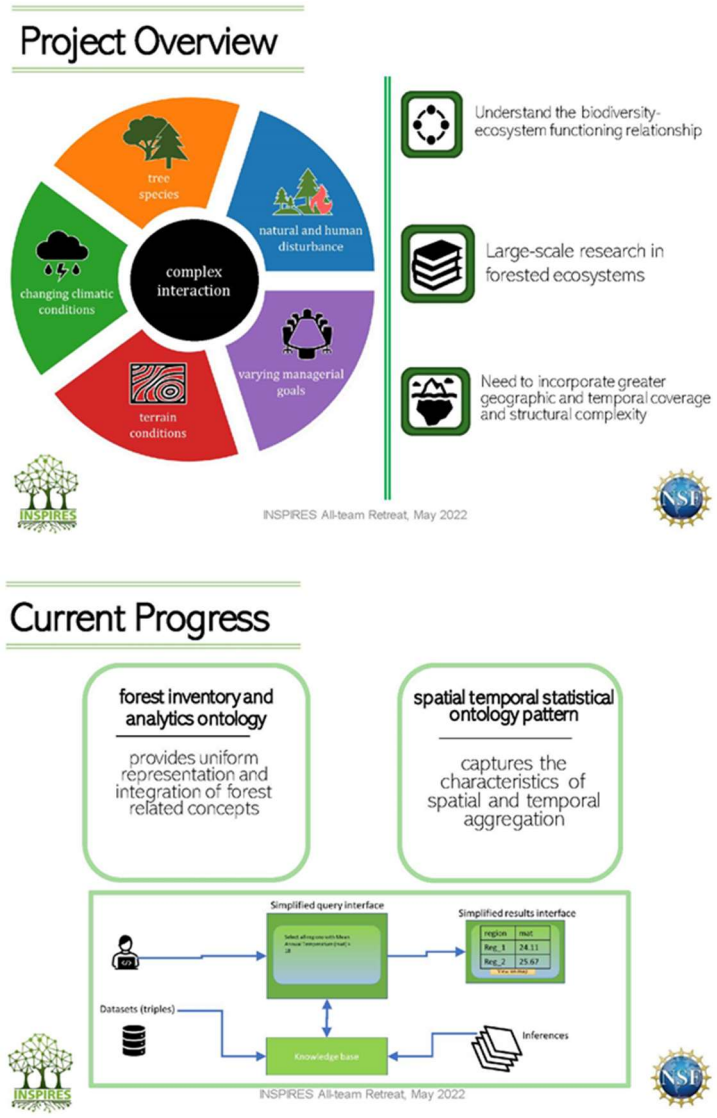


Figure 11. Slides from graduate student Kingsley Wiafe-Kwakye's project, "Growing the Digital Forest," presented at the May 2022 INSPIRES all-team meeting.

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. The focus of Theme 3 in Year 3 was continuing to (1) identify gaps in model representations of key ecological processes in PnET-II and LANDIS-II, particularly as they relate to carbon and nitrogen cycling and (2) evaluate as well as harmonize available model initialization data, particularly related to regional and local climate data that could be collected or modeled by Theme 1 or 2. By expanding LANDIS-II code base for LANDIS-II PnET-Succession module to incorporate nitrogen cycling routines, model improvements now provide for more realistic simulation of tree growth and species competition for light, water, and nitrogen. Collaborative interaction with Theme 1 to collect temperature sensor data along topographic gradients has filled important knowledge and data gaps. Canopy-level measurements to observe species differences in the optimum temperature range for photosynthesis and sun vs. leaf temperature demonstrated that leaf temperature can be substantially higher, which has important implications for growth predictions. In addition, working with undergraduate computer science capstone students, additional decision-support tools within the Forest Ecosystem Status and Trends (ForEST; Figure 12) web application were developed.

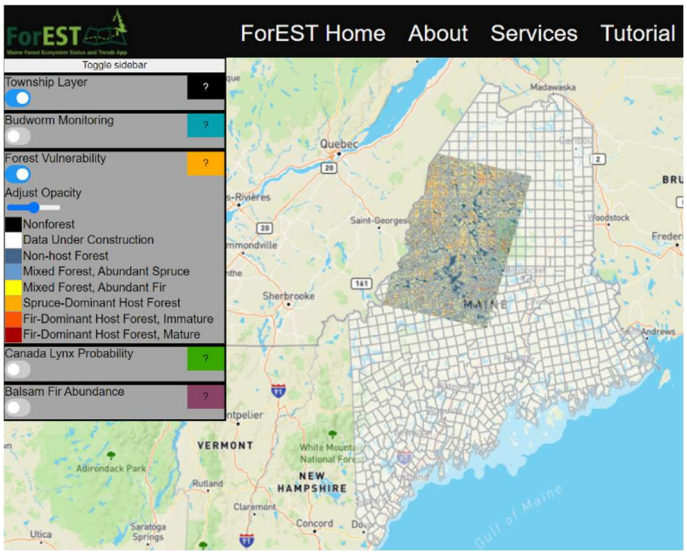


Figure 12. Screenshot of the ForEST web application.

In Year 3, the primary focus was in constructing a common model initialization dataset for a variety of study locations in the region. This data and code will allow for effective model intercomparison assessments, which can help with future model refinement and integration plans. Currently, this model intercomparison is focused on three primary student locations including the Penobscot Experimental Forest in Maine, the Barlett Experimental Forest in New Hampshire, and Victory State Forest in Vermont. This work has also involved researchers from each of the three jurisdictions including Drs. Erin Simons-Legaard (Maine), Jane Foster (Vermont), and Andrew Ouimette (New Hampshire). Through a shared website and code base, substantial progress has been made and should be finalized in Year 4. In addition, Year 3 also saw the integration of AAMU researchers into Theme 3 with plans for using the Paint Rock study site in Alabama as a potential addition to the model intercomparison effort.

Theme 3 primarily consists of researchers who are developing a modeling framework that provides a means for organizing and scaling 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. The primary goal of Theme

3 is to advance a suite of ecosystem models and improve future projections of forest composition, productivity, and the capacity of forests to continue to provide critical ecosystem services to residents of the Northern Forest Region. To meet this overarching goal, researchers in Theme 3 have focused on five specific objectives including:

1) Integration of several unique models that vary in their ability to capture a range of drivers (e.g. climate, geology, management, and disturbance) and responses (e.g., forest composition and products, wildlife habitat, impact on climate, and water and nitrogen cycle effects).
2) Increasing model accessibility to students, researchers, and the forestry community through development of front-end code to standardize and simplify model parameterization and initialization.
3) Identification of model weaknesses and data gaps (including highlighting geographic regions where input data have high uncertainty).
4) Improving the representation of key ecological processes within models.
5) Application of updated models to quantify the impact of various stressors on ecosystem integrity indicators and predict change across Northern Forest Region under future scenarios.

Highlights

Model Integration

- New collaborations with the U.S. Forest Service were developed in our model integration work with integration of the PnET-CN and LANDIS models.
- Launched a new cross-jurisdictional working group and git repository to support multi-model comparison at INSPIRES sites and shared code development.
- Using a shared website and code base across the three jurisdictions, a common model initialization dataset was constructed for effective model intercomparison assessments which will inform future model refinement and integration plans.
- Model intercomparison is focused on three primary study locations including the Penobscot Experimental Forest in Maine, the Bartlett Experimental Forest in New Hampshire, and Victory State Forest in Vermont. This work has been led by researchers from each of the three jurisdictions including Drs. Erin Simons-Legaard (Maine), Jane Foster (Vermont), and Andrew Ouimette (New Hampshire). Substantial progress continues and should be finalized in Year 4.
- Integration of AAMU researchers into Theme 3 with plans for using the Paint Rock study site in Alabama as a potential addition to the model intercomparison effort.
- Nearing completion of an integration of the PnET-CN model and the Landis PnET-Succession model which will allow users to assess interactions between nutrient availability and tree species compositional changes during forest succession.
- Developed a model to assess the importance of various parameters on predicting nitrogen and carbon cycling in coarse dead wood.
- Found that including and correctly parameterizing the stoichiometric demands of the wood decay microbial community has a significant impact on both the capacity of wood to immobilize/store nitrogen, and the long-term fate of wood derived carbon.

- Highlighted the importance of model input parameters varies strongly with time since disturbance, leading to variations in the parameters that are most important to predicting carbon and nitrogen dynamics from woody litter decay over time.
- Parameterizing model inputs with values appropriate for wood decay suggests that N dynamics in dead wood do not account for a significant fraction of the nitrogen imbalance observed at a local forest (Watershed 6 within Hubbard Brook Experimental Forest).

Model Accessibility

- Developed prototype data assimilation framework and code implementation for inverse parameterization of key LANDIS-II parameters for modeling forest growth based on USFS FIA inventory plots.
- Formed new cross-theme working group to share knowledge and expertise working with USFS FIA plots data.
- Recoded the PnET-II model from C++ language into Python for wider user accessibility.

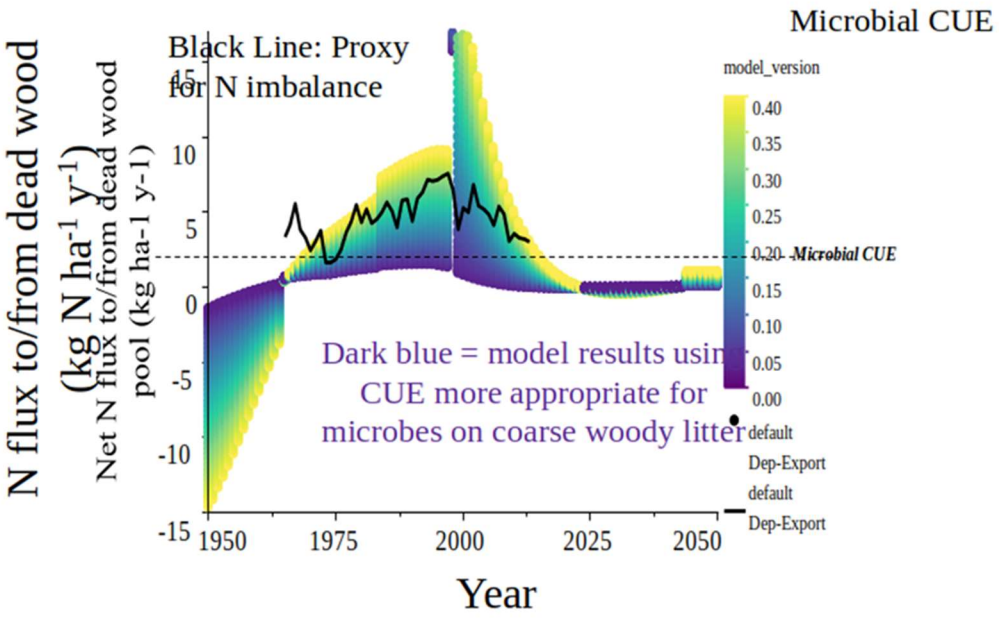


Figure 13. Simulation results from a newly developed coarse woody debris model showing the importance of including microbial stoichiometry when modeling nitrogen cycling in dead wood. Results shown here only vary the microbial carbon-use efficiency (CUE) for a control watershed at the Hubbard Brook Experimental Forest between 1950-2050. When using CUE values more typical for wood decay (< 0.10) coarse woody debris does not explain an observed N imbalance at this watershed. Many models use fixed CUE of > 0.20 (more typical of nitrogen-rich litter) leading to the opposite conclusion. The black line is a proxy for the N imbalance observed at HBEF-W6 (N deposition minus stream N export).

- Developed and published prototype methods and code to process and map foliar biomass metrics from Landsat time series and characterize partial canopy disturbances and their potential effects on carbon fluxes, which can be used to refine parameters and disturbance for the LANDIS-II model.

Model Assessment and Refinement

- Explored developing a common interface for conducting model sensitivity assessments
- Developed a model to assess the importance of forest disturbance, microbial controls, and wood chemistry on wood decay to predict the impact of coarse woody debris on carbon and nitrogen cycling (Figure 13).
- Developed prototype code and analysis to quantify the climatology of cold-air pooling for montane watersheds across the INSPIRES study area using MODIS land-surface temperature data. Maps and climatology will create linkages needed to incorporate high-frequency, fine-scale temperature sensor data from cold-air pooling project in Theme 1 into the LANDIS-II simulation modeling framework for future projections of forest change.
- Updated ForEST web application framework to AngularJS to improve application performance and stability.
- Worked with undergraduate computer science capstone students to develop additional decision-support tools within the Forest Ecosystem Status and Trends (ForEST) web application.

Model Application

- Developed prototype code and analysis to quantify the climatology of cold-air pooling for montane watersheds across the INSPIRES study area using MODIS land-surface temperature data. Maps and climatology will create linkages needed to incorporate high-frequency, fine-scale temperature sensor data from cold-air pooling project in Theme 1 into the LANDIS-II simulation modeling framework for future projections of forest change.
- Successfully applied code developed for data assimilation and model parameterization to support graduate student projects using the LANDIS-II model in ME, VT, and NH.
- Applied newly developed coarse woody debris model to predict long-term carbon and nitrogen cycle dynamics at a long-term research site. Results show that including and correctly parameterizing the stoichiometric demands of the wood decay microbial community has a significant impact on both the capacity of wood to immobilize/store nitrogen, and the long-term fate of wood derived carbon. This work also highlighted that the importance of model input parameters varies strongly with time since disturbance, leading to variations in the parameters that are most important to predicting carbon and nitrogen dynamics from woody litter decay over time.

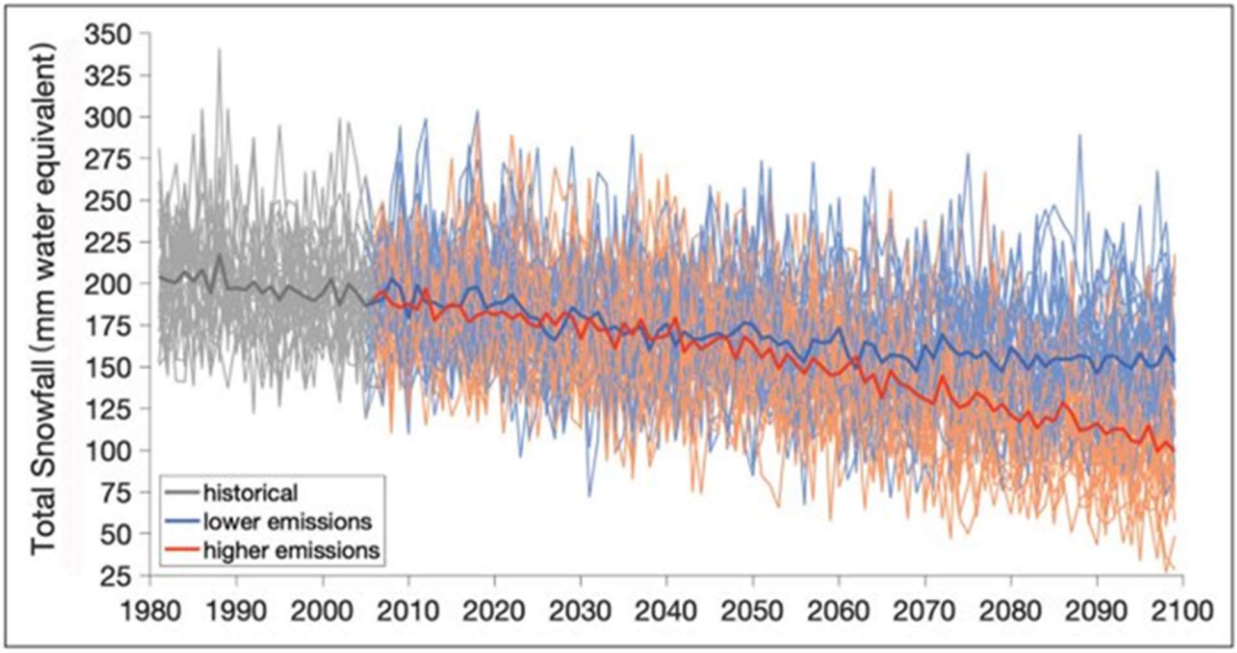


Figure 14. Projections of future total snowfall trends in New England based on alternative emission scenarios as presented in Burakowski et al. (2022)

- Applied the framework developed to process and map foliar biomass metrics from Landsat timeseries to quantify canopy disturbance at North American flux tower sites and evaluated spatial-temporal correlations with eddy-flux data from FLUXNET2015 and UNH custom-processed flux data.
- Future forecasts of regional annual total snowfall trends across New England were made at a fine spatial scale (1/16°) using UNH's Water Balance Model (Figure 14) and published in *Northeastern Naturalist* in February 2022.

Team Members

11 faculty (6 early-career), 1 graduate student, 2 Research Staff (2 early career); 4 ME, 3 VT, and 7 NH

Name	Affiliation	Jurisdiction	Institution	Early Career	Role
Aaron Weiskittel	Center for Research on Sustainable Forests	ME	UMO	N	Faculty
Andrew Ouimette	Earth Systems Research Center	NH	UNH	Y	Research Staff
Anthony D'Amato	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Faculty
Daniel Hayes	School of Forest Resources	ME	UMO	Y	Faculty

Name	Affiliation	Jurisdiction	Institution	Early Career	Role
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
Lisa Scott	Department of Natural Resources and the Environment	NH	UNH	N	Grad Student
Luben Dimov	Rubenstein School of Environment and Natural Resources	VT	UVM	N	Faculty
Mark Ducey	Department of Natural Resources and the Environment	NH	UNH	N	Faculty
Scott Ollinger	Earth Systems Research Center	NH	UNH	N	Faculty
Zaixing Zhou	Earth Systems Research Center	NH	UNH	Y	Research Staff

Research Milestones Progress

Objective	Projects	Project responsible parties	Year 3 Milestones	Milestone Progress
3.1	3.1a Inverse parameterization of ecological models	Foster, Simons-Legaard	Complete model inverse parameterization using small test landscapes across the region; Identify model uncertainty at certain landscape features or types of disturbances	Necessary code for completing a model inverse parameterization has been outlined and initialized Model intercomparison has been started at several key study sites throughout the region and will be useful for understanding key model differences

Objective	Projects	Project responsible parties	Year 3 Milestones	Milestone Progress
3.2	3.2a Model integration and application	Hayes, Burakowski, Ollinger	Initiate model integration and evaluate performance on selected sites; Complete refinement of model representation of disturbance and species response to climate	Necessary data needed for both model initialization and assessment are actively being compiled at numerous locations throughout the region Key model refinements are being made for carbon and nitrogen cycling, which will be critical for accurately portraying potential impacts of climate change on forests Integration of PnET and LANDIS-II models is ongoing with strong involvement of researchers both internal and external to INSPIRES
3.3	3.3a Scenario assessment & trend analysis	Weiskittel, D'Amato, Ducey, Gunn	Complete regional scenarios projections and assess outcomes; Present to stakeholders for input and feedback	Variety of alternative management scenarios and outcomes presented to stakeholders in Maine with additional refinements made Additional scenarios are being implemented and assessed, particularly ones involving climate change and alternative defoliation events

Significant Problems/Unexpected Results/Novel Opportunities

- Delays in the availability of US Forest Service, Forest Inventory and Analysis (FIA) data due to the ongoing pandemic. Currently, data up to 2019 is only available for Maine and New Hampshire, while Vermont has data up to 2020 (Figure 15).
- Instability of US Forest Service, Forest Inventory and Analysis' FIA DataMart, which has delayed access to core files needed for analysis.
- Early withdrawal of a graduate student focusing on Theme 3 work resulting from COVID-related challenges.
- Availability of new data from Paint Rock study site in Alabama.
- Integration of data preparation and modeling approaches from multiple research groups that span multiple scripting languages (e.g. C++, Matlab, Python, R, etc.).

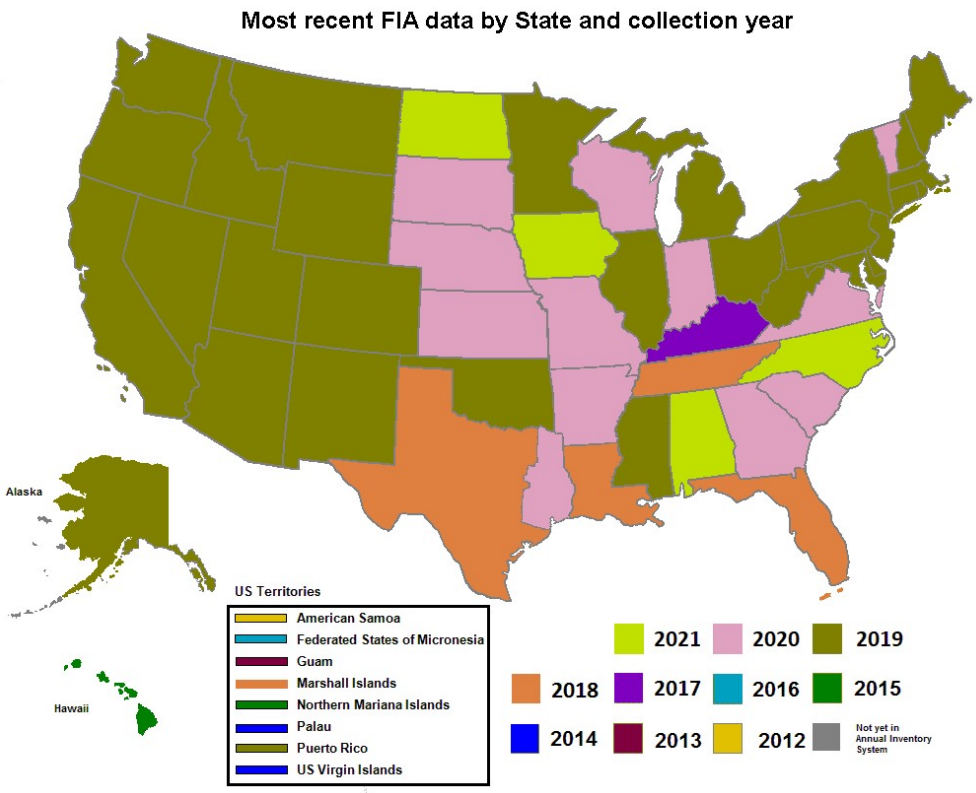


Figure 15. Availability of US Forest Service, Forest Inventory and Analysis (FIA) data by state as of May 1, 2022. Image provided by US Forest Service FIA via https://apps.fs.usda.gov/fia/datamart/recent_load_history.html.

Future Plans

- Complete construction of model intercomparison framework and dataset and conduct multi-model comparison of initial biomass predictions at selected study sites.
- Release version of PnET-Succession model that incorporates the nitrogen cycle of the PnET-CN model into the Landis PnET-Succession model.
- Initiate development of initialization data for regional LANDIS-II application using remotely-sensed data products developed by Theme 2.
- Complete development of Biomass Insects module for LANDIS-II to enable projections of future forest insect outbreaks.
- Complete manuscript/modeling analysis of the influence of coarse woody debris decay on carbon and nitrogen cycling in forests over successional time frames.
- Incorporate regional map and database of foliar nitrogen and photosynthetic capacity for regional model parameterization.

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. Year 2 progress included collaboration across the project themes by attending through monthly meetings, developing collaborative research across the three northern states, recruiting teachers from VT, ME and NH into the project, and 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. Theme 4 kicked off their Year 3 efforts with a professional learning workshop (Photo 4) focused on Quantitative Reasoning in Context (QRC) with regional teachers and INSPIRES researchers, while UVM faculty Dr. Regina Toolin designed and is teaching a graduate-level course to support STEM teachers to incorporate QRC, forestry topics, Big Data and TEK into their classroom activities.

Highlights

- UNH project researchers are collaborating with a VT high school science teacher to install a sensor suite on school property for student-driven research projects about forestry and QRC.
- Initial and follow-up interviews were conducted with 6 Maine teachers in spring 2021.
- Qualitative analysis of all teacher interviews to inform the next interview protocol and capture their thinking and growth over time in the project.
- Conduct a second round of interviews with six Maine teachers in spring/early summer 2022.
- The first summer professional learning workshop series was held in July 2021 with 5 high school teachers from Maine and 8 middle and high school teachers from VT participating in-person and 1 high school teacher from Maine participating virtually (Photo 5).

Photo 4. INSPIRES team members Marina van de Erb, Liz Burakowski, Sara Lyndsay, and Peter Nelson work with teachers from Vermont and Maine at the QRC workshop.

- Professional learning workshops were led by the Theme 4 planning team members in Maine, NH, and VT and involved scientists from other INSPIRES themes including Alix Contosta, Liz Burakowski, and Peter Nelson. Workshop content included learning about components of Quantitative Reasoning in Context, placing forest sensors and gathering data, and group work and planning for classroom activities as part of the Summer 2021 Workshop series.
- Video projects of the workshop and scientist goals on YouTube.

- Maine and Vermont teachers met monthly with the Theme 4 planning team and scientists from other themes in virtual meetings and workshops throughout the 2021-22 school year.
- Project teachers and staff participated in the RiSE Center's June Conference in 2021 and in the Maine STEM Partnership Annual Summit in November 2021.
- Theme 4 planning team member Dr. Franziska Peterson led workshops focused on Quantitative Reasoning in Context at the June Conference and the Maine STEM Partnership Annual Summit.
- Through their course work participating teachers will design classroom activities and assessments. All of the Theme 4 teachers from Vermont are participating in the course.

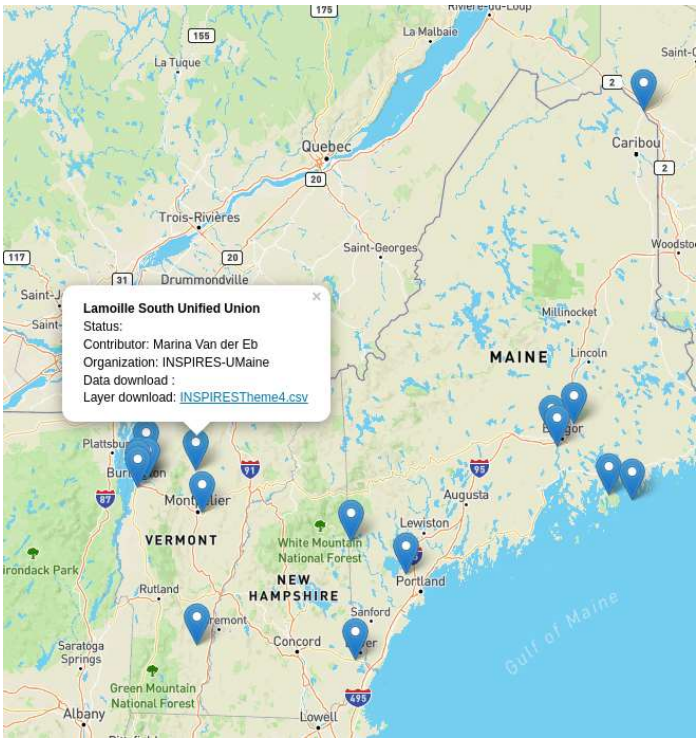


Figure 16. Location and contact information for all participating teachers in the INSPIRES project as available through the online tool, INleaf.

- Melissa Pastore (Theme 1 researcher) presented her research on cold-air pooling during one of the team meetings.
- Graduate Assistant Hazel Cashman presented her thesis work about Traditional Ecological Knowledge (TEK) in forestry contexts.
- The second summer professional learning workshop series will be held in July 18-22, 2022 with 6 Maine teachers and 8 Vermont teachers participating.
- INSPIRES teachers will be invited to the 2022 RiSE Conference June 26-28.
- Initiated partnership with Dawn Lemke and AAMU and will be working together on summer programs and plan to bring pre-service teachers from Alabama to Maine this summer.
- Dr. Franzi Peterson and Graduate Assistant Hazel Cashman are working to code all of the initial interviews with teachers as part of the Theme 4 research focused on teachers' thinking about and use of quantitative reasoning in context in their classrooms.
- A 3-credit INSPIRES Teacher Professional Learning graduate course offered by UVM.
- Location and contact information for all participating high school science teachers was incorporated into the INSPIRES's online collaborative tool INleaf to increase potential interactions between researchers and science teachers (Figure 16).

Team Members

6 Faculty (2 Early-Career), 2 Professional Staff, and 2 Graduate Students; 7 ME, 1 VT, and 2 NH. UNH faculty Liz Burakowski joined Theme 4 in year 3 and will continue in year 4.

Name	Affiliation	Jurisdiction	Institution	Early Career	Role
Elizabeth Burakowski	Institute for the Study of Earth Oceans and Space	NH	UNH	Y	Faculty
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 3 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	Curricular materials are iterated to support integration of quantitative reasoning in context into classroom instruction	Interviews analyzed for current teacher strategies and needs Additional teachers in New Hampshire and Vermont recruited and selected First professional learning workshop conducted July 2021 and another planned for 2022 Curricular materials developed Six 1.5-hour virtual professional learning workshops with partner K-12 teachers 3-credit INSPIRES Teacher Professional Learning graduate course offered by UVM

Objective	Project responsible parties	Year 3 Milestones	Milestone Progress
4.2. Use local Big Data to answer student- and community-relevant science questions	Peterson, Toolin, Millay, Lindsay, McKay, Shulman, Nickerson	Project research documents student learning through curricular materials	Additional 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	Teachers begin to develop an understanding of the integration of big data, forestry, and quantitative reasoning in context; interviews provide evidence of learning for project research	Teachers have developed and began presenting experiences from use of curriculum materials from the project to each other Plans for recruitment of new teachers initiated and summer workshop has been scheduled.

Significant Problems/Unexpected Results/Novel Opportunities

- Recruitment of NH teachers remains a challenge and we are still working to bring NH teachers into the project.
- New teachers from Alabama will be recruited into the project.

Future Plans

- Teachers will pilot the lessons they designed in their classrooms and administer student surveys/classroom assessments.
- Continue holding Theme 4 meetings monthly throughout the academic year.
- Host a third summer learning professional learning workshop in July 2023.
- Support teacher groups as they develop a monograph of their learning experiences that can be shared.

Photo 5. Teacher workshop participants install solar panel power source for data collectors.

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, and this has resulted in several important project outcomes, including 4 intra- and 1 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 16 intra- (5 awarded) and 16 inter- (3 awarded) jurisdictional proposals through Year 3.

In Year 3, research products included 13 (12 published; 1 under review) peer-reviewed articles, 1 peer-reviewed conference proceedings, 10 presentations, and 3 data/model/technology products (Appendix 1). 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). In addition, INSPIRES PI and Co-PIs had several articles in Year 3 in highly prominent academic journals including *Science* (Impact Factor = 47.73) and *Scientific Reports* (Impact Factor = 4.38). Several of the publications were multi-author and interjurisdictional (4) that included INSPIRES trainees, early-career, and senior faculty as co-authors**. Overall, INSPIRES has resulted in 27 peer-reviewed publications through Year 3 with the majority (18) being interjurisdictional and 5 being intra-jurisdictional.** Although down from Year 2 (22 vs. 12), reflecting the continued lack of regional or national conferences due to the pandemic, the INSPIRES team has identified several new potential publications and this will be a primary focus in Year 4. In addition, the number of presentations was on par with Year 2 (14 vs. 10) despite the lack of conferences. These were primarily by INSPIRES early-career faculty or professional staff (5) and trainees (1); presentations by faculty given at regional (5) and national (5) meetings.

The number of proposals submitted in Year 3 was also consistent with Year 2 in terms of funding requested as the focus has continued to shift to larger competitive grants. As of May 2022, INSPIRES researchers have submitted a total of 8 proposals totaling $23,733,100 in requested funding, with 2 projects awarded ($818,197) and 5 still pending ($22,714,987). The Year 3 proposals were led primarily by early-career faculty (5) and were submitted to a variety of sources including the National Science Foundation (2) and other Federal agencies (3). Two of the 5 proposals led by early-career INSPIRES faculty were inter-jurisdictional. Details on the specific research proposals and Year 3 awards are provided in Table 5.

Table 5. Year 3 Proposals and Funding Status

PI	Proposal Title	Funding Organization	Amount Requested	Status	Amount Awarded
Ollinger (PI), Lemke* (Co-PI) [+]	Investigating drought and cold resilience of northeastern US trees to inform ecological modeling and forest management practices	NSF	$1,252,541	Pending	-
Abedi (PI), Weiskittel (Co-PI), Yasaei Sekeh* (Co-PI), Legaard* (SP), Hayes* (SP)	Theme 3: AI-FOREST Research Institute	NSF	$20,000,000	Pending	-
D'Amato (PI)	Supporting forest-dependent birds and ecosystem services with climate adaptation in Northeastern forests	Department of Interior Climate Adaptation Science Center	$364,814	Pending	-
D'Amato (PI), Weiskittel (Co-PI), Burakowski* (Co-PI), Nelson (Co-PI), Contosta* (Co-PI), Lutz* (Co-PI) [+]	Managing for the cold: developing adaptation practices to preserve cold habitat in Northern Forests	Department of Interior Climate Adaptation Science Center	$392,586	Pending	-
Nelson (PI), D'Amato (Co-PI), Burakowski* (Co-PI), Contosta* (Co-PI), Lutz* (Co-PI) [+]	Managing for the cold: developing adaptation practices to preserve cold habitat in Northern Forests	Northeastern States Research Cooperative	$199,916	Not Awarded	-
Simons-Legaard* (PI), Legaard* (Co-PI)	Optimizing the carbon sequestration and economic potential of natural climate solutions from Maine's working forests	Northeastern States Research Cooperative	$180,960	Not Awarded	-
Total Submitted Yr 3					**$23,733,100**
Pending					**$22,714,987**
Yasaei Sekeh* (PI)	CAREER: Foundations of Deep Neural Network Robustness and Efficiency	NSF	$679,004	Awarded	$679,004
D'Amato (PI)	Implementing forest adaptation options for Northern Forest ecosystems	Northeastern States Research Cooperative	$139,193	Awarded	$139,193
Total Awarded Yr 3					**$818,197**

*Early-career faculty

[+]Inter-jurisdictional proposal

Inter-Jurisdictional Collaboration

A key tenet of the INSPIRES effort is to ensure and enhance 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 focused on continuing to build cross-theme, inter-jurisdictional collaboration in the face of the ongoing pandemic. New cross-theme, inter-jurisdictional ideas 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. **In Year 3, specific efforts were made to encourage cross-theme and inter-jurisdictional collaboration, particularly with the involvement of new project partners at AAMU.** Of note, AAMU PI Dawn Lemke spent several weeks in Maine to meet with project participants and external stakeholders to better understand potential collaborative opportunities. Within New Hampshire, a portion of the funds originally allocated to the University of New Hampshire were redirected to Dartmouth College to increase undergraduate student involvement in INSPIRES and support an early-career, soft-money faculty member there.

Comfortable, open dialogues between team members, particularly inter-jurisdictional ones, have been exceedingly difficult to achieve during the project due to the pandemic. Efforts at improving virtual meeting experiences and effectiveness have been of high priority to the CLT, and we were excited to build momentum from our January virtual meeting to our in-person retreat in May 2022. Ongoing efforts to encourage and shift focus onto inter-jurisdictional collaboration like synthetic publications with early-career researchers and the formation of the collaborative research committee in Year 2 have helped to build effective inter-jurisdictional collaboration. As highlighted at the beginning of this annual report, a table of potential publications and proposals has been drafted, which will be used to track progress. **Important Year 3 successes were continual meetings of the cross-theme, cross-jurisdictional committee, numerous synergistic opportunities identified with AAMU, and the onboarding of Collaborative Project Coordinator Dr. Emily Uhrig who has helped to create additional inter-jurisdictional collaborative opportunities for project participants.** Dr. Uhrig has met with numerous INSPIRES researchers including new faculty at AAMU and has worked to support both early-career faculty and students.

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 was completed during the Year 3 assessment to highlight new inter-jurisdictional collaborations across the primary institutions that has been created by INSPIRES (see Evaluation Year 3 and Appendix 2: External Evaluation Report). As suggested in our external review panel report in Year 2, 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 continues to employ mixed and highly interactive approaches to enhance inter-disciplinary collaboration including a facilitated team-building exercises at the January 2022 All-Team meeting (Figure 17), which led to the formation of tables on potential publications and proposals presented at the beginning of the Year 3 annual report. The team exercise has helped to engage team members, generate innovative ideas for collaboration, facilitate synergistic opportunities, and review project progress after the last three years,

which is often quite difficult to achieve in virtual meetings with more than ten participants. For comparison, most INSPIRES quarterly all-team meetings have 50 or more participants. The field-based workshop in May provided the occasion to identify future opportunities for the project. In addition, we will investigate institutional resources for seed grants when we meet with our Tri-Jurisdictional Institutional Advisory Board in the fall of 2022. The focus of this meeting is on better integration across jurisdictions, more effective leveraging of institutional resources, and project sustainability following the NSF grant, particularly as the project enters its final year of funding. It is hoped that this advisory board will continue to meet regularly to discuss these key topics. Seed grants for writing retreats, conference or workshop attendance, and professional development have been offered to the team, particularly if involvement with AAMU project participants can be achieved. However, most seed grants to facilitate travel have been limited due to the global pandemic. Finally, we continue to explore new communication tools in Year 3 that demonstrate the strong and growing inter-disciplinary collaboration on this project such as a quarterly project newsletter.

Figure 17. Word cloud visioning exercise from January 2022 virtual all-team meeting.

In Year 2, 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." Theme 4 efforts of the past year and plans going forward will enhance future inter-jurisdictional collaboration, which we hope will greatly improve sustainability beyond the end of the project. This was achieved in Year 3 by the recruitment of additional high school teachers in the project and the strong involvement of INSPIRES researchers to regularly present their science to the teachers with plans for another summer professional workshop to bring everyone together to discuss next steps. Teachers have been very engaged and enthusiastic towards the project because they see the value of relevant material in their curriculum.

Workforce Development

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 3 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 have been addressed

through ensuring successful inter-jurisdictional collaborations and providing significant workforce development opportunities. Year 3 saw the onboarding of several new project participants, which has helped to broaden and diversify participation. **Based on the Year 3 Data Outcomes Portal, INSPIRES has been successful at enhancing research capacity across the institutions involved by significantly leveraging the investment being made by NSF. INSPIRES researchers have been very active with proposal development and submission as 49 proposals have been submitted with 21 of them awarded and another 13 still pending. This has generated $14,071,276 million in available new funding, which represents a current ratio of 3.1 for funding generated to amount of funding awarded by the NSF EPSCoR RII Track-2 grant. The majority (60%) of these additional research awards has been obtained through other NSF programs, while most the remainder (30%) 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 Team 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 Year 4.** Future research capacity in this area was discussed with the INSPIRES Tri-Jurisdictional Institutional Advisory Board in April and will be a focus for the remainder of Year 3 and as we move into Year 4. The UMaine team continues to build additional research capacity by better connecting and creating synergies with the other University of Maine Track 2 project (Award #2019470; led by Dr. Brian McGill), which also involves University of Vermont researchers.

Jurisdictional Impacts

Maine

Year 3 saw the continued involvement of numerous early-career faculty members and students at the University of Maine. The INSPIRES effort continues to be primarily led and supported by the University of Maine with involvement of numerous support staff including an Outreach and Communications Specialist (Meg Fergusson), Project Financial Manager (Leslee Canty-Noyes), Administrative Coordinator (Stefania Marthakis) and most recently, a Collaborative Project Coordinator (Emily Uhrig). An important focus in Year 3 at the University of Maine was increasing external communication for the project, which has taken the form of team member profiles posted on social media, e-newsletters that highlight ongoing collaborative efforts, and active involvement on both Twitter and Instagram. The INSPIRES Twitter page has seen increased activity in the last year with additional followers and impressions. As highlighted above, Dr. Emily Uhrig has been an

instrumental project participant who has helped to better coordinate the Theme 2 team, facilitate monthly student meetings, and increase collaboration across both themes as well as jurisdictions, particularly in building new linkages to partners at AAMU. University of Maine INSPIRES graduate student Nicholas Soucy was a Center for Undergraduate Research's 2022 Student Symposium award winner for his INSPIRES-related research (Figure 18).

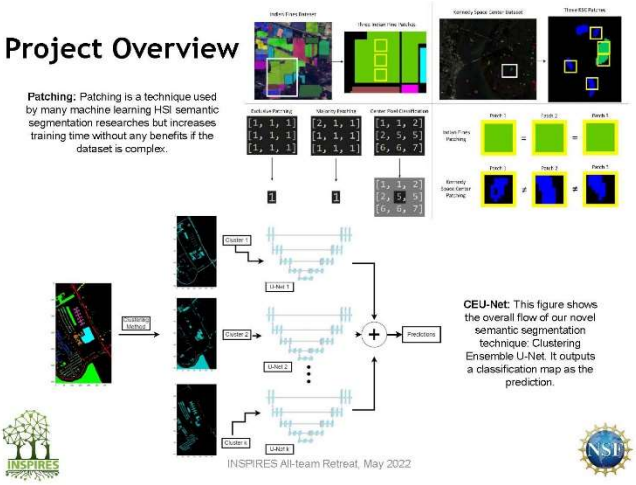


Figure 18. UMaine's Nicholas Soucy won the award for the Engineering and Information Sciences category for the project "CEU-Net: Ensemble Semantic Segmentation of Hyper-spectral Images Using Clustering," and is currently advised by early-career faculty member, Dr. Salimeh Yasaei Sekeh.

With the current momentum and cross-campus collaboration created through INSPIRES, several large collaborative proposals have been drafted and are varying stages of submission. PI Weiskittel is leading an NSF EPSCoR Track 1 concept paper that has been well received both internally and externally. Co-PI Ali Abedi is leading a $20M NSF AI Research Institute proposal that includes involvement of the AAMU partners. Also, PI Weiskittel has been part of several related USDA proposals including a $10M Sustainable Agriculture Systems and a $65M Climate Smart as well as a $45M EDA Build Back Better proposal. These various synergistic activities can help to leverage and sustain the collaborations, outcomes, and knowledge generated by INSPIRES. These sustainability activities are important and vital as INSPIRES moves into its final year.

New Hampshire

The University of New Hampshire team consists of 8 faculty (4 early career), 4 research staff (2 early career), and 3 graduate students. In Year 3, UNH team members focused on building research infrastructure and strengthening external collaborations. Over the past year, led by early career faculty Alix Contosta, **researchers from UNH deployed low-cost sensor prototypes at field sites at numerous field sites across the three states.** This included an interjurisdictional collaboration with UVM and UMaine to establish a set of 48 monitoring plots aimed at understanding the effects of cold-air pooling on local species composition and climate. PhD student Jack Hastings led the construction of a lab-based goniometer setup, allowing for the quantification of leaf to branch scale reflectance. This infrastructure is being used to understand how forest canopies interact with light to improve both remote sensing techniques as well as modeling forest carbon uptake. Early career research scientist Andrew Ouimette developed a new model to simulate carbon and nitrogen dynamics during wood decay, while Zaixing Zhou is leading an effort to formally integrate a landscape successional model (LANDIS) with a biogeochemical model (PnET-CN) (Figure 19). PnET has also been re-coded from the C++ to Python to make model development accessible to students and other researchers. Ouimette, Hastings, Zhou, and Kaitlyn Baillargeon are also collaborating with UVM and UMaine

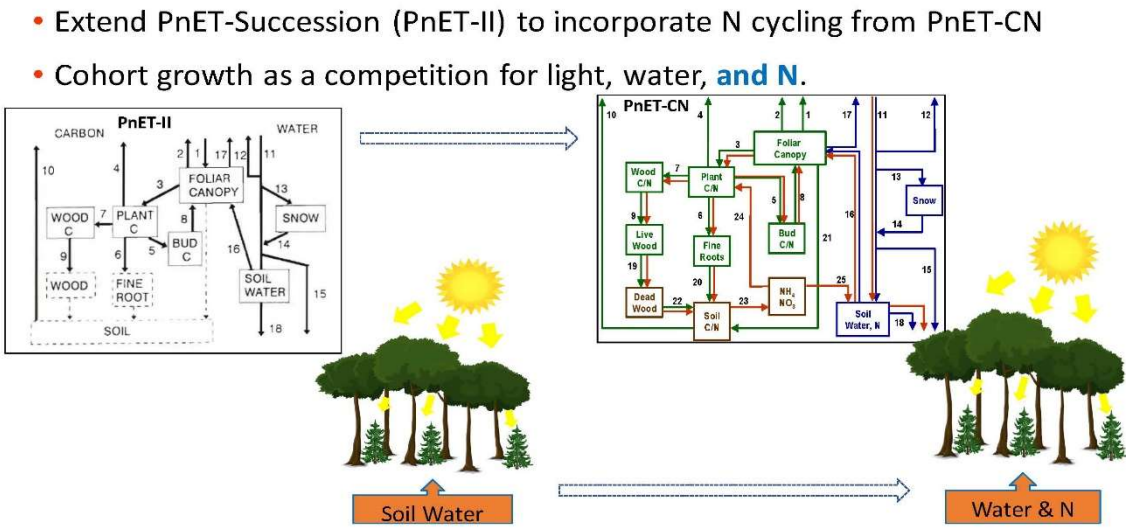


Figure 19. Illustration of integration of nitrogen feedback in LANDIS PnET-Succession from team meeting presentation by INSPIRES researcher Zaixing Zhou.

to develop a regional parameter database (including a regional remotely sensed map of foliar traits) and front-end code to make application of LANDIS and PnET streamlined and easier for students and stakeholders. **C0-PI Ollinger also led a $1.25M proposal in collaboration with AAMU's Dawn Lemke that was submitted to NSF's Organismal Response to Climate Change program. The proposal focuses on forest sensitivity to drought using contrasting sites in New Hampshire and Alabama. The UNH-AAMU team is a new collaboration that was made possible by the addition of AAMU to the INSPIRES project.**

Year 4 plans include expansion of the cold-air pooling sensor network across all jurisdictions. In addition to additional meteorological sensor deployment, this will include field campaigns to quantify plant physiological traits related to drought and temperature tolerance as well as forest productivity. UNH members from Themes 1, 2, and 3 will also attempt to develop ultra-low-cost radiation sensors to deploy within tree crowns that will allow quantification tree species-specific interactions with light. UNH team members also plan to continue model development with the goal of publicly releasing new model versions in Year 4, and will continue to build a regional input parameter database to increase model accessibility.

Vermont

The team based out of the University of Vermont represents 7 faculty, 1 post-doc, 2 graduate students, and 2 research technicians. These participants span three academic units within the University of Vermont. **Dr. Luben Dimov joined the team this year and was instrumental in coordinating with his former institution, AAMU, in securing supplemental funding to partner with the INSPIRES team.** Dave Lutz and his student Emma Hazard and new student Laurella Marin, from Dartmouth College, also remain an integral part of our UVM-based team. UVM team members focused efforts on inter-jurisdictional collaborations across each theme, with an emphasis on attending project-wide monthly theme meetings. There were also several field

visits to newly-established INSPIRES sensor sites in Corinth and Brunswick, VT (Nulhegan Basin) for all team members to share ideas and lessons learned. In addition, **the UVM team organized and hosted a workshop for 45 forest managers and other stakeholders at the Corinth, VT INSPIRES site in September 2021 to demonstrate adaptation strategies for addressing the impacts of non-native insects and diseases (**Photo 6**).** This workshop included demonstrations of the sensor networks installed at this site and their applications to guiding strategies to address global change impacts on forests in the region.

Photo 6. UVM INSPIRES Research Technician Karin Rand describes application of sensor networks at Corinth, VT INSPIRES site for examining impacts of the introduced emerald ash borer on Northern Forests as part of workshop and field tour for foresters and other natural resource managers in September 2021.

Considerable effort in Year 3 was put into increasing regional capacity for advanced sensoring through establishment of new study sites and maintenance of existing sites established in the prior year. To this end, summer field crews, largely composed of undergraduate research technicians supported by the INSPIRES project, were able to establish and measure forest inventory and sensoring plots at the Corinth (VT) and Second College Grant (NH) INSPIRES sensor sites, as well as establish a new INSPIRES sensor site at the US Fish and Wildlife Service Nulhegan Refuge in northeastern VT, which was done in close collaboration with UNH Theme 1 members. **A regional field campaign for a cold-air pooling assessment was led by an early career scientist at UVM (Pastore) in collaboration with early career scientists from the other two jurisdictions (Contosta-UNH; Nelson-UMaine)**. This work established 48 monitoring plots across the three jurisdictions and resulted in the publication of an initial concept paper in Ecology. Theme 4 continued teacher training with the 9 teachers recruited in 2021, including a UVM seminar course that contained guest lectures from researchers on the INSPIRES team. In addition, UVM and UNH investigators on Theme 1 installed an INSPIRES sensor network at a high school in Vermont.

Alabama

Due to processing delays at all institutions, the NSF supplemental grant funding was not finalized until February 2022, which delayed certain paperwork and planned expenditures. Regardless, during this time, faculty members at AAMU attended virtual meetings and built new collaborations with the broader INSPIRES team. Paperwork for hiring the planned post-doc transfer is expected by the end of May with a July 1, 2022 start date. This first year has had both challenges as those outlined above, but inspiring and likely long-lasting collaborations have already been formed. For example, Dr. Dedrick Davis is now working with Theme 1

Photo 7. AAMU summer field crew of undergraduates that will work to complete research related to INSPIRES.

researchers to bring new wireless environmental sensor technology developed under INSPIRES to AAMU. He will also be running a summer field instrumentation course for students at AAMU this summer that will be directly supported through this supplemental grant. **Dr. Lemke spent extended time Maine this past January, which helped to build new partnerships across the INSPIRES jurisdictions on a range of potential applications including the environmental sensor efforts and the educational components of the project.** Dr. Lemke has been mentored by several faculty across the INSPIRES institutions with guidance in building out her base 20 ha forest plot. She has also participated in two collaborative proposals with INSPIRES faculty. Graduate students have been involved with INSPIRES graduate meetings, giving them a depth of interactions that have been difficult during Covid. Over the summer there will be a full engagement of faculty, students and technicians in integrating sensors into both education and forest research at Alabama A&M. With the new post doc, Dr. Chen, starting in May/June the research components of the supplement should ramp up. Full student research and education opportunities facilitated through this grant should be in place by the fall. A team of undergraduate student technicians who will complete fieldwork at Paint Rock this summer has been recruited and trained (Photo 7).

Overall Project Integration

As noted in the External Evaluator's report, **robust research collaboration among project participants is currently happening and there is now an equal number of both intra- and inter-jurisdictional research collaborations.** This is critical as the project enters into its final year and there is an important recognition that the team needs to better identify and prioritize how the connections established because of the INSPIRES project might be sustained or expanded in the long-term. Consequently, overall project integration has been a primary focus in Year 3 with several specific initiatives including cross-theme meetings, improved coordination with involved students, and strategic identification of priority publications as well as proposals. Facilitated discussions at the January all-team meeting (Figure 20) and an open format with a planned field visit for the three-day workshop in late May will be critical for helping to achieve more effective project integration. In addition, better project integration was achieved with the involvement of Dr. Emily Uhrig who serves as the project's collaboration coordinator and started in the fall of 2021. She has been vital for directly connecting with various team members, identifying potential collaboration opportunities, and helping to provide better project integration support. The success of these various efforts has been demonstrated with

continued strong involvement of project participants across all research themes as well as jurisdictions, increased involvement and interactions between students on the project, and focus on collaborative publications or proposals. Despite only being involved in the project since this fall, the partnership with AAMU has been quite strong and they have been very well integrated into the project. This has led to additional collaborative opportunities and new proposals, which have been quite productive for all project participants. **Going into the final year of the project, overall project integration will remain the highest priority and significant effort will be made to ensure the completion of numerous collaborative outcomes.** This will be done in conjunction with improved stakeholder engagement and outreach to ensure the future sustainability of this effort.

What worked well during today's meeting?

- Having structured prompts for breakout groups was much more productive than freeform discussion. There needs to be certain prompts to help discussion flow.
- The breakout room was nice. It was helpful to see some graphical results of surveys on the project from students and faculty.
- Great facilitation - I was unsure how far we could get with such a large group, but it seemed productive given the questions your provided to focus on.
- I thought today went well. It was nice to hear from Heather and Sarah did a great job facilitating. I think it was a little challenging to get in depth on some of the small group discussions but I think that's a reality of zoom conversations vs in person conversations. Hopefully we can push these ideas further during at in person meeting at some point.
- Organization and format of various break out sessions was beneficial
- Overall setting of goals for the next one and a half years.
- Short, focused breakouts
- Facilitated small group discussions with clear directions for discussion topics and deliverables
- Strong participation and good discussion; Supportive and engaging

How can we improve meetings like this in the future?

- Having some breakouts that involve putting theme members together may be a good way to start. Then migrating to random breakout groups with each person bringing some focused interests may help get everyone's feet under them.
- Include some lightning talks, boiled down from presentations people are giving on the project.
- Having a facilitator in the breakout rooms is helpful and makes things go more smoothly. It often ends up happening, but not always.
- More streamlined project reporting. Highlight the most essential successes and challenges.
- In person meetings depending on pandemic situation.
- Maybe taboo, but forced (encouraged participation by everyone in a breakout) - I feel like I talk too much and others are a bit shy but I'd like to hear what they think
- More time in breakouts and less time hearing reporting
- In-person would be ideal but potentially more focused Zoom meetings on specific topics

Figure 20. Commentary on the January virtual all-team meeting.

BROADENING PARTICIPATION

Team Demographics

Significant focus in Year 3 was the successful integration of the AAMU team into INSPIRES. An overall summary of current team member composition across the four jurisdictions is provided in Table 6, while a detailed list of all personnel is provided in Appendix 3**Error! Reference source not found.**. Based on the Data Outcomes Portal report (Appendix 6), INSPIRES faculty composition still has strong representation of early-career investigators (54%) composed of a high percentage of those identifying as female (46%). In terms of race, 10%, 5%, and 36% 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 (20) represented remains relatively high for current team size (45 faculty). 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. **There are 82 active project participants across the four jurisdictions with 20 senior researchers (24%), 25 early career researchers (30%), 2 post-docs (2%), 19 graduate students (23%), 2 undergraduate students (2%), and 14 other participants (17%).** Since the project started, there have been 2 post-doc, 4 undergraduate, and 7 graduate trainees who have graduated.

Table 6. Summary of INSPIRES Team Personnel by Role and Jurisdiction

Role	Jurisdiction				Total
	Maine	New Hampshire	Vermont	Alabama	
Faculty (Early-career)	22 (10)	12 (9)	8 (3)	3 (3)	**45**
Staff (Professional/ Support)	8	2	2	3	**15**
Trainees (Undergraduate/ graduates)	8 (1/7)	6 (1/5)	5 (0/5)	2 (0/2)	**21**
Post-doc	1	-	1	-	**2**
Total	**39**	**20**	**15**	**8**	**82**

Development/Recruitment of Diverse Early Career Faculty

A continued focus in Year 3 was on encouraging early-career faculty to lead high-impact synthesis publications. The benefits for early-career faculty throughout the project have primarily stemmed from theme and institutional cross-collaborations, which are enhancing research and analytical skills for team members. The results of these efforts were quite successful in Year 3 as highlighted above. In particular, INSPIRES UVM post-doc, Melissa Pastore, teamed with other INSPIRES faculty there to write a synthesis publication in top-tier ecological journal (Ecology; Impact Factor = 5.49) on a topic that emerged from Theme 1 discussions. The publication is available online (https://doi.org/10.1002/ecy.3717) and several additional

ones are planned for Year 4 as outlined in the potential publication table near the beginning of this annual report. Similar efforts will also be made on proposal development.

There have been multiple opportunities for early career faculty, particularly with helping to lead or co-lead within the specific research themes. Currently, there are 25 early-career faculty in INSPIRES with a nearly 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 direct support from senior faculty members, which is helping build leadership and organizational skills.** Support for undergraduate and graduate students, equipment, and travel support have all been provided to early-career faculty members. This has also had direct benefits for the early-career faculty members. For example, INSPIRES graduate student Nicholas Soucy (see Appendix 4. Team Member Profiles) won the award for the Engineering and Information Sciences category for the project at the 2022 UMaine Student Symposium in the category Virtual Graduate Presentations and submitted two papers for publication from his research. Nicholas is advised by INSPIRES early career faculty, Dr. Salimeh Yasaei Sekeh, who was recently selected for NSF CAREERS award (#2144960) in Computer and Information Science & Engineering this past year, which was related to some of the research she has pursued with Nicholas Soucy and INSPIRES in general.

At each institution, the Core Leadership Team has continued to check-in with all team members, particularly early-career faculty, to ensure they have the resources needed to successfully 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. This has been particularly important during this project and Year 3 especially given the potential unintended consequences and impacts of the ongoing pandemic. For several early-career faculty members, PI Weiskittel has written reference 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 continue to 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. **To ensure successful outcomes of this project for early-career faculty, the Core Leadership Team plans to provide additional funds in Year 4 to support collaboration, particularly those involving AAMU.**

Development/Recruitment of Diverse Students

Currently, there are 1 female post-doc, 2 undergraduate (1 female) and 19 (11 female) graduate students across the four institutions that are involved with the project. Student diversity significantly increased with the involvement of AAMU as most of them are female and from underrepresented groups. **Overall, 20% of the project's trainees currently identify as an underrepresented minority and 57% identify as an underrepresented group.** Since the project started, 1 (100%), 6 (86%), and 3 (75%) post-doc, graduate, and undergraduate trainees, respectively, were female. The CLT has continued to endeavor to welcome all students on the INSPIRES project, introducing them to the full team and encouraging cross-institutional and cross-jurisdictional connections. With the coordination and guidance provided by project collaboration coordinator Dr. Emily Uhrig, **INSPIRES students have been organizing and utilizing monthly check-in virtual meetings across institutions and jurisdictions**. These sessions have included student-led discussion on their

research as we as guest speakers (mostly female and early-career) from the US Forest Service, National Park Service, Appalachian Mountain Club, and AAMU. These individuals have joined the student meetings to present their research interests as well as discuss their specific organizations and career paths.

Additional opportunities have been provided for students to present findings during both all-team and theme virtual meetings. Graduate students gave flash talks about their research at the all-team meeting in May as well as have been encouraged to reach out and interact with other INSPIRES team members over the coming field season. In addition, INSPIRES graduate students have actively contributed to the project's social media accounts, which has helped to build collaboration and networking across jurisdictions. **Ongoing mentoring and recruitment for the remainder of Year 3 will continue, particularly for undergraduates, and going forward there will be a specific focus on underrepresented groups, particularly racial minorities, and Native Americans. This is especially important for AAMU and will be a high priority for Year 4.**

The pandemic continues to be especially difficult for graduate students due to limited in-person support and high isolation. In Year 3, one graduate student had to withdraw from the projects due to complications and challenges created by the pandemic, and thus fewer withdrawals than prior years of the project. **The Core Leadership Team continues to recognize these challenges and strives to work hard to resolve hardships for both mentors and mentees.** Efforts in Year 3 have focused on refining MEE materials and ensuring students have every opportunity to gain new professional experiences. For example, a field trip to Alabama is being planned so students can help train students there on wireless sensor development and deployment. In July, students from Alabama plan to travel to New Hampshire and learn about ongoing field data collection efforts happening as part of INSPIRES, which will provide invaluable in-person time to connect with fellow students and mentors in the northeast. **Overall, the current students remain highly engaged and enthusiastic about the project, particularly the involvement of underrepresented students from AAMU.**

Leadership and Governance

After over 2 years of meeting monthly to assess project progress, potential issues, and team needs, the Core Leadership Team (CLT) has stepped back a notch to organically allow team faculty and graduate students to lead and organize research projects. As pandemic-related adjustments are becoming less onerous and core research efforts are becoming well established, along with the potential for more in-person and interactive project management, project and theme leads have become proactive and continue to help guide the research. **The role of the CLT has become more focused on ensuring successful outcomes from the research such as synthesis of key research to overall project goals and student retention, while focusing on continued collaboration and long-term research capacity needs.** Project engagement and overall team fatigue remain high concerns for the CLT. The high uncertainty surrounding the ongoing pandemic and general team disappointment over the cancellation of an in-person retreat scheduled for January has been redirected toward a May retreat, which should lead into a collaborative and exciting field season, which we expect will provide a strong boost to overall team morale, particularly with trainees.

As outlined in the original proposal and our current governance document, an additional key project element was the formation of several important committees including a Tri-Jurisdictional Institutional Advisory Board (IAB), and two project committees: Collaborative Research Committee (CRC) and Mentoring, Education, & Engagement (MEE) Committee. The IAB is from a range of disciplines and institutional contexts across jurisdictions that have: (1) helped INSPIRES achieve its research and education goals and outcomes; (2)

respond to external assessment; (3) identify potential jurisdictional barriers to minimize their potential impact on the project; (4) help promote the relevance of INSPIRES to key university stakeholders such as industry, NGOs, and other sectors; and (5) assist with sustainability by helping to identify related research opportunities. The MEE Committee (led by Co-PI D'Amato) has shared mentorship and effective advising across the project and lead educational and professional development activities, including potential course development, writing retreats, and field trips to promote cross-project learning and research advancement. The MEE works closely with the CRC (led by Co-PI Ollinger) to ensure strong cross-institutional and jurisdictional collaborative opportunities. 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. CRC has continued to host monthly cross-theme collaboration meetings where project participants discuss ongoing research and areas of potentially high synergy. Both MEE and CRC have been greatly assisted with the addition of project collaborative coordinator Dr. Emily Uhrig who has assisted with committee key functions, organization, and implementation. She will have a key role in the final year of the project by helping to build and sustain the ongoing synergistic activities that both MEE and CRC have initiated.

While the CLT continued to support these various committees in Year 3, the CLT felt the ongoing impacts of the global pandemic made it too difficult to form an EAB. Regardless, **INSPIRES team members remain highly engaged with stakeholders as 66% and 75% of the Year 3 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 continues to feel well connected with stakeholders and it is believed that a formal EAB would potentially be redundant at this stage of the project, particularly given the input provided by the external evaluator and the recent review panel. Regardless, INSPIRES faculty and the CLT have continued to maintain a list of potential EAB members and will work on connecting with these individuals directly given the future shift to project sustainability and outreach efforts.

To help sustain this positive and significant momentum of INSPIRES, **the CLT continue to revise and update the project implementation plan, particularly the overall project and theme-specific research milestones.** The preparation and presentation of key project briefing materials for the IAB helped identify project strengths and potential opportunities that were explored in Year 3 and will be a primary focus in Year 4. In particular, **the CLT and IAB continue to feel the key strengths are: (1) successful 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; (3) the focus and support for developing an integrated entity that can produce convergent outcomes and products (e.g., the Digital Forest Framework); and (4) the successful integration of a new partner (i.e., AAMU) into the project during an ongoing pandemic.** These core strengths have been clearly expressed to the IAB and the CLT will fully leverage them in the final year of the project. The addition of perspective and input from AMMU PI Dawn Lemke has been invaluable to CLT discussions. She already feels like INSPIRES has been a tremendous help for her to build linkages to both researchers at her own institution as well as externally. PI Weiskittel and Co-PI Lemke have continued ongoing discussions to help leverage and sustain these collaborations, particularly with INSPIRES post-doc Cen Chen now transitioning from full-time employment at the University of Maine to AAMU.

Table 7. INSPIRES Benchmarks and Accomplishments

Program Area	Output/Outcome/ Impact Indicators	Annual Project Benchmarks	Year 3 Accomplishments
Research Capacity	Interdisciplinary and convergent research collaborations Post-docs recruited Graduate students enrolled New regional Complex Systems Research Consortium	3 post-docs and 8 graduate students 3 research assistants, strategic plan presented to internal/external advisory boards	Increased team size through MSI supplemental grant with AAMU 2 post-docs, 19 graduate students, 8 research assistants Project strategic plan updated Internal advisory board updated in August 2021 and priorities identified Potential publications and proposals identified
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 (4) and proposals (2) Graduate student led presentations (2) and publications (1) 2 data products publicly available
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	Significantly broaden participation with AAMU's involvement Undergraduates involved (2) 47% female trainees, and trainee participation from underrepresented groups (57%) Participation in an inter-institutional graduate course at AAMU Student exchanges with AAMU

Program Area	Output/Outcome/ Impact Indicators	Annual Project Benchmarks	Year 3 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) 1,000 students impacted (Yrs 2-4) 20 involved (Yrs 2-4) post-docs/graduate/under-graduate students gain experience in K-12 education, perspectives from WaYS reflected in curricular materials	55% of faculty involved are early career (25) 17 high school science teachers actively involved in Maine (8) and Vermont (9) Summer hands-on teacher's workshop held in Maine in July 2021 Project participants have presented and collaborated with K-12 educators on a regular basis A 3-credit INSPIRES Teacher Professional Learning graduate course offered by UVM 3-hour spatial ML workshop presented by ESRI
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	New partnership created 6 outreach events across the primary jurisdictions Several recent media features Active social media presence Connections to Maine tribal councils strengthened with collaboration planned

EVALUATION Year 3

Overview

The Implementation Group (TIG) completed the Year 3 evaluation activities, and the full report is provided in Appendix 2. In Year 3, students were surveyed in October 2021, faculty and non-faculty researchers were surveyed in November-December 2021, and a follow-up focus group interview with graduate students was conducted on November 10, 2021. Dr. Maysaa Alobaidi, who conducted the baseline evaluation report for AAAS in Year 1 and TIG in Year 2 was retained in Year 3 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. In addition, a survey of faculty and researchers from AAMU conducted in March 2022. A report prepared by Integrated Learning Innovations on Year 3 results entered in the Data Outcomes Portal has been included in evaluation materials sent to our program officer. The Year 3 final ILI report was revised and received on April 1, 2022 and shared with TIG.

Outcomes

Response to the Year 3 survey varied from 50% (faculty) to 75% (undergraduate students), while a 83% response rate was achieved for the AAMU baseline survey. The evaluation report indicated that: (1) early career investigators continue to show robust participation in project activities; (2) the project team is involved equally in intra- and inter-jurisdictional research collaborations; (3) majority (75%) of project participants have engaged or plan to engage with external stakeholders; (4) data suggests that the INSPIRES project has high potential to make a significant contribution to developing the STEM workforce in the participating jurisdictions; (5) addition of the MSI supplement in 2021 to the project has significantly enhanced the diversity of the INSPIRES project faculty researchers, and students. Based on the student focus-group, the evaluators noted that INSPIRES has provided an important network that serves as a support system, has given opportunities to make a scientific contribution with societal impact, and has had highly supportive mentors. From the survey, specific recommendations were: (1) increased transparency on how project data, resources, and funding are being shared or allocated; (2) identify and prioritize how the connections established as a result of the INSPIRES project might be sustained or expanded in the long-term; and (3) consider ways in which external stakeholders might be engaged in evaluation activities to enable assessment of the effectiveness and outcomes of these collaborations and the broader societal impact of INSPIRES project activities. From the student focus-group, specific recommendations were: (1) increased exposure to non-academics; (2) improved inter-theme interactions and integration; and (3) better clarity on who will be the end users of products developed by the INSPIRES project.

Next Steps

Based on this input from the project participants, the Core Leadership Team will share the findings and recommendations to the team, which will be a basis of discussion at the May annual retreat. Given the project is moving into its final year of funding, emphasis will be placed on ensuring long-lasting outcomes from the effort and better engaging stakeholders in a strategic yet highly targeted manner. A future team meeting is being planned in Alabama to help better engage team members there and next summer's annual retreat might include a one-day open-house to showcase all the great outcomes and outputs of INSPIRES. Based on the input of the students, the project collaboration coordinator will continue to engage trainees and help build potential connections to non-academics, which has been a primary focus of the ongoing monthly meetings. Going forward, students would be encouraged to participate in the regular cross-theme meetings and the monthly meetings might include specific stakeholders with stated needs that INSPIRES researchers

are currently working on. Next year, a summative assessment by an external expert panel, which is currently planned for January 2023, will assess the extent to which the research activities and products are progressing as planned and are contributing new research capabilities to the jurisdictions involved, which will help to better showcase the real collaboration and contributions of this effort.

"Our work contributes to building a more informed citizenry who understand data and how it can inform policy and decision making. I hope that these students will become adults who use this knowledge to inform future forest policy and management, as voting citizens and also possibly as scientists."

Survey response on how faculty researchers expect their work as part of the project to influence future forest policy/management decisions

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. In Year 3, the guidelines for effective collaboration for student mentors and mentees have been updated and revised by this committee with input from all INSPIRES team members. **The MEE provides students with the space to openly discuss challenges they are facing, network with fellow students, and hear from the other INSPIRES team members about their research as well as professional development.** This committee has been especially important during this project given the ongoing and evolving nature of the current pandemic, which has been particularly challenging for graduate students starting new programs. Project collaborative coordinator Dr. Emily Uhrig has been vital for keeping the students engaged and helping to support the ongoing efforts of this committee. For Year 4, the committee hopes to better document and learn from the projects.

Collaborative Research Committee (CRC)

The Collaborative Research Committee (CRC) led by Co-PI Ollinger has continued to meet regularly to discuss cross-theme and inter-jurisdictional research collaborations. The CRC took the lead on a key discussion focused on joint publications and proposals at the January 2022 all-team meeting. **An outcome of this is a cross-jurisdictional/cross-theme shared table of potential publications and proposals that is accessible to**

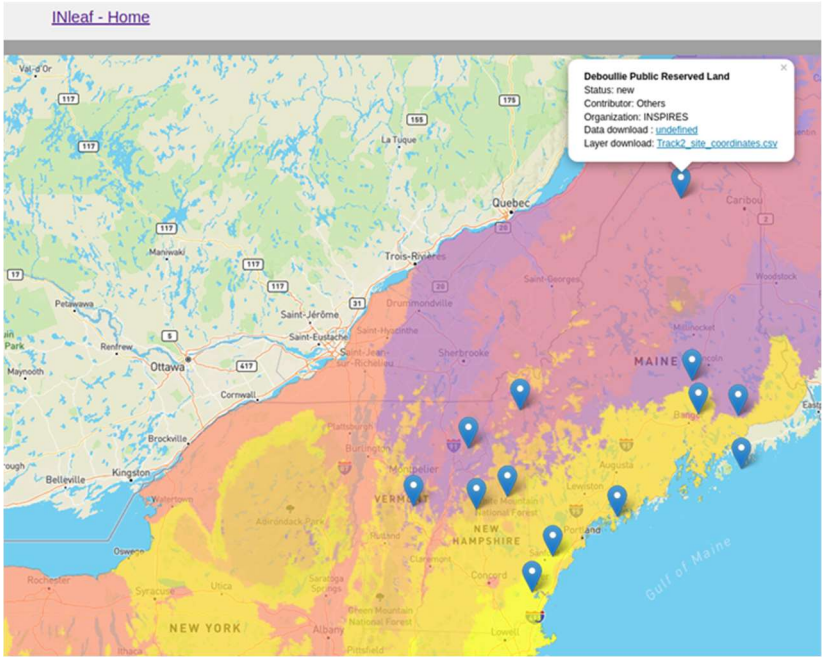


Figure 21. INleaf online platform created by team member Leo Edmiston-Cyr (UMaine) showcasing INSPIRES research locations across the three primary jurisdictions and the climate zones developed by Theme 2 in Year 2. The tool is available at: http://inleaf.inspires.acg.maine.edu/.

the full team and allows team members to contribute ideas and connect with possible collaborators. In addition, the CRC led to the creation of InLeaf, which is an online platform for geospatial data sharing and visualization (Figure 21). In Year 3, InLeaf has been continued to be refined, updated, and expanded by INSPIRES team member Leo Edmiston-Cyr, and it was recently presented to the Theme 4 high school teachers as a potential tool for their QRC curriculum activities and was well received. The CRC has also identified key regional research infrastructure needs in Year 3, which has led INSPIRES partner Appalachian Mountain Club to develop a briefing paper that has been shared and presented to Federal delegations of the three northeast jurisdictions. This brief paper focuses on the changing winters in New England (a key research topic in Theme 1) and the need for better monitoring through an integrated network of snow monitoring stations, similar to SnoTel in the western US. The Appalachian Mountain Club has also connected and presented this to the USDA SnoTel leadership. All parties have recognized the clear need for SnoTel-East and it is currently being prioritized for potential Federal funding, which would be a direct result of the CRC and the partnerships that INSPIRES has helped to foster. **In Year 4, CRC will focus on outlining and planning the Complex Systems Regional Consortium, which will help to leverage and sustain the momentum created by INSPIRES.**

Data Sharing Subcommittee (DSS)

A cross-theme/cross-institutional subcommittee finalized and updated a concise document that would provide a foundational data sharing implementation plan in Year 3 (See Appendix X). The DSS is co-led by Leo Edmiston-Cyr (UMaine) and Mary Martin (UNH) with active participation from across the different themes. In Year 3, the DSS continued to maintain the necessary cyberinfrastructure for effective data sharing and provided additional data standards as well as templates to maintain consistency across themes. These templates are currently being refined to encourage and ease data sharing via the Environmental Data Initiative, which is the long-term repository for all data created by the INSPIRES effort. To accomplish this, the DSS has provided Excel-based templates for both the raw data and metadata, while R code is currently being developed to further simplify the process. The DSS is currently working with several INSPIRES researchers to prepare and upload their data to the Environmental Data Initiative's online repository. In Year 4, the DSS will continue to encourage data submissions and sharing, particularly following the project completion.

Inter-jurisdictional Advisory Board (IAB)

The Inter-jurisdictional Advisory Board (IAB) was formed in Year 2 and formally met in Year 3 (August 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 August 2021 IAB meeting with the CLT 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, Arctic Initiative) and finally, linkages to the region's tribal nations. Specific outcomes of the meeting were a focus on cross-jurisdictional collaboration issues at the next National EPSCoR meeting in November 2022, linking the INSPIRES Theme 4

education and outreach efforts to key EPSCoR representatives, importance of supporting institutional Indigenous Knowledge research, and the importance of common regional environmental monitoring infrastructure, which led to the SnoTel-East briefing paper. 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. A copy of the Year 3 annual report and plans for a summer IAB meeting will be made available to the IAB in the coming weeks. **A key focal item of the IAB in Year 4 will be leveraging the current collaborations with AAMU and sustaining INSPIRES following the project's completion with NSF.**

Collaborative Research Development

The INSPIRES project started August 1, 2019 and is a relatively large multi-jurisdictional, multi-disciplinary effort with over 80 team members now. **Over the last three years, the project has focused on team building 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 continued to conduct facilitated team-building exercises with the full team in January 2022. The team was highly appreciative of the in-person collaboration with cross-institutional, cross-theme team building during the multi-day retreat in May 2022. Despite pandemic-imposed difficulties, the CLT has successfully incorporated 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 including a planned summer e-newsletter that will go to both the team and external project collaborators. Online documents and resources to help foster team collaboration are regularly reviewed and updated. The team website, shared project calendar, project jargon or acronym dictionary, summary of project resources, anonymous feedback form, social media sites, and YouTube channel continue to highlight a multitude of team successes.

A primary focus during Year 2 was on the initiation of cross-theme, inter-jurisdictional research efforts as outlined in this annual report with team building still ongoing, particularly with a new project partner (AAMU). The project implementation plan developed in Year 1 provided the necessary structure, governance, strategic assessment, and plans for research, communications, and evaluation, which has continued to be updated and refined to help guide project strategic activities. A major success in Year 2 was the development and implementation of a detailed data sharing implementation plan. **In Year 3, collaborative research developed has been primarily supported and enhanced by the new collaborative project coordinator (Dr. Emily Uhrig) who has helped to facilitate synergistic connections, particularly with our new team members at AAMU.** In addition, a new subaward with Dartmouth College was established in Year 3 using reallocated funding from UNH and will now support an early-career faculty member (David Lutz) as well as his undergraduate research assistants who have been involved with the effort since Year 1. This should help facilitate additional collaboration opportunities and capacity, particularly given the potential linkages to AAMU.

Finally, collaborative research development has been facilitated by identifying key topics that resonate across themes. Some of the most important key topics have been team collaboration platforms, knowledge to action, and K-12 education, which will receive more attention and focus at future team meetings. Team members have already started forming working groups to work on these additional topics. For example,

during the January 2022 full-team meeting, INSPIRES researchers Peter Nelson and Ken Bundy led an open discussion and tutorial session on how to effectively navigate and use Github for collaboratively developing code, which is a collaborative platform that has been successfully used by several research themes in INSPIRES now. Collaborative research development has also been enhanced with the online tool InLeaf, which allows researchers to openly share and visualize data from INSPIRES across the involved themes and jurisdictions. InLeaf will likely be the primary online platform for sustaining future INSPIRES efforts and sharing the outcomes with a broader audience. **As the team enters Year 4 and begins considering project wrap-up, ensuring continued collaborative research development will take priority and the CLT will engage with team members to ensure successful outcomes from the effort.**

FUTURE PLANS

Despite the continued negative impacts and challenges created from the ongoing global pandemic, INSPIRES has continued to effectively collaborate, enhance research capacity, and produce relevant outcomes across four EPSCoR jurisdictions in Year 3. Key Year 4 project plans and milestones will include:

- Continuation of regular research theme and subcommittee meetings with quarterly all-team meetings and an annual project retreat scheduled for January 2023 in Alabama
- Directly work with both the project's external evaluator and internal advisory board to develop refined survey instruments to collect data from project constituencies
- Complete summative assessment by an external expert panel, which is planned to coincide with annual project retreat in January 2023
- 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 and successfully launch certain project communication materials such as a regular e-newsletter for project participants and external stakeholders
- Finalize and widely share key project materials such as the governance agreement, project implementation plan, and project acronym/jargon dictionary and ask project participants for input on their overall usefulness
- Organize and conduct an INSPIRES field trip in June/July 2023 to visit specific research sites and consider future usefulness following the project
- Conduct key stakeholder outreach events such as workshops, site visits, and technical sessions
- Refine mentoring and student engagement based on solicited feedback from project participants
- Work with the Tri-Jurisdictional Institutional Advisory Board (IAB) to sustain the momentum and focus of INSPIRES through a regional consortium
- Strategically survey project team to better understand project successes, challenges, and areas of improvement to fully document lesson learned that can help to guide future efforts
- Have strong team participation at the NSF National EPSCoR meeting in November 2022 to effectively showcase the outcomes and successes of INSPIRES
- Prepare to sustain project elements like website, communication materials, and data following project completion in July 2023
- Promote completion of several collaborative synthesis papers and strategically pursue funding opportunities to help sustain INSPIRES collaboration
- Finalize QRC curriculum teaching materials and implement them in the classroom across the involved jurisdictions
- Host the summer high school science teacher's professional development workshop in both 2022 and 2023
- Based on student input, an online module on technical writing is being developed and will be a focus of monthly discussions in the fall
- Successfully launch several INSPIRES online tools including InLeaf, ForEST, and the Digital Forest

EXPENDITURES AND UNOBLIGATED FUNDS

Year 3 Financial Plan

The ongoing pandemic has continued to create significant challenges with spending the available funding given hiring challenges, limited travel opportunities, and reduced availability of equipment/supplies. Also, significant delays with processing the subawards with AAMU and Dartmouth College limited expenditures from those two institutions in Year 3. Despite these challenges, the project spent more than 80% of the obligated funding for Year 3 (Table 8) and is currently on track to be fully spent out by the end of the project in July 2023.

Across the involved institutions, the funds have primarily been used to support professional staff such as research assistants and post-docs as well as graduate students followed by travel, materials & supplies, and professional services. These trends will likely continue in Year 4 with the AAMU post-doc being fully hired and starting there in June 2022 as well as new graduate students and research assistants at UNH. There is also an expected increase in travel expenditures going forward with the return of in-person workshops and conferences. For example, a multi-day, in-person project retreat and summative assessment is being planned to occur in Alabama in January 2023. A final project symposium in conjunction with the high school science teachers' summer professional workshop at the University of Maine has also been discussed. Overall, it is expected that a no-cost extension will not be required given current project expenditures trends and projections.

Table 8. Funding Expenditures

Item	Spent	Allocated	Variance	% Variance
University of Maine (Project Lead)				
Salary	$252,171.59	$197,770.00	$54,401.59	27.51%
Fringe Benefits	$47,718.29	$36,886.00	$10,832.29	29.37%
Travel	$8,422.10	$15,000.00	$6,577.90	43.85%
Materials and Supplies	$13,925.74	$1,108.00	$12,817.74	1156.84%
Professional Services	$35,565.04	$12,500.00	$23,065.04	184.52%
Computer Services	$99.00	$10,000.00	$9,901.00	99.01%
Other Costs	$25,551.00	$83,817.00	$58,266.00	69.52%
Indirect	$118,675.49	$144,971.00	$26,295.51	18.14%
Total	$502,128.25	$502,053.00	$75.25	100.01%
New Hampshire (University of New Hampshire & Dartmouth)				
Salary	$131,325.88	$219,476.00	$88,150.12	40.16%

Item	Spent	Allocated	Variance	% Variance
Fringe Benefits	$41,439.29	$53,347.00	$11,907.71	22.32%
Travel	$6,666.50	$6,525.00	$141.50	2.17%
Materials and Supplies	$19,018.87	$4,550.00	$14,468.87	318.00%
Professional Services	$5,355.19	$-	$-	-
Computer Services	$-	$2,200.00	$2,200.00	100.00%
Other Costs	$5,954.50	$43,085.00	$37,130.50	86.18%
Indirect	$84,405.31	$144,479.00	$60,073.69	41.58%
Total	$294,165.54	$473,662.00	$179,496.46	62.10%
University of Vermont				
Salary	$184,787.00	$184,787.00	$-	0.00%
Fringe Benefits	$62,973.00	$62,973.00	$-	0.00%
Travel	$21,900.00	$21,900.00	$-	0.00%
Materials and Supplies	$14,658.00	$15,000.00	$342.00	2.28%
Professional Services	$-	$-	$-	-
Computer Services	$-	$4,060.00	$4,060.00	100.00%
Other Costs	$39,245.00	$39,089.00	$156.00	0.40%
Indirect	$158,789.00	$161,683.00	$2,894.00	1.79%
Total	$482,352.00	$489,492.00	$7,140.00	1.46%
Alabama A&M University				
Salary	$40,000.00	$82,554.00	$42,554.00	48.45%
Fringe Benefits	$12,000.00	$28,894.00	$16,894.00	41.53%
Travel	$20,000.00	$30,000.00	$10,000.00	66.67%
Materials and Supplies	$4,500.00	$12,944.00	$8,444.00	34.77%
Professional Services	$-	$-	$-	-
Computer Services	-	-	-	-
Other Costs	$30,000.00	$58,000.00	$28,000.00	51.72%
Indirect	$30,000.00	$74,108.00	$44,108.00	40.48%

Item	Spent	Allocated	Variance	% Variance
Total	$136,500.00	$286,500.00	$150,000.00	47.64%
		Overall Project		
Item	**Spent**	**Allocated**	**Variance**	**% Variance**
Salary	$608,284.47	$684,587.00	$185,105.71	88.85%
Fringe Benefits	$164,130.58	$182,100.00	$39,634.00	90.13%
Travel	$56,988.60	$73,425.00	$16,719.40	77.61%
Materials and Supplies	$52,102.61	$33,602.00	$36,072.61	155.06%
Professional Services	$40,920.23	$12,500.00	$23,065.04	327.36%
Computer Services	$99.00	$16,260.00	$6,260.00	0.61%
Other Costs	$100,750.50	$223,991.00	$123,552.50	44.98%
Indirect	$391,869.80	$525,241.00	$133,371.20	74.61%
Total	$1,415,145.79	$1,751,706.00	$563,780.46	80.79%

APPENDICES

Appendix 1. Products Year 3

Bold indicates INSPIRES project participants.

Journal or Juried Conference Papers (12 published; 1 under review)

Burakowski, E., Sallada, S., **Contosta, A.,** Grogan, D., **Sanders-DeMott, R.** 2022. Tracking environmental change using low-cost instruments during the winter-spring transition season. American Biology Teacher 84(4): 219-222. doi.org/10.1525/abt.2022.84.4.219

Burakowski, E.A., Contosta, A.R., Grogan, D., **Nelson, S.J.**, Garlick, S., Casson, N. 2022. The future of winter in northeastern North America: climate indicators portray continued or accelerated warming and loss of snow that will impact ecosystems and communities. Northeastern Naturalist 28(11): 180-207.

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(2):33. doi.org/10.1007/s13595-021-01059-y

Clark, P.W., D'Amato, A.W., Evans, K.S., Schaberg, P.G., Woodall, C.W. 2021. Ecological memory and regional context influence performance of adaptation plantings in northeastern US temperate forests. Journal of Applied Ecology 14056. doi.org/10.1111/1365-2664.14056

D'Amato, A., Classen, A., Adair, C., Foster, J. 2022. Cold-air pools as microrefugia for ecosystem functions in the face of climate change. Ecology e3717. doi.org/10.1002/ecy.3717

D'Amato, A., Foster, J., Simons-Legaard, E., Weiskittel, A. 2022.Integrating historical observations alters projections of eastern North American spruce-fir habitat under climate change. Ecosphere 13(4): e4016. doi.org/10.1002/ecs2.4016

Gough, C.M., **Foster, J.R.,** Bond-Lamberty, B., Tallant, J.M. 2022. Inferring the effects of partial defoliation on the carbon cycle from forest structure: challenges and opportunities. Environmental Research Letters 17(1):011002. doi.org/10.1088/1748-9326/ac46e9

Naderi, S., Khosroazad, S., **Abedi, A.** 2022. Relay-Assisted Wireless Energy Transfer for Efficient Spectrum Sharing in Harsh Environments. International Journal of Wireless Information Networks 1-10. doi.org/10.1007/s10776-022-00552-z

Ravi Ganesh, M., Blanchard, D., Corso, J.J., **Yasaei Sekeh, S.** 2021. Slimming Neural Networks Using Adaptive Connectivity Scores. arXiv preprint arXiv:2006.12463.doi.org/10.48550/arXiv.2006.12463

Simons-Legaard, E., Legaard, K., Weiskittel, A. 2021. Projecting complex interactions between forest harvest and succession in the northern Acadian Forest Region. Ecological Modeling 456: 109657. doi.org/10.1016/j.ecolmodel.2021.109657

Soucy, A., De Urioste-Stone, S., Fernandez, I.J., **Weiskittel, A.,** Rahimzadeh-Bajgiran, P., Doak, T. 2021. Forest Policies and Adaptation to Climate Change in Maine: Stakeholder Perceptions and Recommendations. Maine Policy Review 30(1): 66-77. doi.org/10.53558/XNWP9949

Soucy, N., Yasaei Sekeh, S.Y. Under Review. CEU-Net: Ensemble Semantic Segmentation of Hyperspectral Images Using

Clustering. IEEE Transactions on Geoscience and Remote Sensing.

Woodall, C.W., **Weiskittel, A.R.** 2021. Relative density of United States forests has shifted to higher levels over last two decades with important implications for future dynamics. Scientific Reports 11(1):18848. doi.org/10.1038/s41598-021-98244-w

Conference Presentations (10)

Baillargeon, L., **Ollinger, S.V., Ouimette, A.,** Sullivan, F., **Martin, M.** 2021. Biodiversity does not Correlate with Productivity in Temperate Forests at Local Scales. AGU Fall Meeting. Dec

Briones, V., Hayes, D., Weiskittel, A. 2021. Analyzing Past and Future Impacts of Seasonal Climate Change on Forest Phenology in Maine. AGU Fall Meeting. Dec

Burakowski, E., Contosta, A., Sanders-Demott, R. 2021. Tracking the Vernal Window using GLOBE protocols. INSPIRES Summer 2021 Teacher Workshop: Quantitative Reasoning in Context. Jul

Contosta, A., Fratini, J., **Lindsay, S., Nelson, S.,** Fronczak, J., **Van der Eb, M.** 2021. Research-Practice Partnerships: Fostering Productive Collaborations Between Researchers and Teachers. Strengthening Research-Guided STEM Teaching and Learning for Maine Students. Nov

Foster, J., LaRue, E., Matthes, J.H., Fahey, R., Hardiman, B. 2021. Landsat time series and disturbed forest structure at NEON tower sites. American Geophysical Union Annual Meeting. Dec

Murray, P., Classen, A.T., D'Amato, A.W., Evans, D., Fraver, S., **Lutz, D.A.,** Woodall, C.W., **Adair, E.C.** 2021. Linking enzymatic activities in deadwood and soil in a managed northeastern forest. Ecological Society of America 2021 Annual Meeting. Aug

Ouimette, A., Ollinger, S.V., Hastings, J., Johnson, C.E., **Foster, J.R., Weiskittel, A.R., D'Amato, A.W.** 2021. Including Microbial Processes is Important for Modelling Carbon and Nitrogen Dynamics During Wood Decay. AGU Fall Meeting. Dec

Peterson, F. 2021. Designing Rich Mathematical Tasks that Support a Growth Mindset. Integrating Research and Practice: Moving Forward in STEM Teaching and Learning through Research-Practice Partnerships. Jun

Peterson, F. 2021. Rich Mathematical Tasks that Promote Reasoning and Problem Solving. Strengthening Research-Guided STEM Teaching and Learning for Maine Students. Nov

Scott, L., Smith, S., **Petrik, M., Gunn, J.,** Belair, E., Buchholz, T., **Ducey, M.** 2021. Rule-based classification to optimize forest carbon sequestration following an eastern spruce budworm outbreak. 2021 International Boreal Forest Research Association Conference. Aug

Video Outreach (3)

Guts of Climate Model: **S**hort educational video by **Liz Burakowski** for local school district for their Coding and Cocoa for Hour of Code week celebration in December 2021

INSPIRES Teacher Tour: Workshop Intro: INSPIRES Theme 4 hosted teachers from around the northeast for a field visit at the Schoodic Institute in Maine to support integration of Quantitative Reasoning in Context using forestry science and research.

INSPIRES Teach Workshop: Research Goals: INSPIRES Theme 3 researchers worked with teachers Maine, Vermont & New Hampshire to install climate data instrumentation with the goal of setting up data collection stations at regional schools.

REPORT
INSPIRES Annual Formative Evaluation

April 2022

Prepared by:
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For:

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The Implementation Group (TIG)

Introduction

The *Leveraging Intelligent Informatics and Smart Data for Improved Understanding of Northern Forest Ecosystem Resiliency* (INSPIRES) project is in its third year of funding by the National Science Foundation (NSF) EPSCoR RII Track-2 program. Demographic data from INSPIRES researchers and trainees, and formative data on research outcomes achieved by the project have been collected annually for three years through the NSF EPSCoR RII Track-2 Data Outcomes Portal (T2-DOP). The project's external evaluator collected additional baseline and annual data about project participants (including demographics, professional backgrounds, individual roles in the project, prior and current collaborations, levels of research productivity, and participants' perceptions about different aspects of project implementation) from INSPIRES faculty and non-faculty researchers using surveys in **year one** (January 2020) and the start of **year two** (November-December 2020) of the award. Baseline graduate and undergraduate student surveys were conducted in September 2020. Survey findings were summarized in Annual Evaluation Reports and shared with the project leadership in April 2020 and April 2021.

This report summarizes findings collected from project participants at the start of **year three**[1]: graduate and undergraduate students were surveyed in October 2021, faculty and non-faculty researchers were surveyed in November-December 2021, and a focus group interview with graduate students was conducted by the project's external evaluator on November 10, 2021. The surveys collected information about project student participants and the outcomes of their participation in INSPIRES project activities. The focus group discussion explored in more depth the impact of the INSPIRES project on graduate student training in the project jurisdictions. The report also includes findings from a survey of faculty and researchers from Alabama Agricultural & Mechanical (AAMU) University conducted in March 2022. AAMU is a Historically Black College and University (HBCU) and an officially recognized Minority Serving Institution (MSI) in an EPSCoR jurisdiction. AAMU joined INSPIRES in fall 2021 under a supplemental award from the NSF EPSCoR RII program. This report summarizes research productivity outcomes data collected by the project through March 31, 2022, including some data compiled in the *NSF EPSCoR RII Track-2 Data Outcomes Portal Formative Feedback Report* for award year 3.[2]

Evaluation surveys were distributed to the following groups in year 3 of the award:

- *INSPIRES Faculty & Researchers* – (N=42): survey launched in December 2021
  - 21 responses (50% response rate)
- *INSPIRES Graduate Students* – (N=14): survey launched in September 2021
  - 7 responses (50% response rate)
- *INSPIRES Undergraduate Students* – (N=4): survey launched in September 2021
  - 3 responses (75% response rate)
- *AAMU Faculty & Researchers* – (N=6): survey launched in March 2022
  - 5 responses (83.3% response rate)

SurveyMonkey® was used as a platform to collect the survey data.

[1] Year One (Year 1), Year Two (Year 2), and Year Three (Year 3) will be used throughout this report to describe data collection timing and surveys, based on definitions used here (in the introduction section).

[2] DOP data are also compiled in the *NSF EPSCoR RII Track-2 Data Outcomes Portal Formative Feedback Report*, *Award Year 3* (April 16, 2022) prepared by Integrated Learning Innovations, Inc.

Survey Participants

Cross-Jurisdictional Participation

Twenty-one (21) INSPIRES faculty and researchers participated in the Year 3 Faculty & Researchers Survey (Figure 1). Significantly more survey responses were obtained from University of Maine participants compared to those affiliated with the University of New Hampshire and the University of Vermont. A nearly equal number of responses were obtained from senior and early-stage investigators.

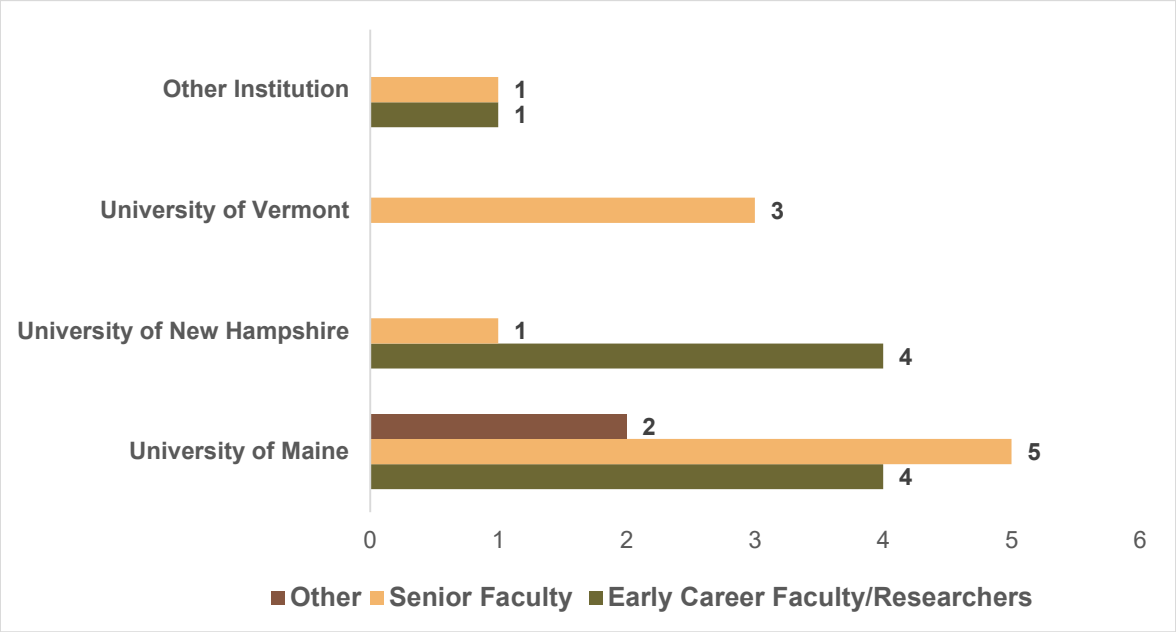


Figure 1: Distribution of Survey Responses by Institution and Career Stage for INSPIRES Faculty and Researchers (N=21)

Cross-disciplinary Research

Faculty and researchers were asked to describe their primary disciplines. Twenty specific disciplines were reported. A word cloud generated from survey responses (Figure 2) indicates the fields of ecology, machine learning, science education, education, forestry, and biometrics are the primary fields of study among investigators.

• Biogeochemistry • Biometrics • Climate Science • Data Science • Ecology • Ecosystem Ecology • Forest Biometrics • Forest remote sensing • Forestry, Forest Ecology and Silviculture • Geochemistry • Machine Learning • Machine Learning (water mission) • Machine Learning/Artificial Intelligence • Marine Sciences • STEM Education • STEM Education Research • STEM Education and Physics • Spatial Informatics • Ecosystem & Global Change Ecology • Science

Figure 2: Primary Disciplines Reported by Faculty and Researchers

Gender and Racial/Ethnic Diversity

Of the faculty and researchers who participated in the Year 3 Faculty & Researcher Survey, 11 (52%) identified as female (Figure 4), and almost all identified as white (Figure 5). Of the new AAMU team members, three (60%) identified as female.

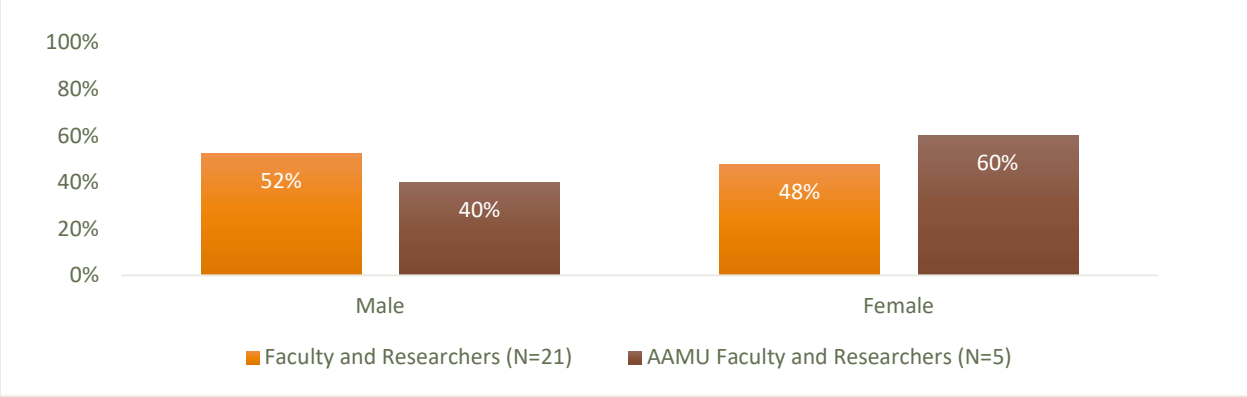


Figure 4: INSPIRES Faculty and Researchers Self-reported Gender Distribution

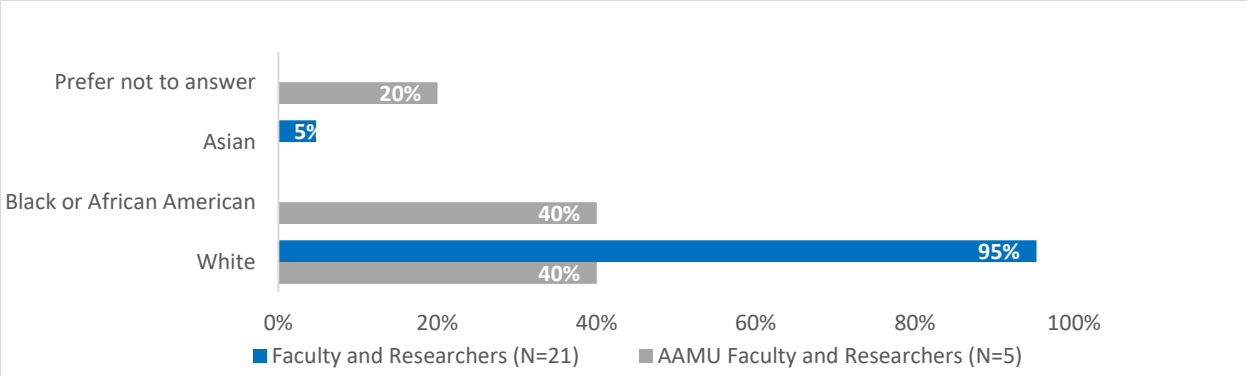


Figure 5: INSPIRES Faculty and Researchers Self-reported Race/Ethnicity Distribution

Of the graduate and undergraduate students who participated in the fall 2021 student survey, 4 (57%) graduate students and 1 undergraduate student identified as male (Figure 6), and most graduates (71.4%) and all undergraduates (100%) identified as white (Figure 7). The majority of the graduate student survey participants are in their second year of graduate training (Figure 8).

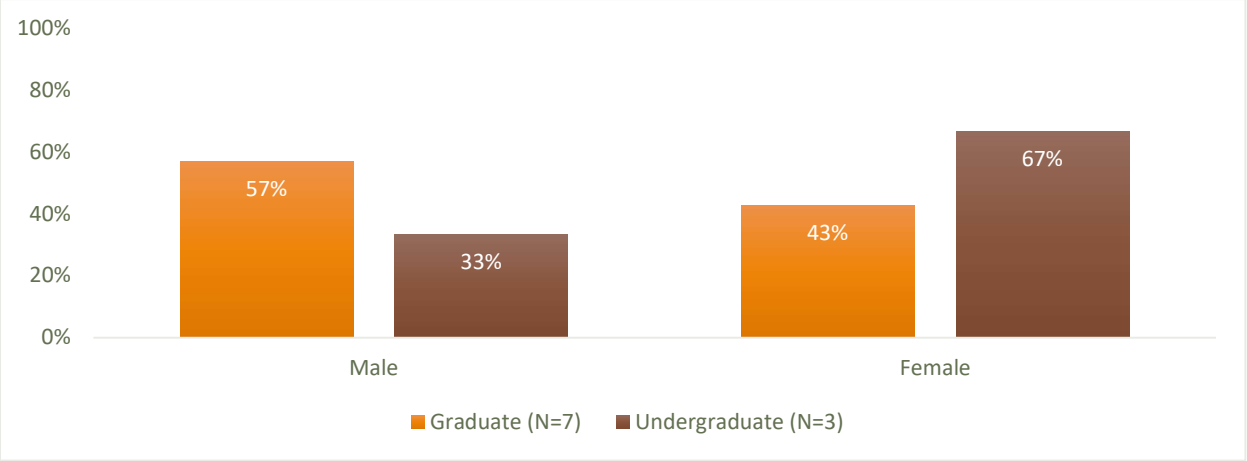


Figure 6: INSPIRES Graduate and Undergraduate Students Self-Reported Gender

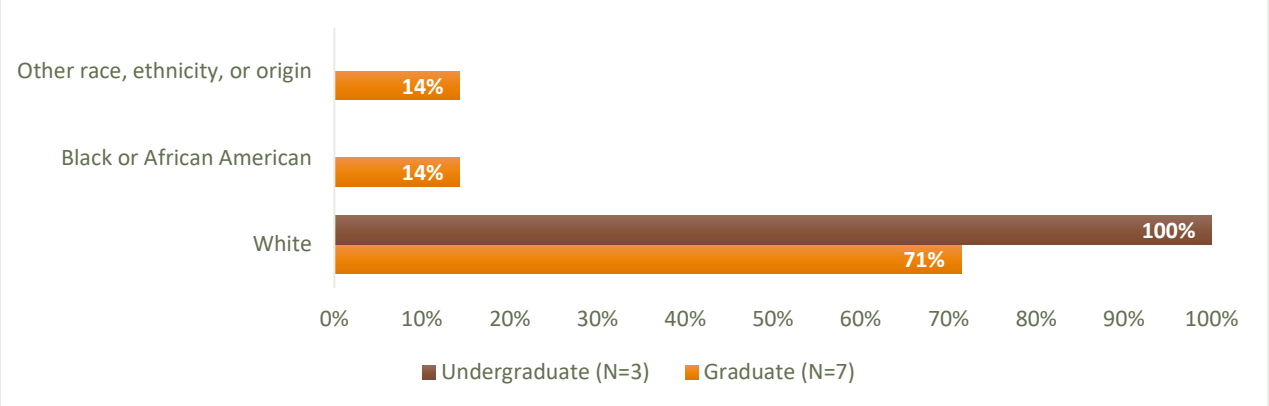


Figure 7: INSPIRES Graduate and Undergraduate Students Self-Reported Race and Ethnicity

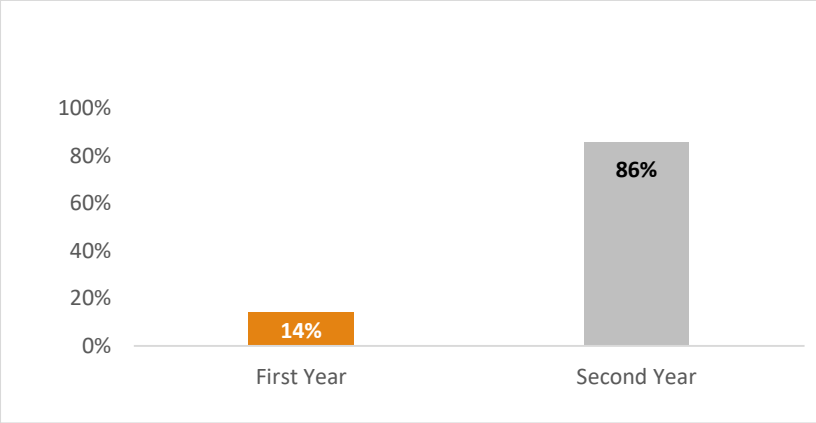


Figure 8: INSPIRES Graduate Students Training Year (N=7)

Project Implementation & Participation

The INSPIRES project faculty and researchers were asked to indicate the extent of their agreement with several statements that describe their understanding of the project's goals and priorities, what the project is trying to achieve, how their individual contribution fits into the project, and the extent of their involvement in the project. As shown in Figure 9, compared to findings reported in 2021, the level of agreement with each of the four statements increased. This may be interpreted as a sign of recovery from the pressure imposed by the COVID-19 pandemic on project operations. AAMU faculty and researchers who participated in the survey either agreed or strongly agreed with the statements, except for the following: 1 out 5 respondents selected, "neither agree nor disagree" in response to the statement "I have a clear understanding of how my contribution advances project goals and objectives", and 2 out of 5 respondents selected "neither agree nor disagree" in response to the statement "I have a clear expectation for the types and extent of support available from the project for graduate and undergraduate students." This likely reflects the early stage of their involvement with the project.

The INSPIRES project faculty and researchers were also asked if the project allows them to pursue their own ideas and develop new ways of contributing to the overall goals. More than 94% of the respondents either agreed or strongly agreed, compared to 76% in reported in 2021 (Figure 10). In response to this question, 3 out of 5 respondents from AAMU answered "Neither agree nor disagree" and the others agreed or strongly agreed.

Faculty and researchers were asked to rate the effectiveness of different communication strategies and tools the project leadership employed to facilitate engagement and collaboration (using a 5-point Likert scale from "very effective" to "ineffective"). The communication strategies or tools that were rated as "very effective" by more than half of the respondents were Zoom and the project emails. Slack, social media, and project member profiles received lower ratings compared to other communication strategies and tools (Figure 11). Survey participants also perceived monthly project meetings as more effective than quarterly

project meetings (Figure 12**)**. The communication strategies or tools that were rated as very effective by most of the AAMU respondents were also Zoom and the project emails.

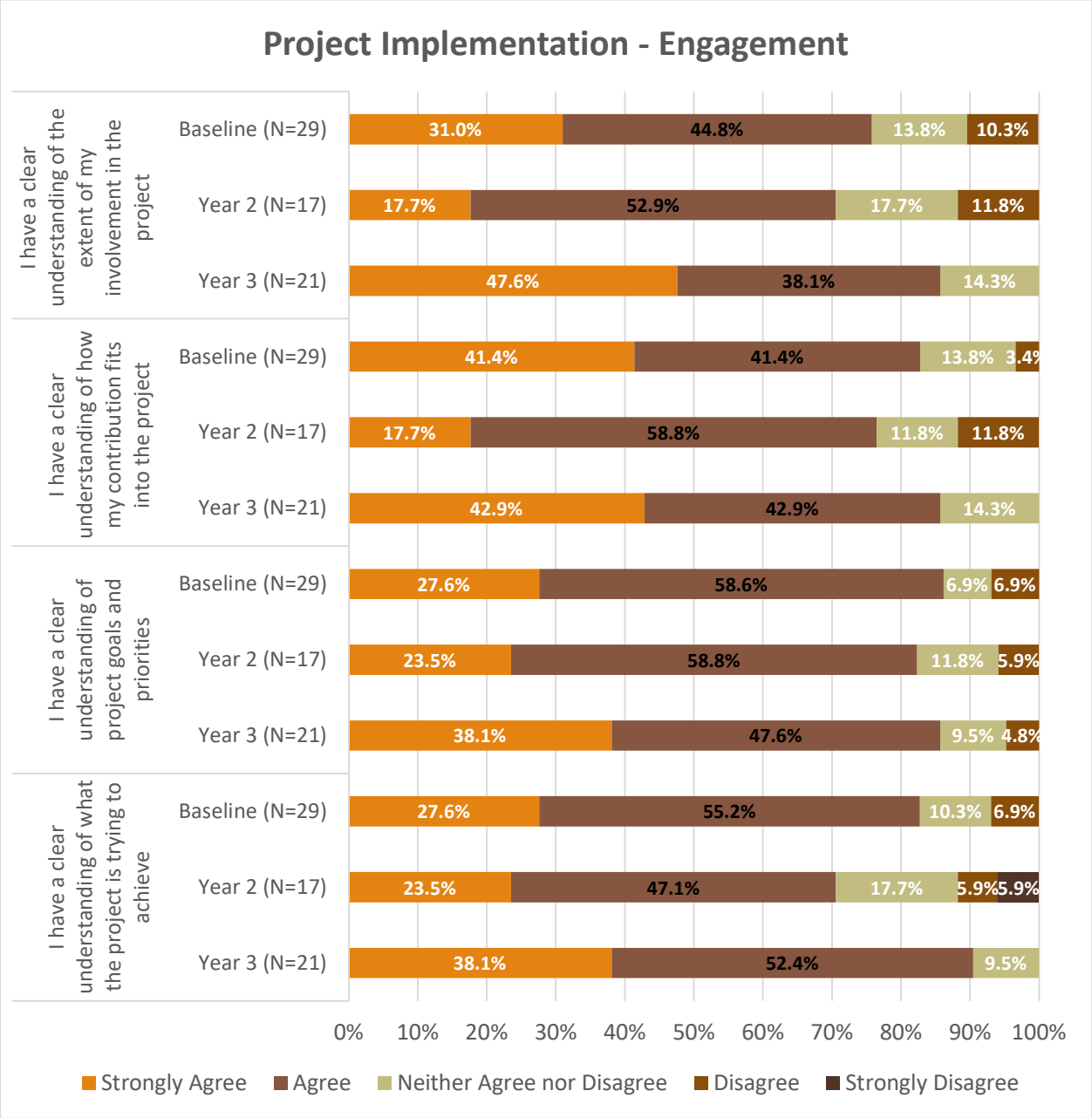


Figure 9: Level of Engagement of INSPIRES Faculty and Researchers

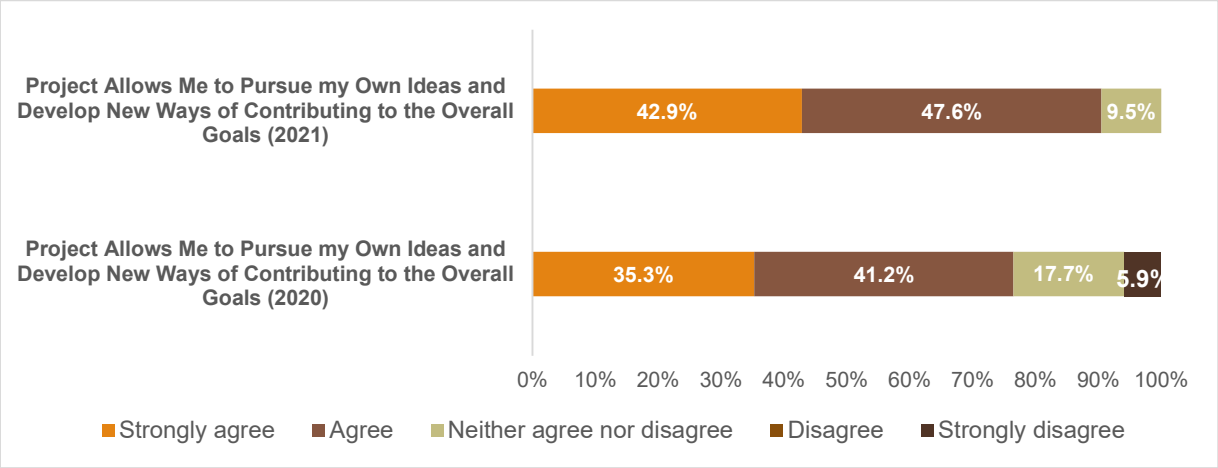


Figure 10: Agreement with the Statement "Project Allows Faculty & Researchers to Pursue their Own Ideas and Develop New Ways of Contributing to the Overall Goals"

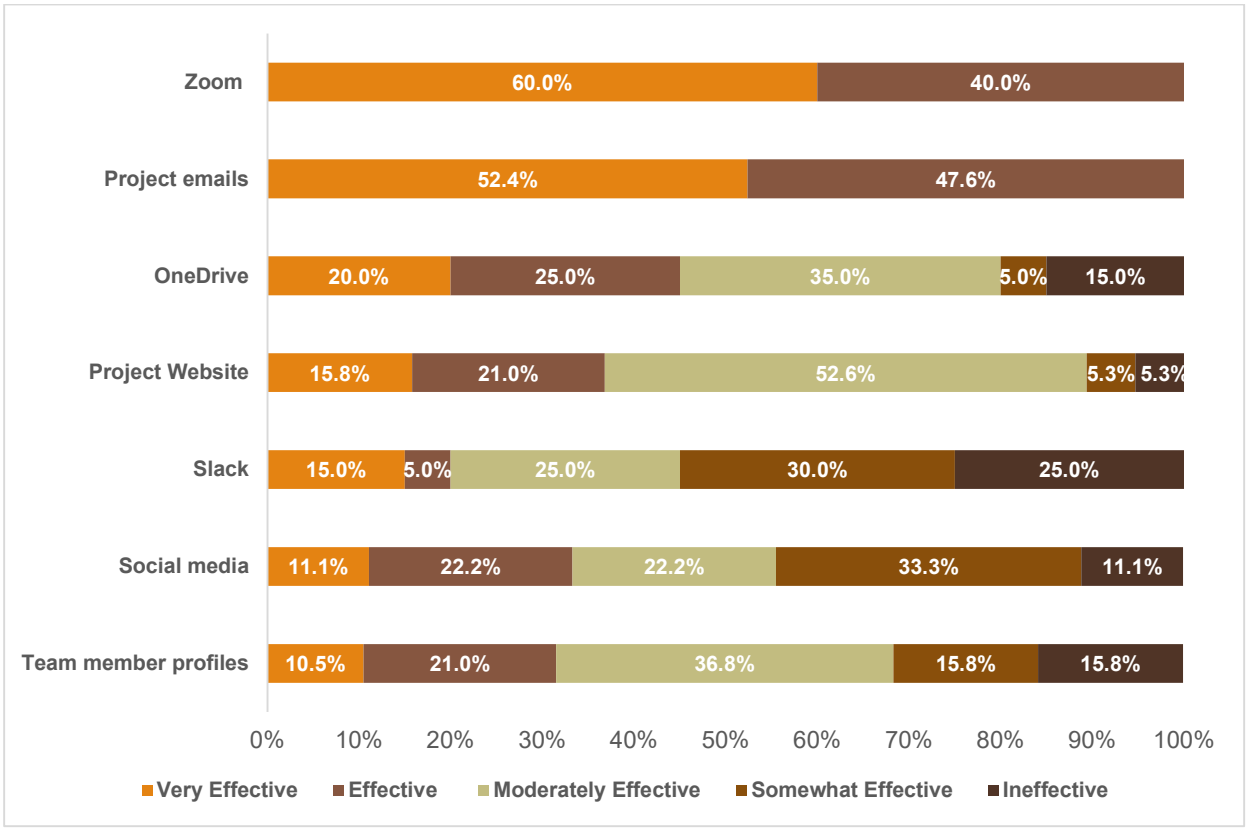


Figure 11: Project Communication Tools & Strategies (N=21)

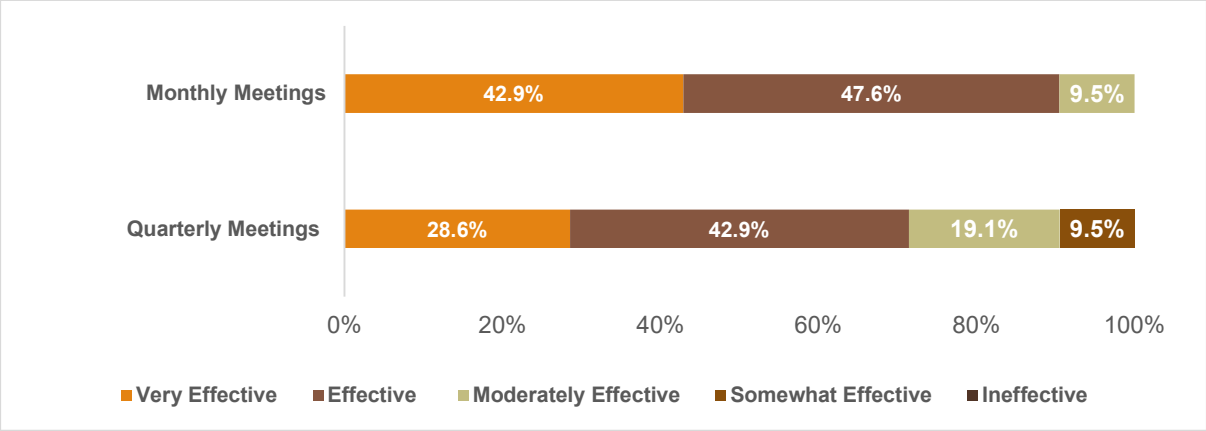


Figure 12: Effectiveness of Project Meetings (N=21)

Faculty and researchers provided feedback on the effectiveness of project meetings, including:

- "I have no strong complaints regarding meeting effectiveness, but I do feel that frequent project updates in monthly meetings limit opportunities to build collaboration. I also feel like within-Theme meetings don't do enough to foster collaboration between Themes. I suspect task- or subject-specific meetings will probably become more prevalent as INSPIRES evolves."

- "Quarterly meetings are too much about presenting work rather than discussing potential collaborations."

Faculty and researchers were also asked to indicate concerns they might have about project implementation feasibility. As shown in Figure 13, more than 71% of the respondents indicated being concerned about the challenges caused by the pandemic, and approximately 50% of the respondents reported being concerned about time constraints and funding limitations. Similar responses were provided by AAMU participants.

Faculty and researchers provided feedback on implementation feasibility issues, including:

- "As someone who is working on three projects within INSPIRES, it's not clear how to balance those competing needs at times. As someone who is on INSPIRES most of my time, it's a little easier to balance than for people with lots of other time constraints (e.g., teaching + other research + INSPIRES). Basically, I keep hearing about a lack of time to actually do the work."

- "I'm not concerned. I think that my team will be able to meet our goals and, in any areas, where we have difficulty meeting specific aspects of the goals, the project is flexible enough that we can adapt and adjust so that the progress we make can contribute to longer-term outcomes."

- "Themes are working to integrate. Challenging with such a large group."

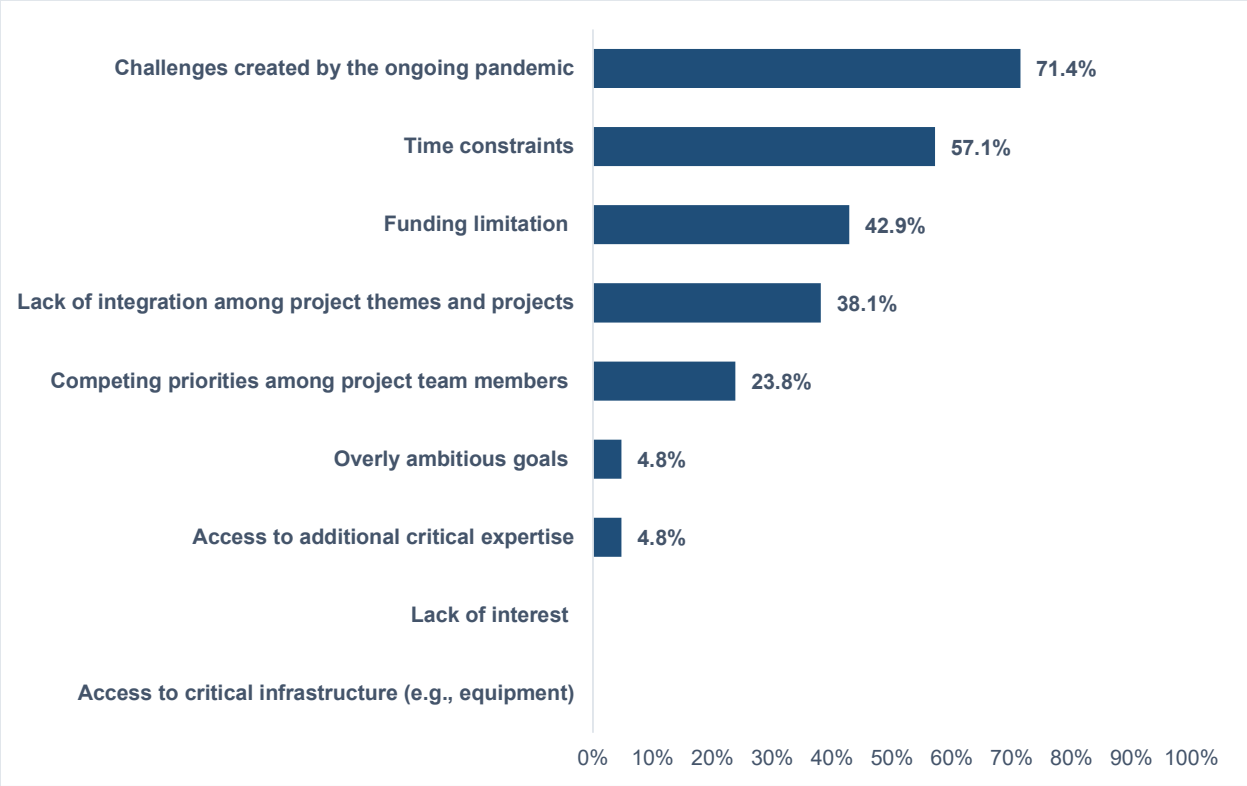


Figure 13: Concerns about the Project Implementation Feasibility (N=21)

Research Productivity

Project participants reported various types of research outputs they produced in the third year of the project through the T-2 DOP. A total of 46 entries were included in the "Researchers" sheet. Researchers in the project are required to report the following information for each project year:

- Funding (proposals submitted and funded)
- Publications
- Patents (submitted and awarded)
- Presentations
- Trainees

A detailed presentation and discussion of research outputs (i.e., proposals, grants, and publications) produced by the INSPIRES project faculty and researchers are provided in the *Formative Feedback Report - Award Year 3 Report*.[3]

[3] Integrated Learning Innovations, Inc. (on Behalf of NSF EPSCoR), 2022. *NSF EPSCoR RII Track-2 Data Outcomes Portal: Formative Feedback Report - Award Year 3*.

The level of research productivity by career stage, based on the number of proposals submitted *and* funded, as well as the number of publications and patents submitted *and* awarded, is shown in Table 1. The numbers reported in 2022 are slightly higher than those reported in 2021: 16 proposals were funded (versus 15 reported in 2021), and 20 publications were published (versus 18 reported in 2021). A list of the journals in which project participants published their research is provided in Table 2.

Table 1: Research Products Reported in 2021 by Researcher Career Stage

Classification	Number of Research Products	Number of Researchers Reported				
		Submitting Proposals	Funded Proposals	Publications	Submitting Patents	Awarded Patents
Early-Career Researcher (N=25)	0	12	16	16	25	25
	1-3	7	9	7		
	4-6	2	0	2		
	7-10	3	0			
	>10	1	0			
Senior Researcher (N=21)	0	11	14	10	21	21
	1-3	5	6	9		
	4-6	3	1			
	7-10	1		1		
	>10	1		1		

Table 2: Journals in Which INSPIRES Project Participants Published in 2021

Full Journal Title	Number of Researchers
Forest Ecology and Management	4
Remote Sensing	3
Environmental Research Letters	2
Global Change Biology	2
Scientific Reports	2
2020 25th International Conference on Pattern Recognition (ICPR)	1
American Biology Teacher	1
Annals of Forest Science	1
Canadian Journal of Forest Research	1
Carbon Management	1
Diversity and Distributions	1
Ecological Modeling	1
Ecology	1
Ecosphere	1
Ecosystems	1
Forest Policy and Economics	1
IEEE Transactions on Geoscience and Remote Sensing	1
International Journal of Wireless Information Networks	1
Journal of Applied Ecology	1
Machine Learning with Applications	1
Maine Policy Review	1
Northeastern Naturalist	1
Proceedings of the National Academy of Sciences	1
The ISME Journal	1
https://urtc.mit.edu/	1
https://www.micc.unifi.it/icpr2020/	1

Most of the publications produced were published in peer-reviewed journals, and more than half were published in open access journals. More than 87% of participants indicated their publications were supported in part or in total by the INSPIRES T-2 award.

33 out of 34 (97.06%) participants indicated the journal to which their articles were submitted was peer-reviewed.

18 out of 32 (56.25%) participants indicated the journal to which their articles were submitted was open access.

28 out of 32 (87.5%) participants indicated their publications were supported in part or in total by the INSPIRES T-2 award.

Project participants reported giving a total of 36 presentations in year 3 of the project (versus 24 in year 2). Details about the type of presentations given by participants are provided in Figure 14**.** Under the "other" category, participants listed: annual meeting, seminar, webinar, workshop, conference, project all-hands meeting.

More than 60% of the project participants (22 out of 36) indicated that their presentations were supported in part or in total by the T-2 award.

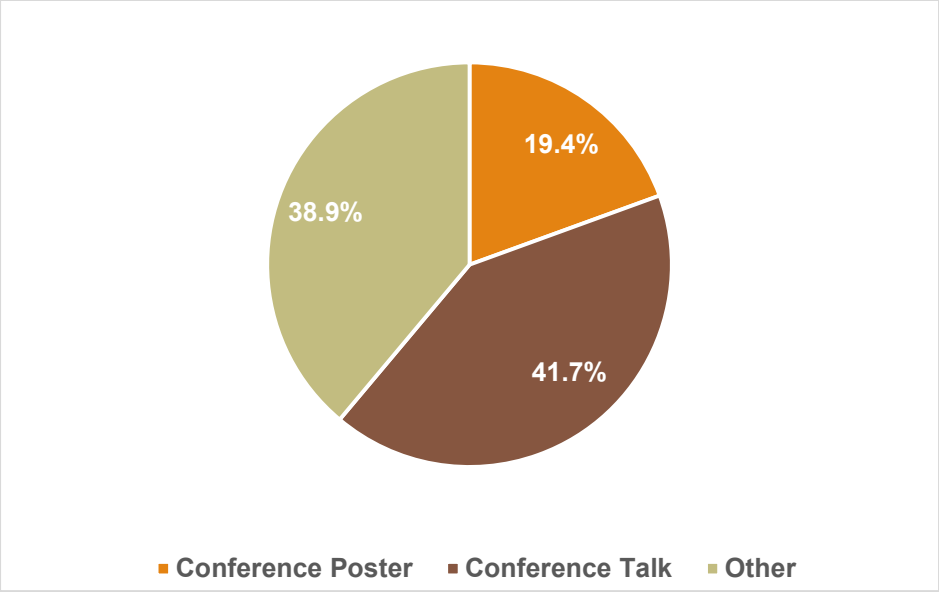


Figure 14: Presentations Listed by INSPIRES Project Participants

Federal agencies (primarily NSF, USDA, and NASA) were the primary targets and sources of funding for project participants (Figure 15). This finding is similar to what was reported in 2021.

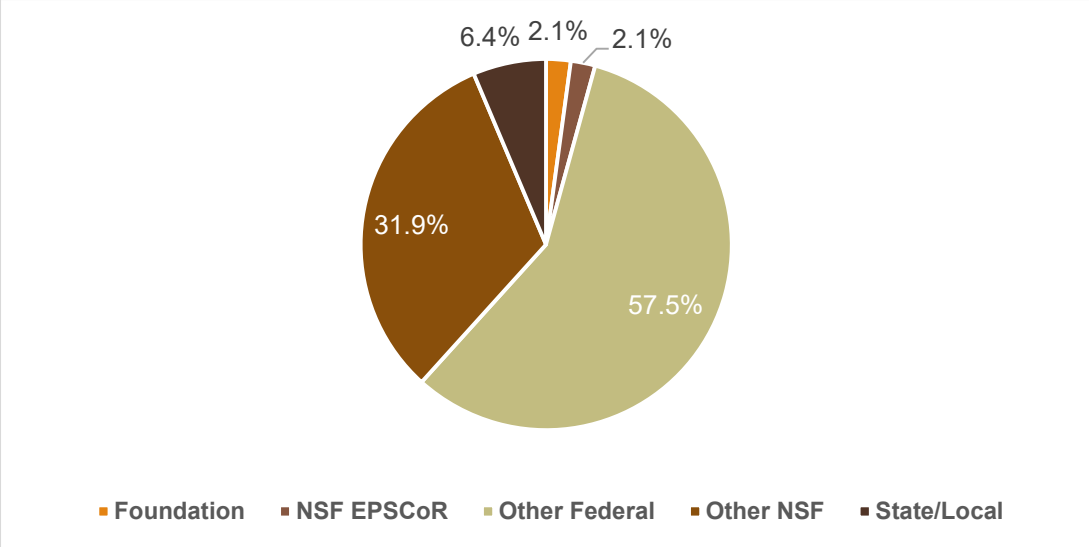


Figure 15: Funding Organizations

Project participants reported submitting 47 funding proposals in 2021 (a 25% increase from 2021): 43 proposals (91.4%) were supported in part or in total by the T-2 award.

The average and the range of the funding amount requested was:

- Total amount requested for all proposals, N=47: $44,363,866 ($30,000 - $12,500,000)
- Total amount awarded, N=20: $ 11,419,252 ($30,000 - $2,996,759)
- Total among requested for submitted and pending proposals, N=13: $17,337,540 ($100,000 - $12,500,000)

More than 42% of proposals submitted were awarded in 2021: 28% are pending (Figure 16).

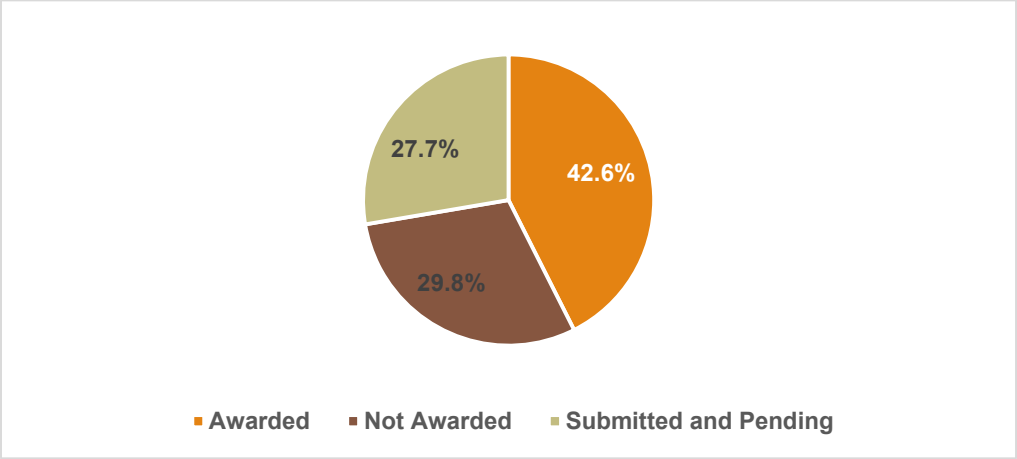


Figure 16: Status of Proposals Submitted by INSPIRES Project Participants (N=21)

Awards received by project participants (as reported in T2-DOP) are listed in Table 3 by awarding agency and program.

Table 3: Awards Received by Project Participants

Agency/ Organization	Program/Department	Total Requested
NASA	Carbon Monitoring System	$940,308
	Global Ecosystem Dynamics Investigation	$497,469
NSF	Division of Earth Sciences	$3,199,116
	Future of Work at the Human-Technology Frontier	$2,996,759
	Industry-University Research Partnerships	$500,000
	Signals in the Soil	$1,199,160
	FW-HTP-P	$150,000
USDA	AFRI NIFA CARE Program	$300,000
	Conservation Innovation Grants	$120,000
	NIFA AFRI Foundational Program	$470,835
	NIFA	$5,000,000
	NIFA--New Beginnings for Tribal Students	$283,000
DoE	U.S. China Clean Energy Research Center	$100,000
US Forest Service	Extramural Agreement	$30,000
Gund Institute for Environment	Gund Catalyst Awards	$50,000
Water Resources Research Inst.		$36,000
Other Federal Project		$487,717

Project participants reported pending awards (Table 4) from the following organizations:

Table 4: INSPIRES Participants - Pending Awards and Agency

Organization/Agency	Award
NSF Biology Integration Institute (BII)	$12,499,985
NSF Dynamics of Integrated Socio-Environmental Systems (DISES)	$916,672
DOE	$2,000,000
Department of Interior, Climate Adaptation Plan	N/A
NSF Macrosystem Biology	$1,199,387
NASA-EPSCoR	$100,000
NSF NRT	$299,658
Northeastern States Research Cooperative (NSRC)	$144,354
Northeast Climate Adaptation Science Center	N/A
NIH R01	$1,101,898

The institutional affiliation of trainees reported in the T2-DOP is illustrated in Figure 17.

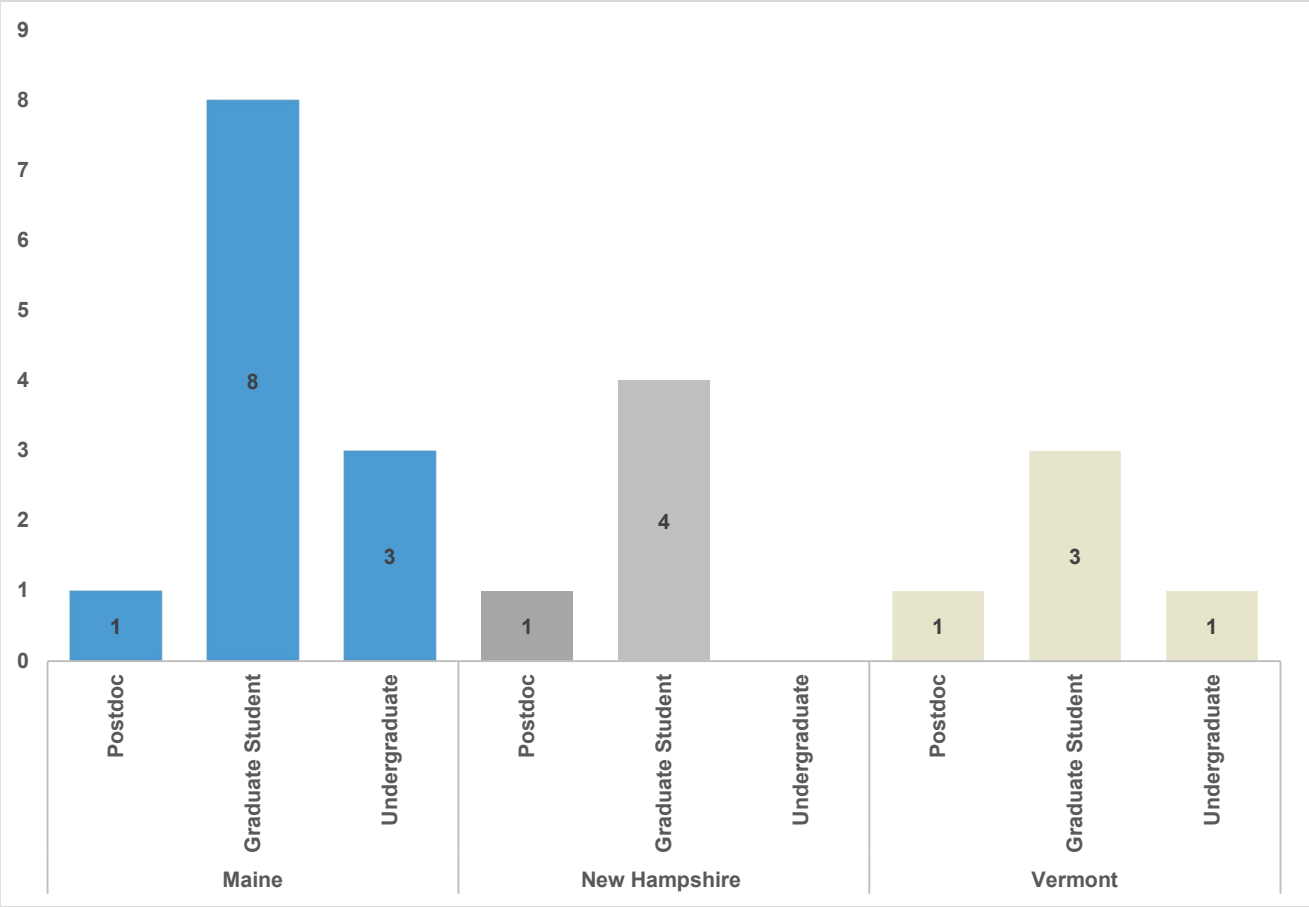


Figure 17: Number of INSPIRES Project Trainees by Jurisdiction

Other research products reported in the T2-DOP (83.3% of which were supported in part or in total by the INSPIRES T-2 award) include:

- The IWiN system - designed and developed under the leadership of Dr. Ali Abedi in his Wireless Sensor Networks Laboratory (WiSe-Net Lab). System modules were implemented and refined, in 2022, integration tests and completion of system development are a priority.

- An R package for hyperspectral and geospatial machine learning inference was developed and released in 2021. The team had achieved a 93% reduction in processing time by the close of the year 3 reporting period and is now able to process images larger than 10GB. This work culminated in the release of the alpha release of lecospectR as an R package. Refinements and bug fixes are ongoing in 2022 to finalize the package API and functionality.

- A web-based data labeling application - developed based on code developed by Software Engineer Chris Wilson, will be completed in 2022.

- A prototype for a Digital Forest Web Interface to query the database.

- INdendro, a Band Dendrometer with networked data logging of LoRa network which measures changes in tree diameter by measuring the change in tension of a sprung non-elastic band wrapped around the girth of the tree. This first prototype has been installed on a white pine (*Pinus strobus*) in an open area. Data collection commenced during the installation process and continues to the present moment.

- INleaf allows INSPIRES researchers to easily stage geospatial and site-specific data logs in a map by filling out a metadata template and placing the files in OneDrive folders.

- A 3-credit INSPIRES Teacher Professional Learning graduate course offered by UVM.

- Six 1.5-hour virtual professional learning workshops with partner K-12 teachers.

- Host for 4-day summer institute at Schoodic Education Research Center with all collaborating teachers in July 2021.

- The Maine STEM Partnership site created a page to share INSPIRES with the broader educator community: the page highlights Theme 4 work and connects to the project website.

- Updated code component of the Laboratory of ecological spectroscopy (lecospec) which comprises people, hardware, and code for processing imaging spectroscopy data for mapping plants: https://github.com/nelsopet/lecospec.

- First Prototype OWL/RDF Knowledgebase for the Digital Forest; stored as a GraphDB database; not yet publicly shared.

- 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.

Collaborations and Team Science

INSPIRES faculty and researchers were asked if the extent of their involvement in interdisciplinary research has changed as a result of their participation in the INSPIRES project. As shown in Figure 18, approximately 60% of survey respondents indicated that their involvement in interdisciplinary research has increased from the project start, while approximately 35% said it has been constant.

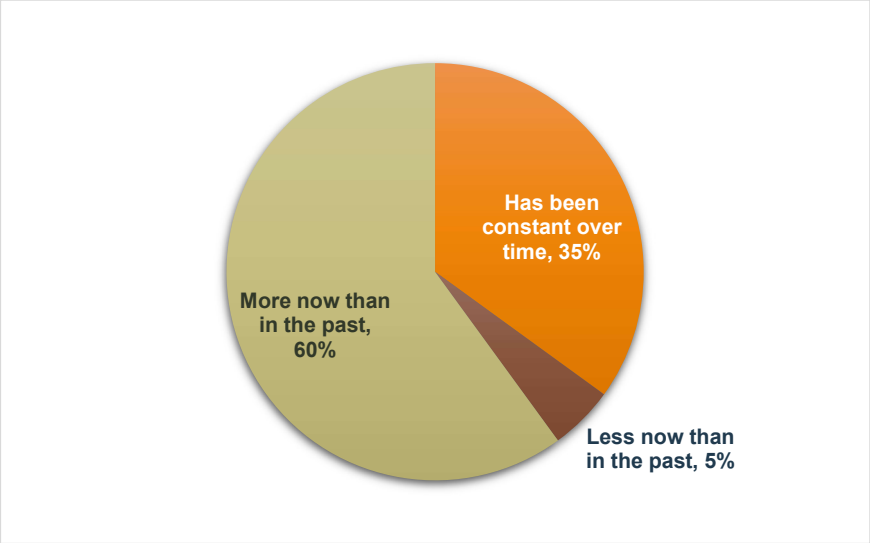


Figure 18: The Extent of Involvement in Interdisciplinary Research as a result of Participation in INSPIRES (N=21)

Results from the 2021 INSPIRES Faculty & Researchers annual survey demonstrated that most of the research projects included participants from at least two institutions. Two research projects (3.3 *Scenario Assessment and Trends Analysis* and 4.1b *Use Big Data to Answer Student-and-Community Relevant Questions*) included participants from the three New England jurisdictions (Figure 19). It is important to keep in mind that with a 50% percent response rate, these findings may not be representative of the actual state of collaboration among researchers from the three jurisdictions on INSPIRES research projects. In addition, these data do not reflect collaborations initiated with AAMU team members in 2022 under the new supplemental award.

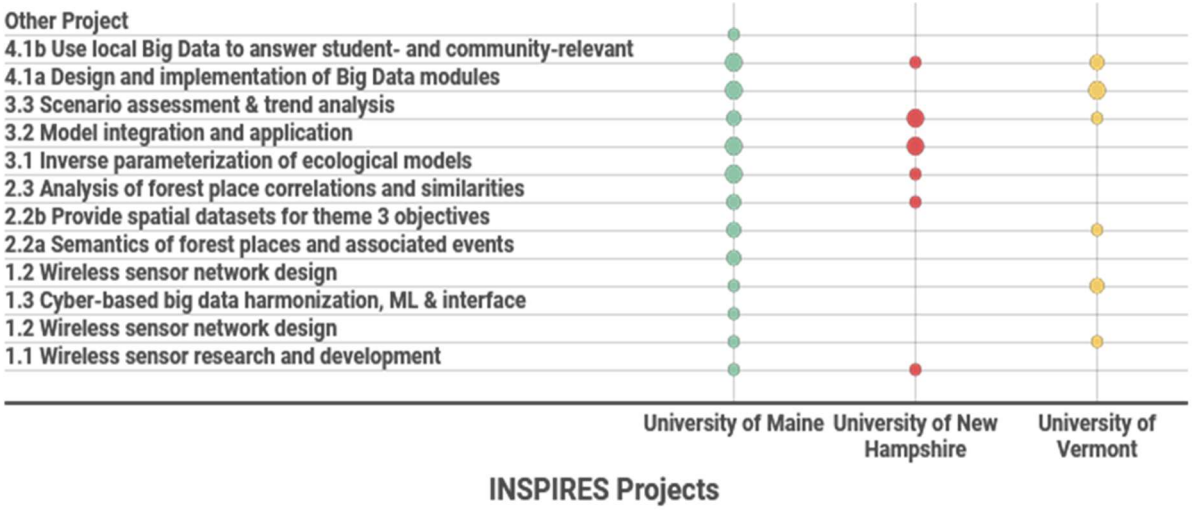


Figure 19: Cross-Institutional Representation on Research Projects by INSPIRES Faculty & Researchers (N=21). Size of dots indicates number of participants.

Results from the 2021 INSPIRES Graduate Student Survey show that graduate students from the three universities are distributed across research projects with no overlap (i.e., research projects included only 1 graduate student) (Figure 20**Figure**). Here again, it is important to keep in mind that with a 50% percent response rate, these findings may not be representative of the actual participation of graduate students from the three jurisdictions in INSPIRES research projects. Data from the T2-DOP show that most graduate students are being advised/mentored by faculty from the same institution they are affiliated with, which indicates limited opportunities for or interest in cross-institutional advising of trainees.

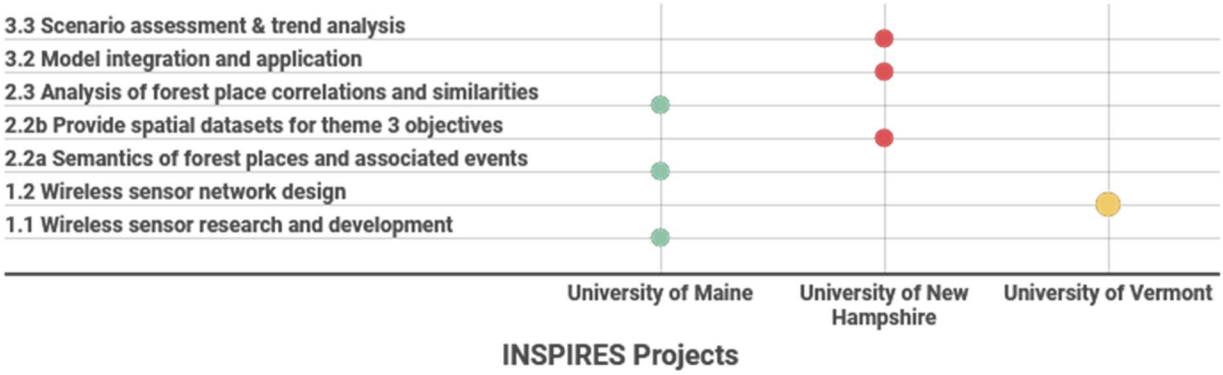


Figure 20: Cross-Institutional Representation on Research Projects by INSPIRES Graduate Students (N=7). Size of dots indicates number of participants.

All of the AAMU faculty and researcher survey participants indicated involvement in Theme 2, and 3 out of 5 respondents indicated involvement in Theme 3 (Figure 21).

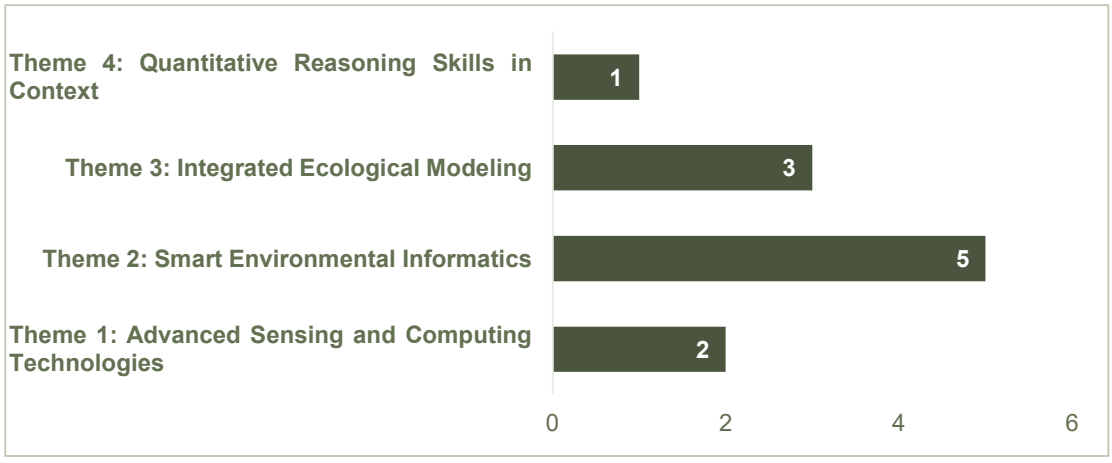


Figure 21: Representation on INSPIRES Research Themes by AAMU Faculty and Researchers (N=5)

Collaboration Networks

The year 3 Faculty & Researchers Survey included a set of questions to examine the collaboration networks developed to achieve project goals. Survey participants were asked to indicate if they are currently working with other members of the project team on INSPIRES-related activities and to specify the nature of those collaborations.

The density of the overall collaboration network on INSPIRES-related activities (i.e., 21 faculty and researchers for all six activities) is 0.096, which means that 9.6% (compared to 10% at baseline) of all possible connections or relationships in this network are actualized. It is important to note that the response rate achieved with the baseline survey was significantly higher (93% in 2020, as opposed to 50% with the current survey). The average number of connections reported by survey participants to other members of the project is 6 (compared to 6 at baseline), and only 40% (compared to 50% at baseline) of these connections are reciprocated (connections reported in the opposite direction between the same people). Again, caution is needed when interpreting survey results given the difference in response rate between baseline and the year 3 survey. The extent of current collaborations among INSPIRES project faculty and researchers is summarized in Table 5.

Table 5: Network Metrics, Based on Type of Collaboration – INSPIRES Project

Network Metrics	Studies or Grants	Publications	Developing Models and Tools	Stakeholder Engagement	Developing or Teaching Course
Network Density	0.018	0.007	0.008	0.006	0.003
Average Number of Collaborations	5	2	2.3	2.1	1
Reciprocity	0.293	0.327	0.185	0.089	0.190

Table 6: Faculty and researcher collaboration activities

	Studies or Grants	Publications	Developing Models and Tools	Stakeholder Engagement	Developing Teaching Course	Mentoring and Training
Aaron Weiskittle, Umaine - Senior Faculty	•	•				
Aimee Classen, UVM - Senior Faculty	•	•				•
Alix Contosa, UNH - Early Career Researcher			•			•
Anthony D'Amato, UVM - Senior Faculty	•	•	•	•		•
Dave Lutz, Dartmouth - Early Career Researcher	•					
Erin Simons-Legaard, Umaine - Early Career Researcher			•			
Laura Millay, Umaine - Professional Staff				•		
Regina Toolin, Umaine - Senior Faculty	•			•	•	
Sara Lindsay, Umaine - Senior Faculty				•		
Susan McKay, Umaine - Senior Faculty						•

These INSPIRES faculty and researchers have the highest number of connections overall:

- D'Amato, Anthony- UVM – Senior Faculty (19 connections reported)
- Contosta, Alix- UNH – Early-Career Researcher (18 connections reported)
- Weiskittel, Aaron- UMaine – Senior Faculty (16 connections reported)
- Toolin, Regina- UMaine – Senior Faculty (16 connections reported)

Collaboration on research projects or grants is the most predominant reason or goal for collaboration, and reciprocity (both individuals indicate that a collaboration in this area exists) is more likely with collaborations on research projects or grants (Figure 22). Diagrams presenting current network metrics are presented in Appendix II.

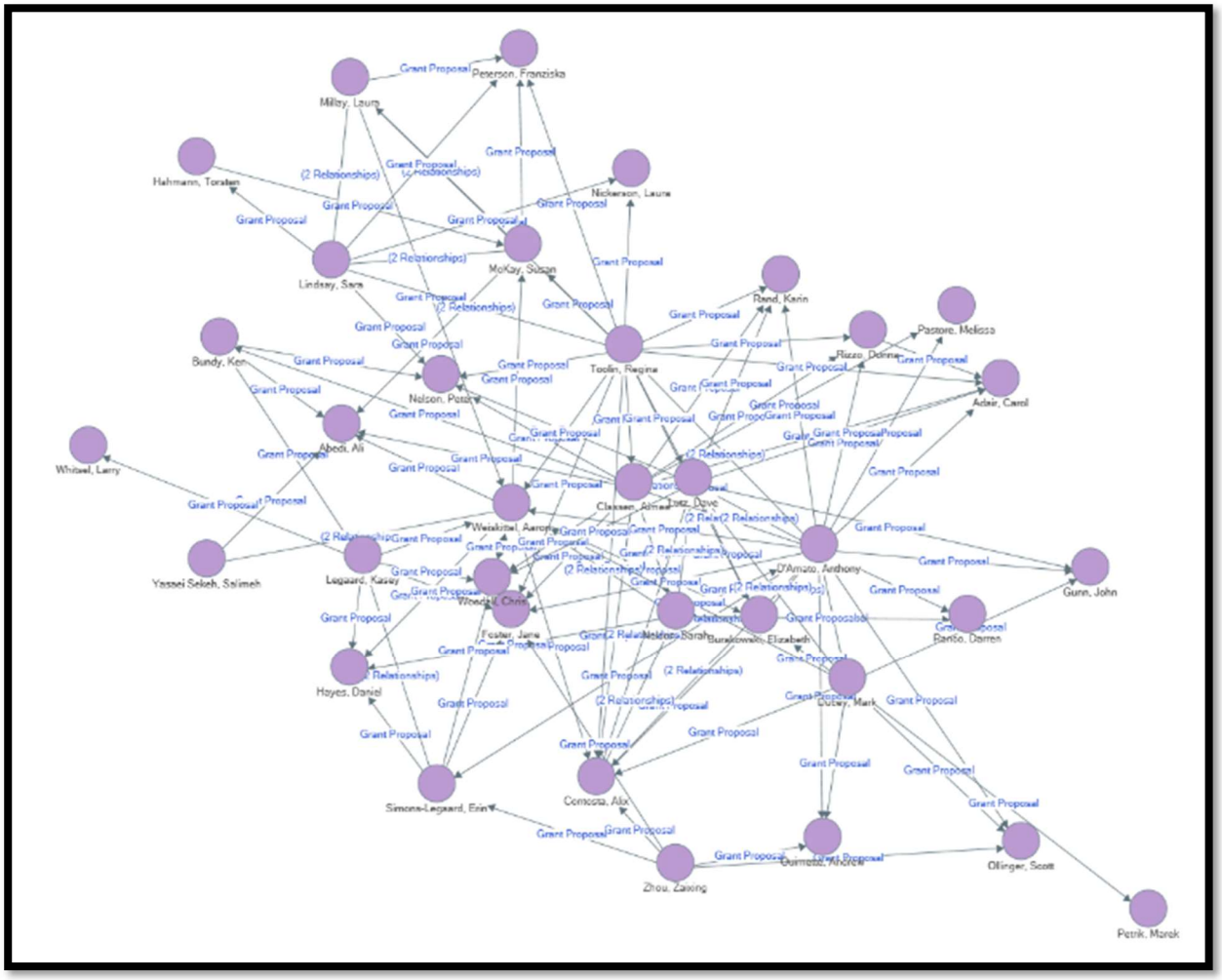


Figure 22: Collaboration among INSPIRES Faculty & Researchers on Studies or Grants

Collaborations among AAMU Faculty and Researchers

The density of the AAMU collaboration network on INSPIRES-related activities (i.e., 5 faculty and researchers for four activities) is 0.075: 7.5% of all possible connections or relationships in this network are actualized. The average number of connections reported by AAMU survey participants to other members of the project is 2:44% of these connections are reciprocated (connections reported in the opposite direction between the same people). The AAMU PI (Dawn Lemke) has the highest number of

connections (12) reported. Collaboration on research projects or grants is the most predominant reason or goal for collaboration (Table 7). Note that the supplement was initiated late in fall 2021, collaborations between the AAMU faculty and researchers and the more established INSPIRES project research team have recently started.

Table 7: Network Metrics, Based on Type of Collaboration – Supplement

Network Metrics	Studies or Grants	Publications	Mentoring or Training	Developing or Teaching Course
Network Density	0.072	0.010	0.023	0.007
Average Number of Collaborations	1.9	0.2	0.6	0.2
Reciprocity	0.455	0.667	0.571	0

Analyses of other AAMU collaboration networks are presented in Appendix II.

Collaboration Outcomes

INSPIRES Faculty & Researcher Survey participants were asked to indicate their level of agreement with several statements describing the potential benefits of collaborations established as part of the INSPIRES project. As shown in Figure 23, in 2021, participants' level of agreement that project collaborations have resulted in tangible benefits increased compared to 2020. However, 1 participant commented that the benefits of collaboration "have been very uneven across project participants, especially early career and research faculty."

The participants were asked to identify barriers to successful project collaborations (Figure 24). Perception of collaboration barriers was lower in 2021 compared to 2020, except in terms of:

- Varying research practices and priorities within different disciplines (an additional 13.5% of participants perceived these as barriers in 2021)
- Misalignment of research interests among project participants (an additional 11% of participants perceived these as barriers in 2021)

Survey participants identified several other barriers:

- "I think the biggest challenge for Theme 4 research is limited time. Researchers across the 3 states are working together for the first time through this project; it takes time to learn how to talk with each other about our research (even though we are in similar disciplines across the jurisdictions, there are differences in language and approach) and it takes time to learn how to effectively collaborate. We each have very limited time on this project and full plates of other projects we are working on; as a result, our research progress is sometimes slow."

- "It is very challenging to build teams amid a pandemic (especially by limiting in-person interactions)."

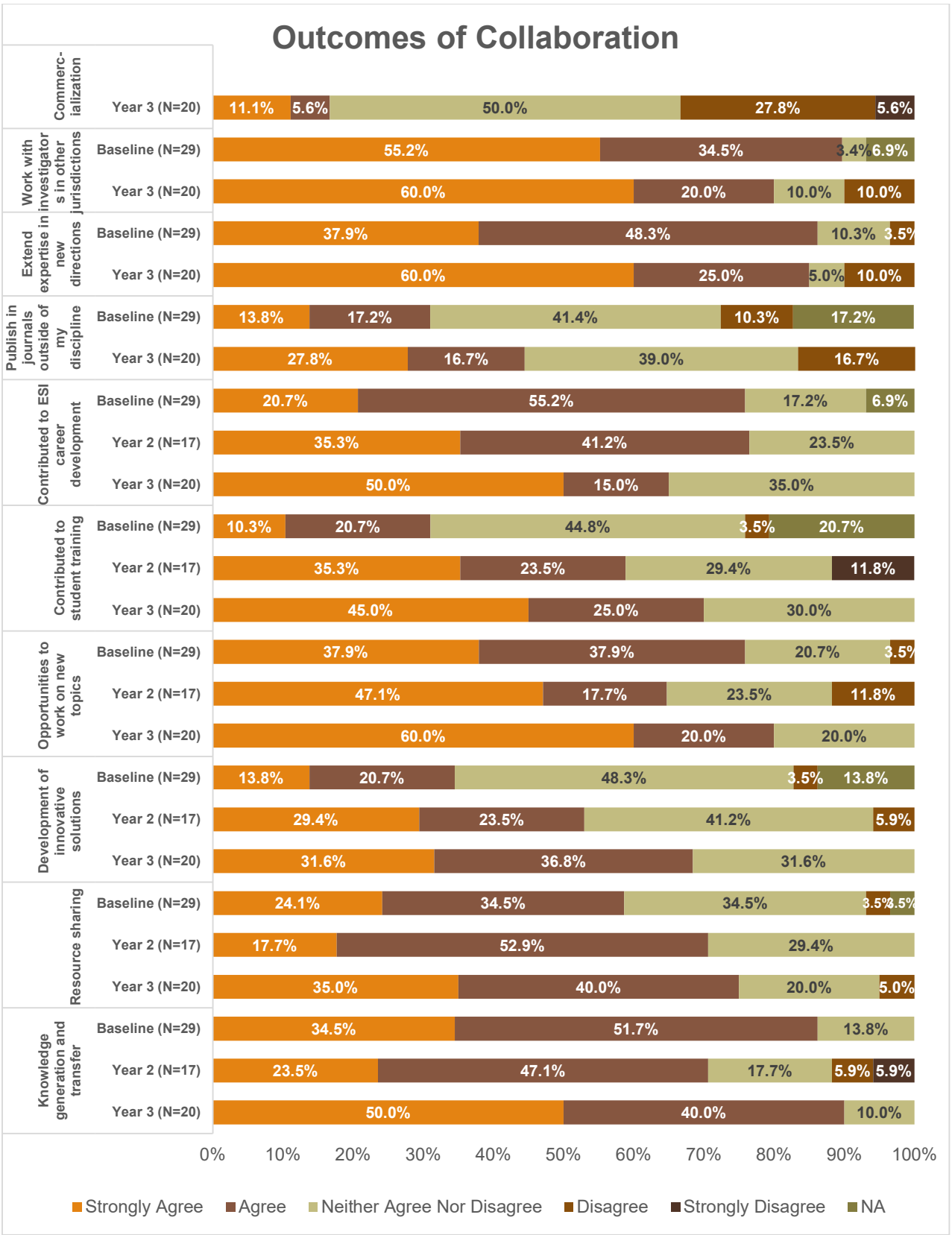


Figure 23: Anticipated Benefits of the INSPIRES Project Collaborations

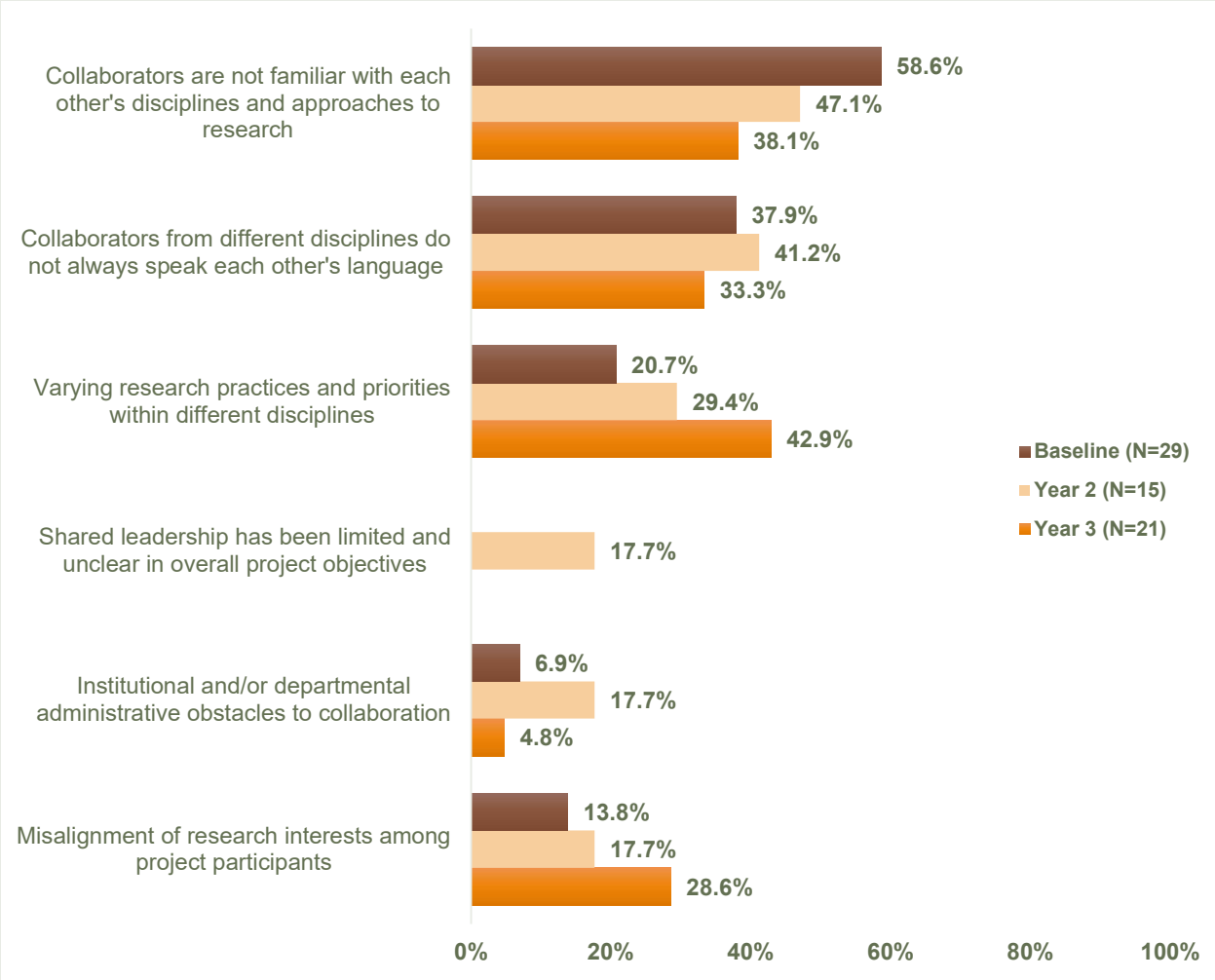


Figure 24: Barriers to Research Collaborations in the Project

Faculty and researchers were asked to indicate the extent of their agreement with seven statements describing different aspects of team science. As shown in Figure 25, survey respondents indicated (based on agreement levels):

- Team members communicate expectations openly and clearly with each other, and
- Team members feel safe to share ideas and ask questions of other team members.

The area that might need further attention from project leadership (based on the overall agreement levels) is:

- Knowledge, data, and resources are distributed transparently among team members.

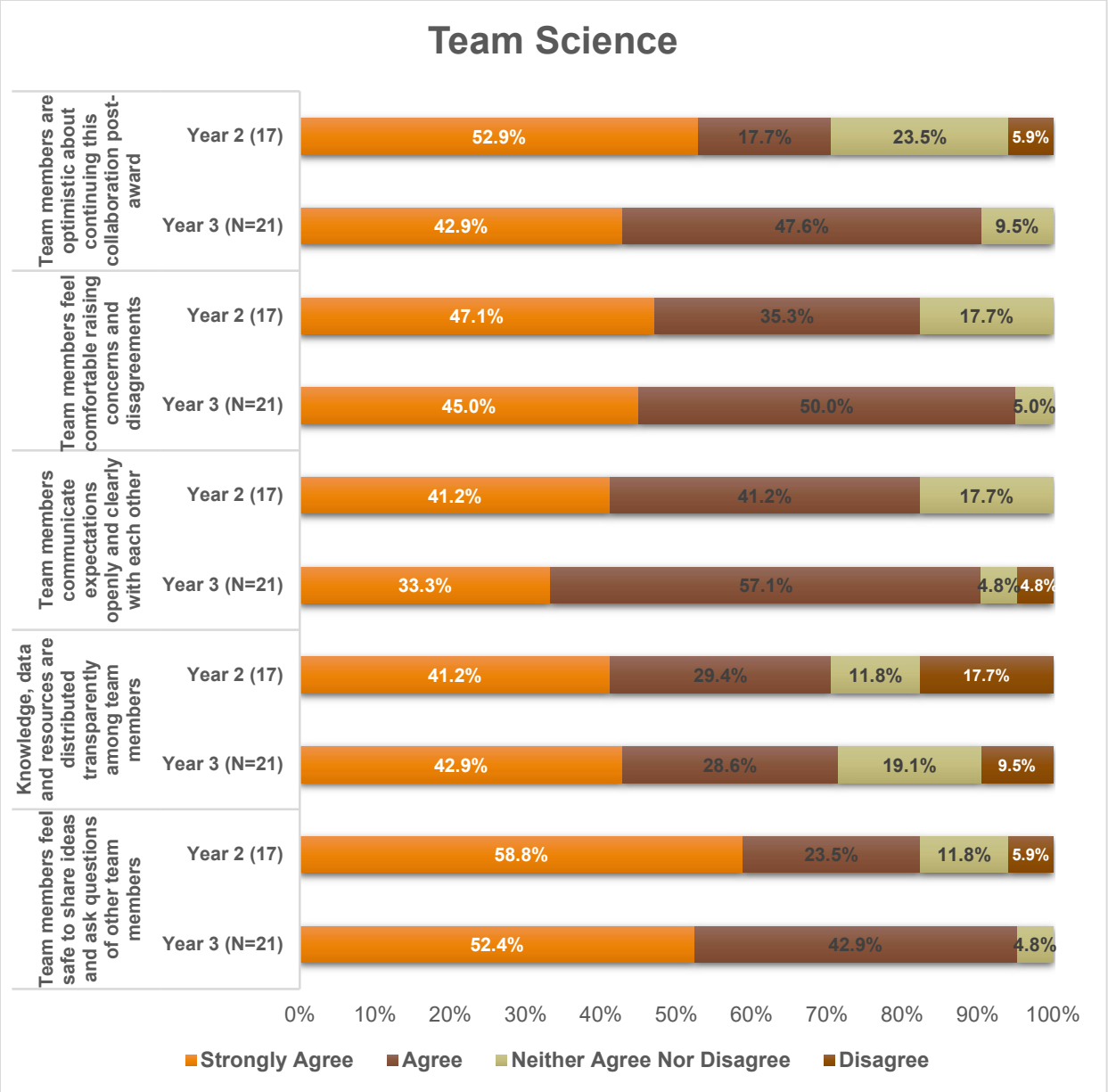


Figure 25: Perceptions of INSPIRES Team Science Principles (N=21)

Mentoring and Training

As can be seen in Figure 26, almost 50% of the participants in the 2021 INSPIRES Faculty and Researchers Survey reported working with at least one mentee, and mentoring is taking place across career stages.

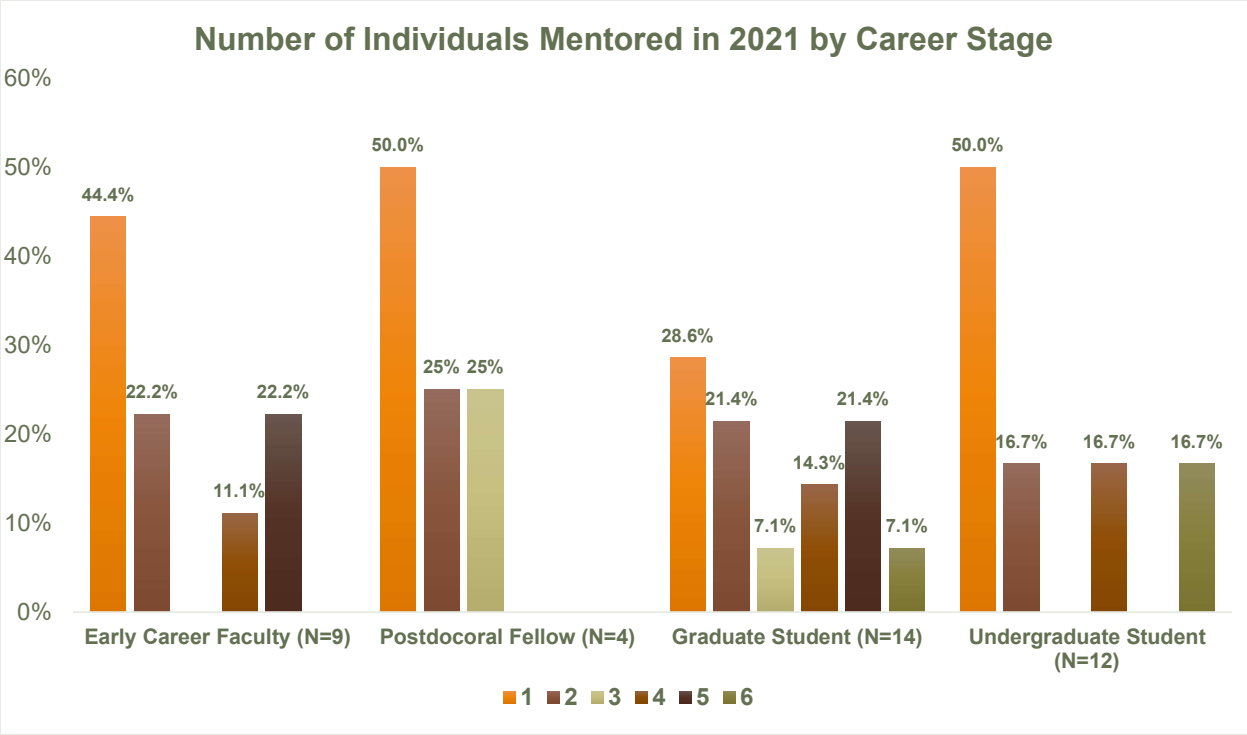


Figure 26: Number of Individuals Mentored in 2021 by Career Stage- Main INSPIRES Project

Participants in the AAMU faculty and researchers' surveys also indicated that they mentor trainees across stages of career development.

Several participants in the year 3 Faculty & Researchers survey indicated that they use one or more of the project resources developed by the INSPIRES leadership team when working with their INSPIRES-affiliated mentors/mentees, as indicated in Figure 27.

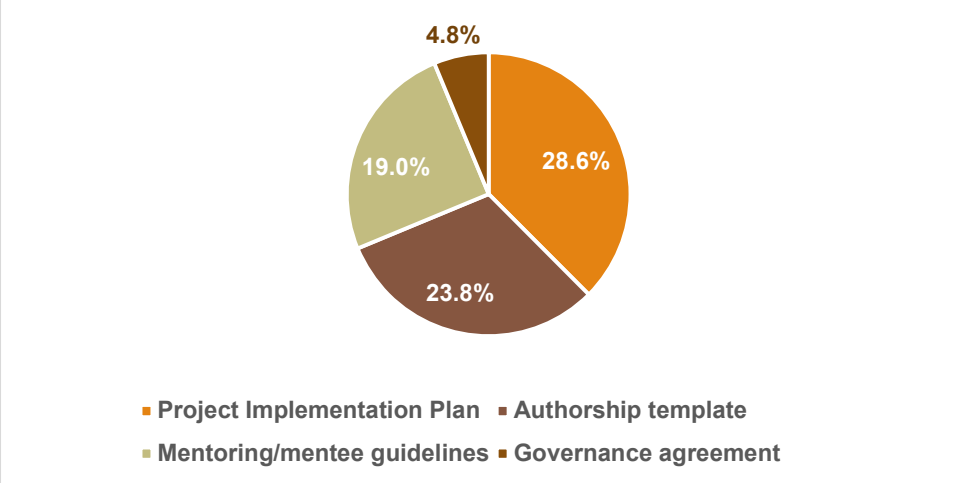


Figure 27: Project Resources Used when Working with Mentees (N=15)

Among AAMU faculty and researchers, only one respondent indicated that they currently use (or are planning to use) an Individual Development Plan (IDP) when working with their INSPIRES-affiliated mentors/mentees.

When asked if they have been mentored by senior faculty in 2021, approximately 26% of participants in the year 3 Faculty & Researchers Survey said "yes". Only 2 respondents indicated seeking mentorship from a senior faculty member in 2021. Two (2) Assistant Professors, 2 Support Faculty Members, and 1 Professional Staff reported being mentored by senior faculty.

The following faculty were named as senior mentors by survey participants:

- Ali Abedi (UMaine),
- Kasey Legaard (UMaine),
- Peter Nelson (Schoodic Institute)
- Susan McKay, UMaine
- Sara Lindsay, UMaine
- Regina Toolin, UVM
- Aimee Classen, UVM
- Tony D'Amato, UVM
- Aaron Weiskittel, UMaine

Among the INSPIRES project faculty and researchers who participated in the year 3 survey, 45% indicated that they meet with the mentees or mentors on a weekly basis (Figure 28).

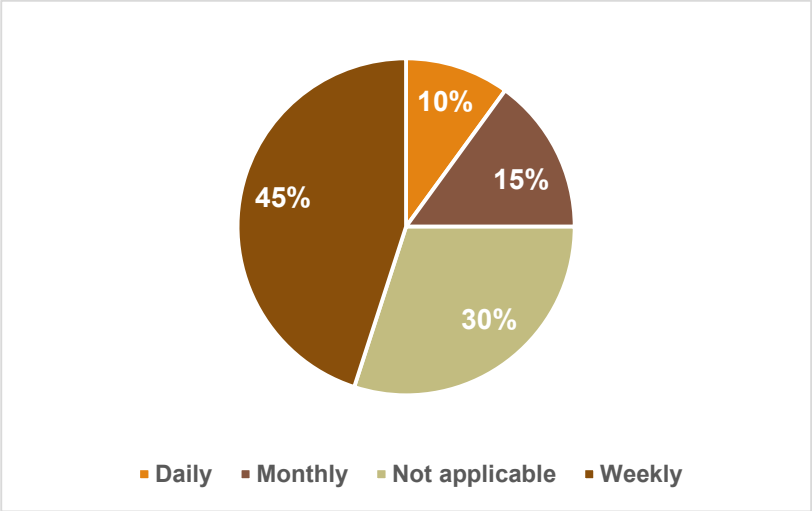


Figure 28: Frequency of Communication with Project-affiliated Mentors/Mentees (N=21)

Survey participants were asked to indicate the extent to which they work with their mentees in several areas. As shown in Figure 29, in 2021, "research projects and interest" was the primary focus area of mentor-mentee relationships: 52.4% of respondents indicated that they work with their mentees in this area either to a large extent or to a very large extent. Notably, only 14% of the respondents indicated focusing on "career interests" with their mentees.

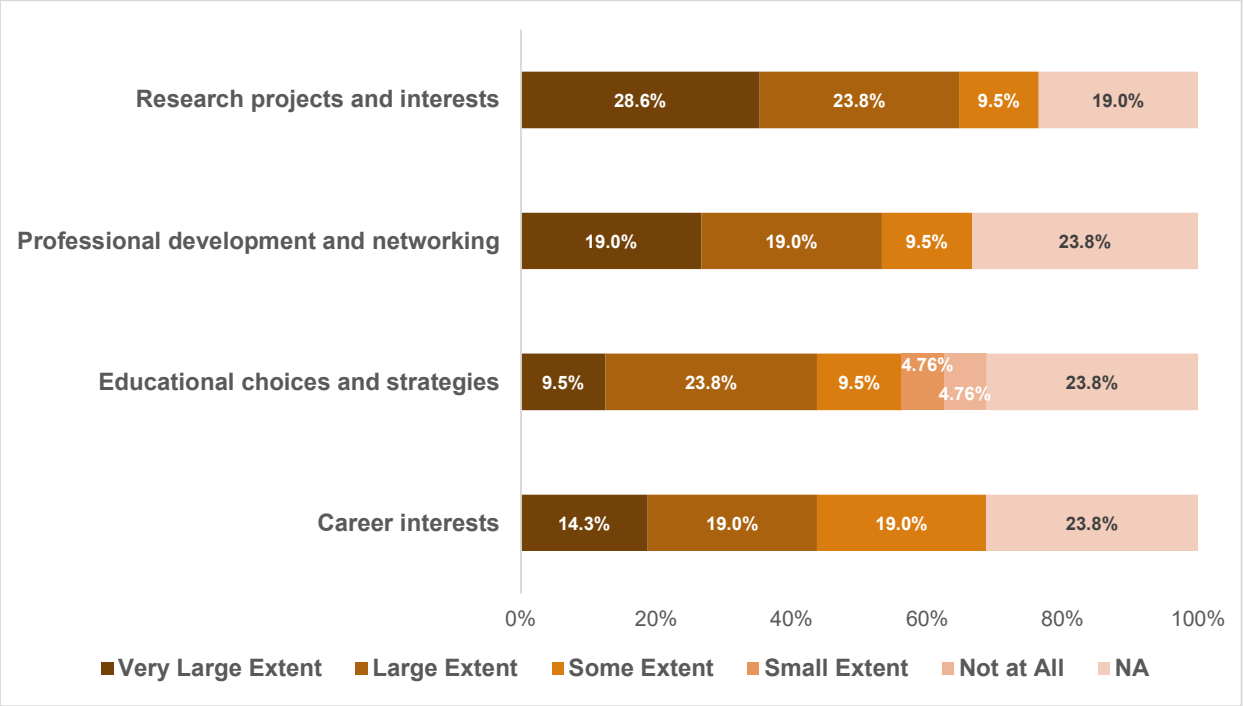


Figure 29: Focus Area for Mentoring (N=21)

Graduate Students' Experiences and Outcomes

INSPIRES graduate students were asked to 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'). Figure 30 shows the average level of ability in these different areas reported in 2020 compared to currently (for 2021) and quantifies the positive improvements in graduate students' knowledge and skills. Areas with the highest level of improvement include:

- Apply concepts and methods from multiple disciplines to address a research problem
- Design and teach a course in their field/discipline
- Collaborate with researchers trained in different disciplines
- Explain how their research connects to issues that are important to society

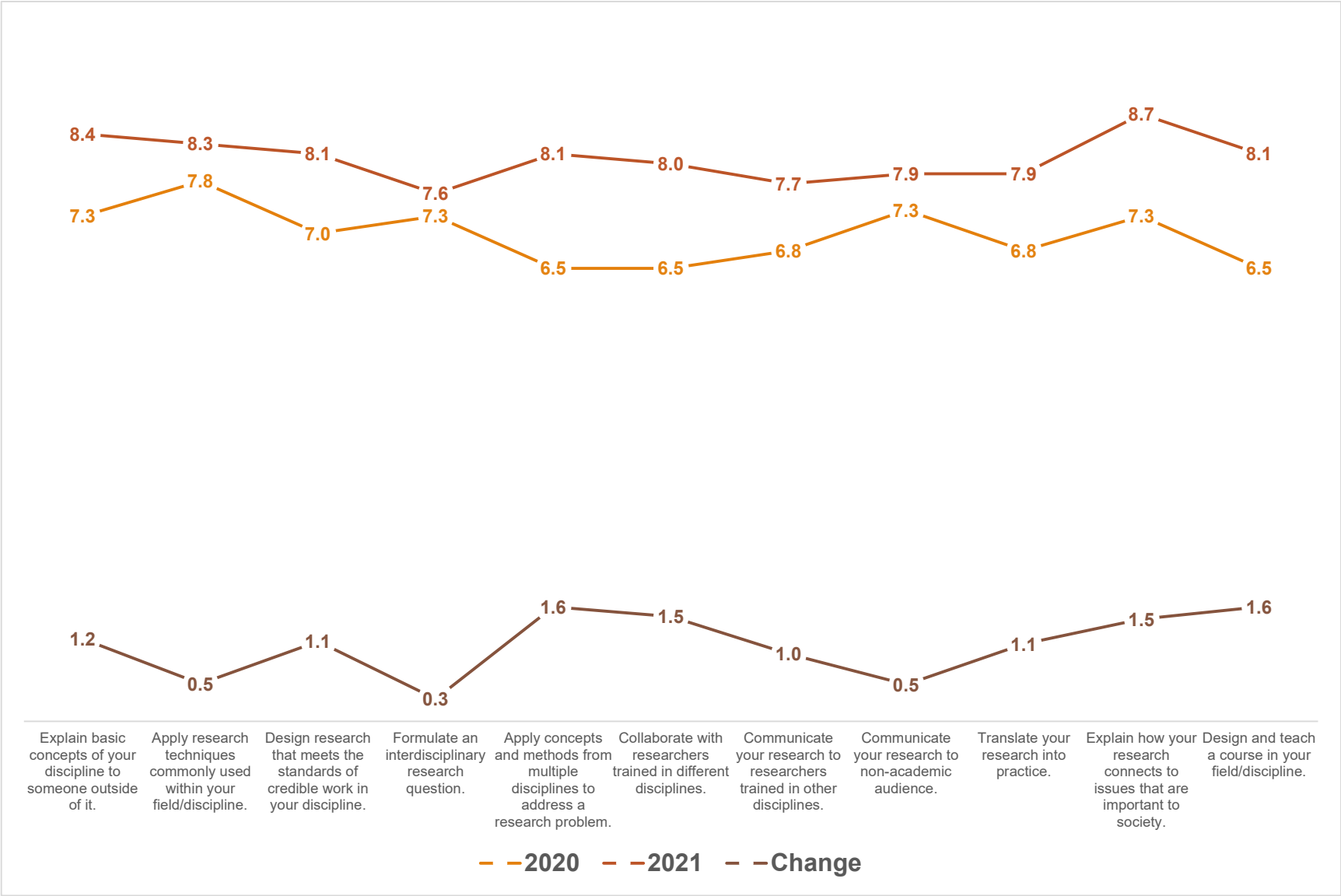


Figure 30: INSPIRES Graduate Students Self-Reported Knowledge and Skill Gain

INSPIRES 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 31, the area where the most significant gains have been made was “Learning to use instrumentation or techniques that are not typically used in the student’s own discipline.”

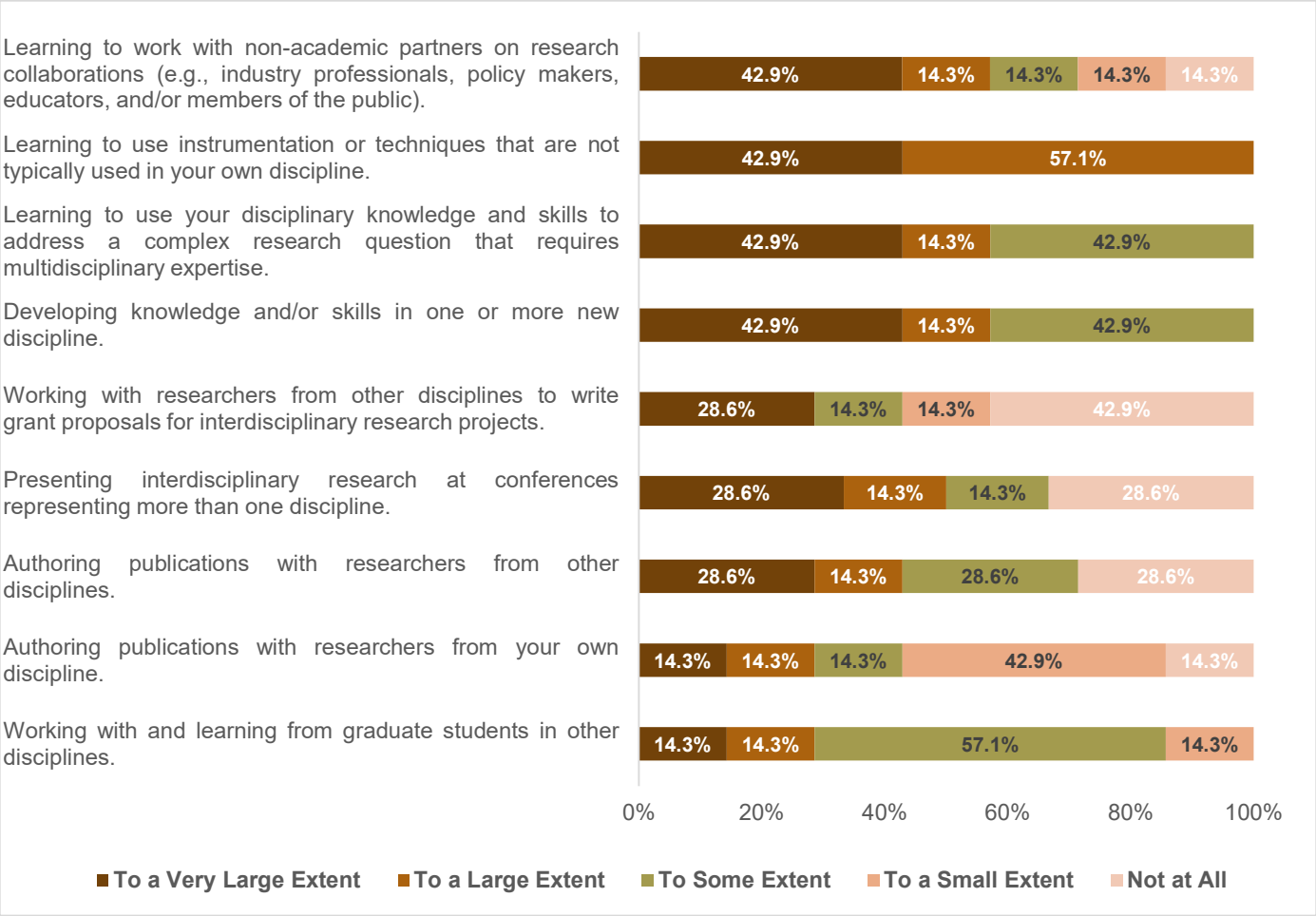


Figure 31: Competency Gains Achieved through the INSPIRES Project

Graduate students who participated in the survey demonstrated a relatively high level of confidence in their ability to recognize and adhere to ethical principles of research conduct (Figure 32). The one area that may benefit from further attention from project leadership is related to ethical issues related to intellectual property rights (IP) and conflicts of interest (CoI).

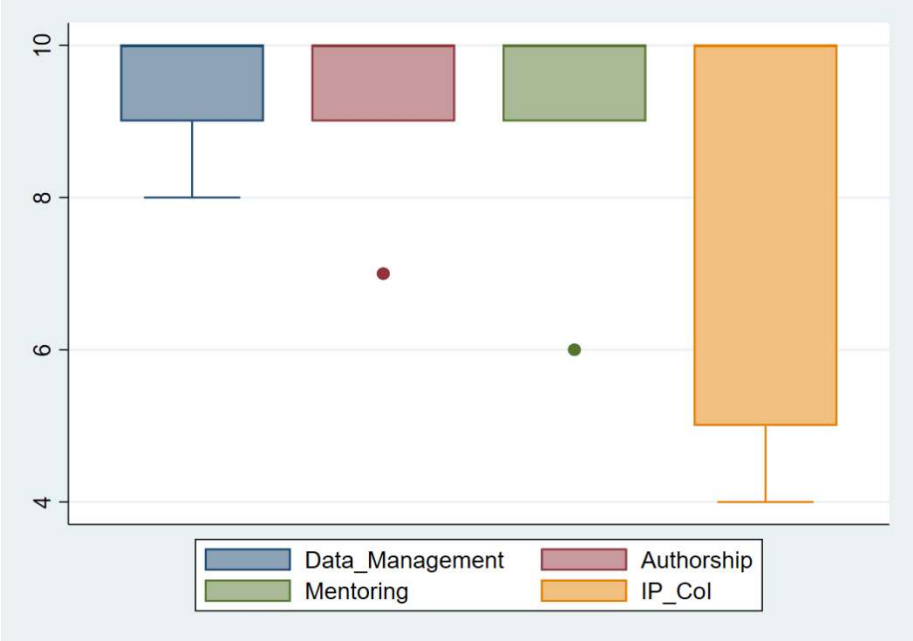


Figure 32: Self-rated Ability to Recognize and Adhere to Ethical Principles of Research Conduct – Graduate Students

Similar to what was reported by INSPIRES faculty and researchers, most of the graduate students who participated in the 2021 survey (85.7%) indicated that the meetings with their mentors are largely focused on their research projects and professional development and networking strategies (Figure 33).

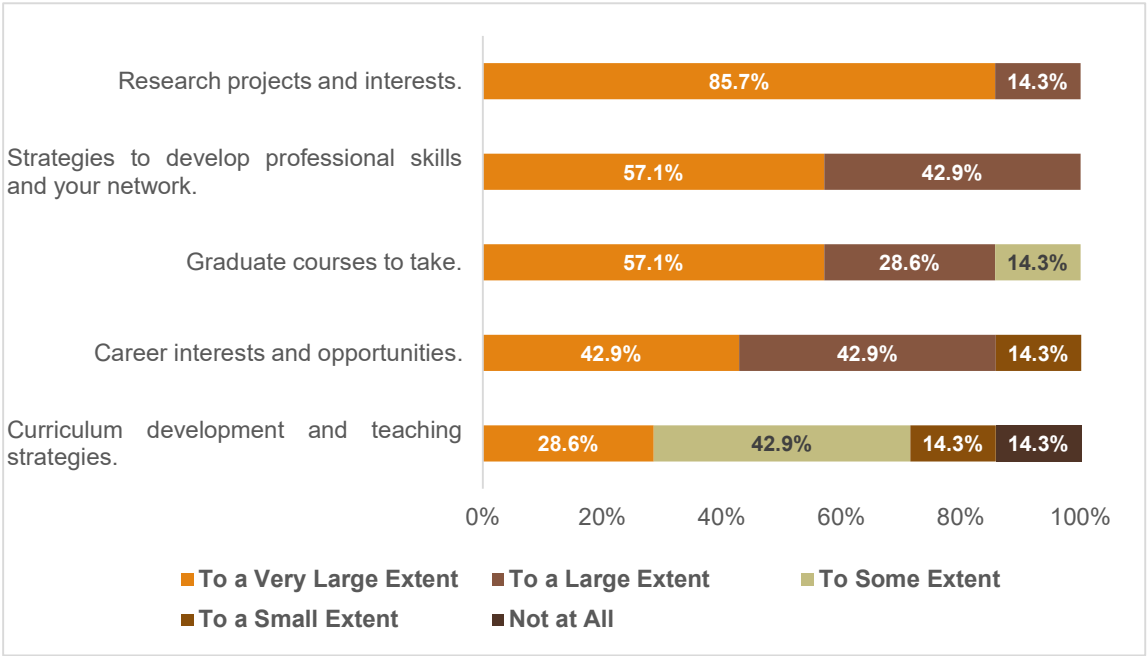


Figure 33: Areas of Focus in Discussions with Mentors

INSPIRES graduate students were asked to identify key activities they engaged in in 2021. As shown in Figure 34, most students indicated that they presented their research to an academic or professional audience, gave a talk to an audience outside their discipline, and conducted a field or laboratory research as a research assistant.

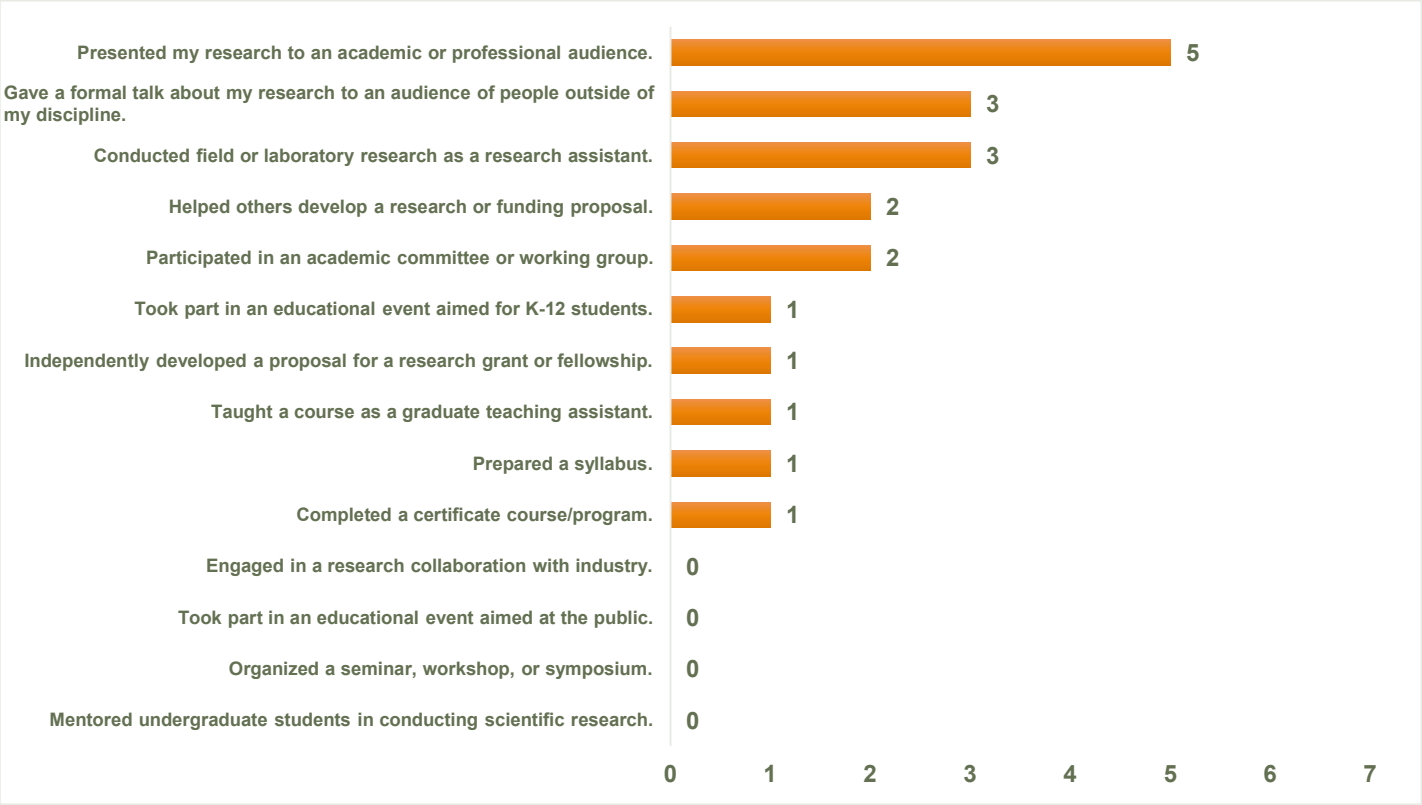


Figure 34: Areas of Focus in Discussions with Mentors

Themes Emerging from Graduate Student Focus Group Discussions

The evaluation team conducted a focus group discussion with INSPIRES graduate students on November 10, 2021, to get a deeper insight into their graduate training experience. Several themes emerged that indicate program strengths and opportunities for improvement.

Graduate students indicated that the INSPIRES project supports their academic research development in a variety of ways, including by providing

- a network that serves as a support system for graduate students,
- opportunities for research collaborations,
- opportunities to develop experience in technology development (e.g., build sensors),
- opportunities to make a scientific contribution with societal impact,
- opportunities to present research, and
- access to resources.

Regarding mentoring and career development resources, INSPIRES graduate students noted:

- supportive mentors,
- opportunities for professional development and networking, and

- a New England-centric research and professional network that might be leveraged in the future.

INSPIRES graduate students noted there may be opportunities to improve:

- exposure to non-academics,
- inter-theme interactions and integration (graduate students indicated there is less than optimal connection among project themes, and a need for more clarity on how data from individual projects on which students are working will feed into other themes),
- clarity on who will be the end users of products developed by the INSPIRES project,
- regular interaction with advisors, and
- feedback from advisors on whether students are making sufficient progress.

Undergraduate Students' Experiences and Outcomes

Figure 35 shows the level of confidence INSPIRES undergraduate students have in their ability to perform a variety of research-related tasks. Overall, students expressed a high level of confidence in all areas, with relatively higher levels observed in their ability to work independently, work effectively with others in lab or field settings, and search the literature to identify information needed to support research.

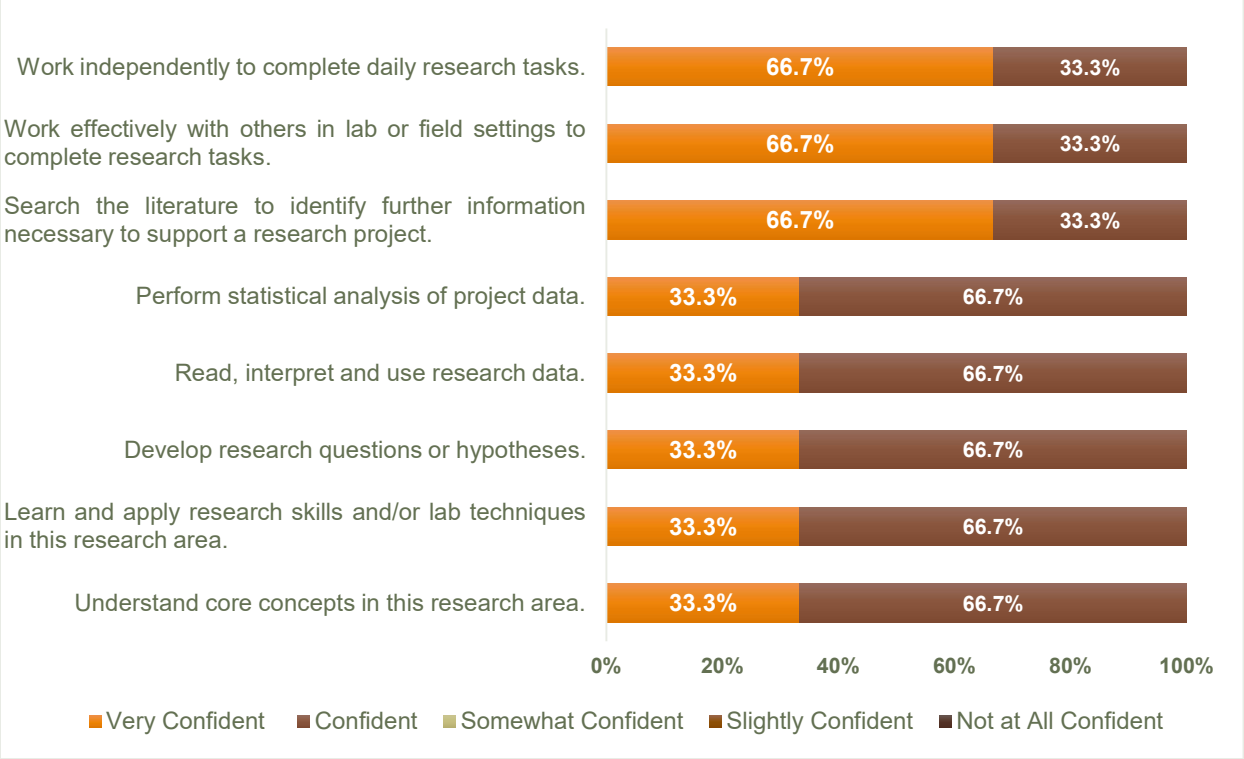


Figure 35: Undergraduate Students' Research Knowledge and Skills – Level of Confidence in Ability (N=3)

When asked to indicate their level of confidence in their ability to perform a variety of science communication tasks, INSPIRES undergraduate students who responded to the 2021 survey expressed 100% confidence in the ability to give an oral research presentation in a formal group setting and to discuss research literature/results in informal group settings (Figure 36).

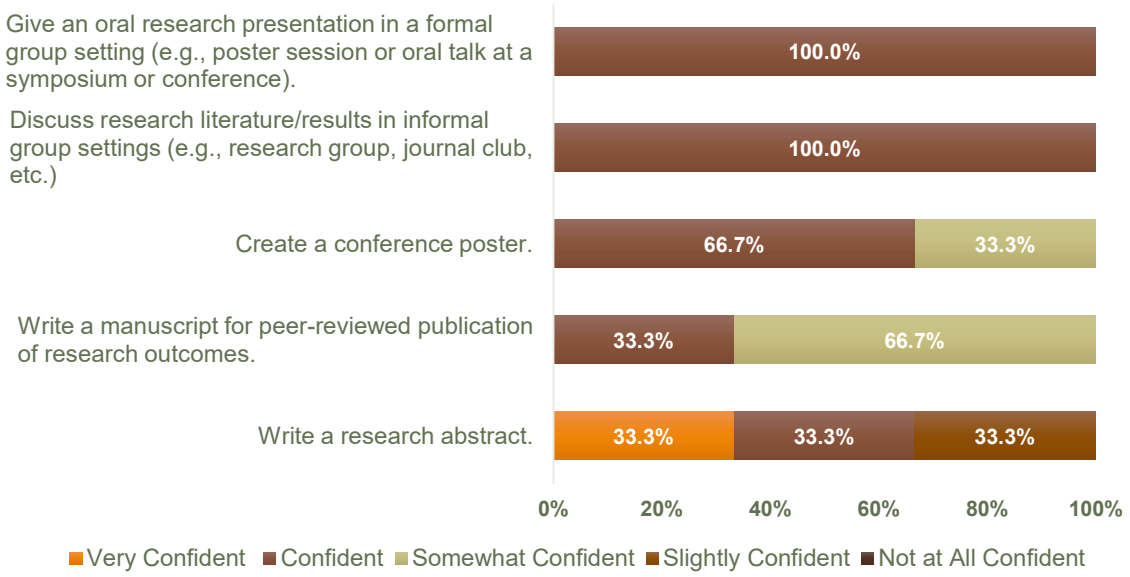


Figure 36: INSPIRES Undergraduate Students' Communication Skills – Level of Confidence in Ability

Compared to graduate students, INSPIRES undergraduate students who participated in the 2021 survey indicated a lower level of confidence in their ability to recognize and adhere to ethical principles of research conduct (Figure 37). Similar to graduate students, undergraduates reported the lowest level of confidence with intellectual property rights (IP) and conflicts of interest (CoI).

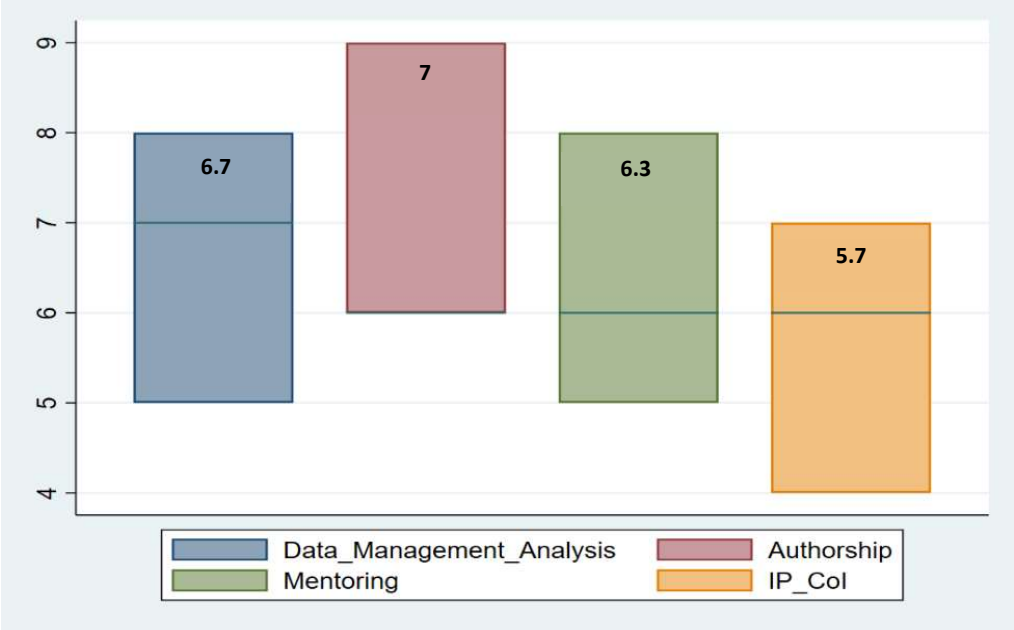


Figure 37: Self-rated Ability to Recognize and Adhere to Ethical Principles of Research Conduct – Undergraduate Students

External Stakeholder Engagements

INSPIRES faculty and researchers were asked if they engaged in research collaborations or partnerships with external stakeholders in 2021. Approximately 66.6% of the survey respondents answered "yes," indicating engagement in 2021 in a research collaboration or partnership with either an existing or a new collaborator or partner (Figure 38).

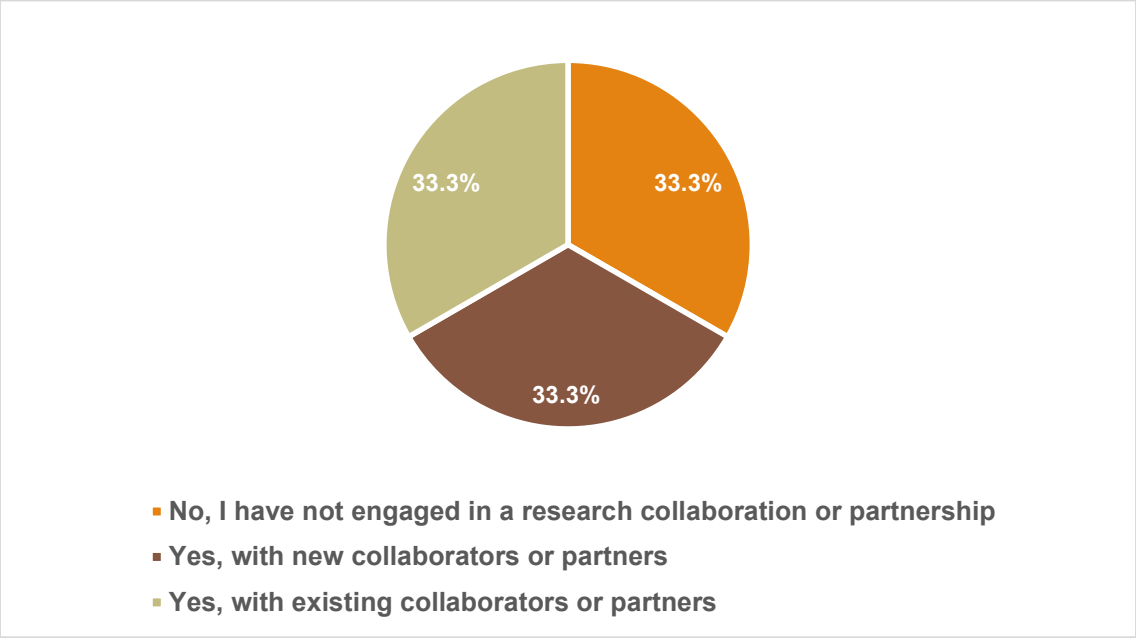


Figure 38: Stakeholder Engagement

Respondents indicated engagement with the following external stakeholders:

- NSF-funded STEM+C
- USDA-HEC
- USFS
- Forest Stewards Guild
- MASN
- Appalachian Mountain Club
- USDA/FS

INSPIRES faculty and researchers were also asked if they plan to engage in a research collaboration or partnership with external stakeholders in a project-related area during the coming year: 75% of the respondents answered "yes" (Figure 39).

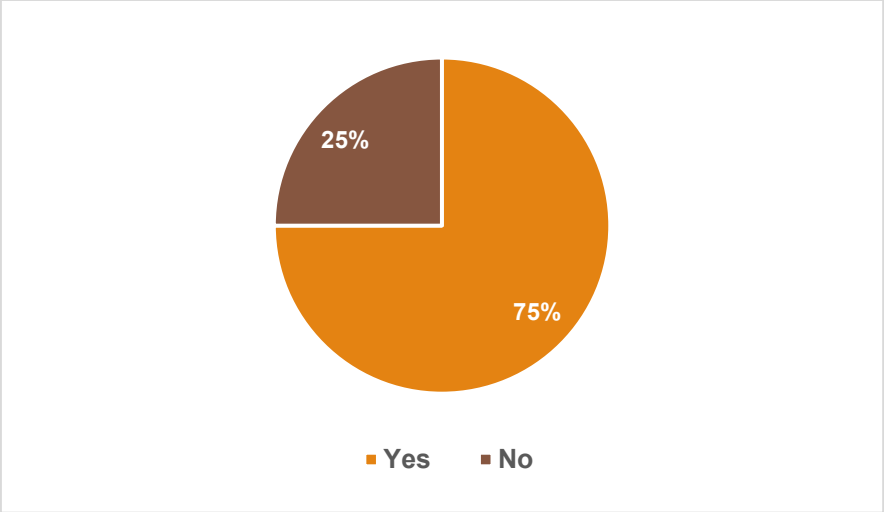


Figure 39: Plan to Engage in a Research Collaboration or Partnership with External Stakeholders in a Project-Related Area in the Coming Year

- 28.6% indicated they were able to leverage your INSPIRES-related research outcomes to generate additional research funding.
- 15% indicated that research findings from INSPIRES-related studies have contributed to further research conducted by others.
- 66.7% indicated that they expect their work as part of the project to benefit K-12 students.
- 61.9% indicated that they expect their work as part of the project to influence future forest policy/management decisions.

The year 3 INSPIRES faculty and researchers survey also included a set of questions about additional contributions by project participants and outcomes in a variety of areas including future funding, contribution to scientific knowledge, contribution to STEM workforce development in the three jurisdictions, and contribution to force policy decision making.

INSPIRES faculty and researchers were asked whether they expect their work as part of the project to influence future forest policy/management decisions. Respondents provided the following comments:

- "Our work contributes to building a more informed citizenry who understand data and how it can inform policy and decision making. I hope that these students will become adults who use this knowledge to inform future forest policy and management, as voting citizens and also possibly as scientists."
- "I processed a bunch of LiDAR data that will be used (after some more processing) in forest management practices."
- "Better estimate the effect of environment and climate on the forest productivity and diversity."
- "I expect that policy/management decisions will be influenced by data that I ultimately produce under INSPIRES support."
- "My project as a part of INSPIRES goal improves semantic segmentation models' performance on the Hyperspectral images (HSI). Our novel Machine Learning algorithms accurately classify diversified

land cover in remotely sensed images when compared to existing approaches. This, hence, influences decision-making and the future of forest management significantly."
- "Management scenarios for forest carbon storage."
- "Better monitoring and future projections of alternative futures."

Summary and Conclusion

The evaluation plan for the INSPIRES project outlined key goals to be achieved in each of the EPSCoR Track-2 Award target areas: development of research capacity, inter-jurisdictional collaborations and partnerships, and education and workforce development. Analyses of data collected from the annual surveys, in conjunction with data from the T2-DOP, illustrate progress toward achieving these goals and highlight areas where adjustments are needed.

Research Capacity

Question: What progress has been made in achieving the key benchmarks and milestones in each of the project's four research themes?

- ✓ Similar level of research productivity was observed in year 3 compared to year 2, as indicated by the number of proposals submitted, awards received, and articles published.
- ✓ More than half of the INSPIRES project faculty and researchers are early career investigators. Evidence from the surveys and the T2-DOP report shows robust participation in project activities and indicates the T2-award supported research productivity.
- ✓ The surveys and T2-DOP did not collect information on the progress of technical or research capabilities development: the T2-DOP Feedback Report lists tools, databases, and software developed. A summative assessment by an external, expert panel, planned for January 2023, will assess the extent to which these activities and products are progressing as planned and are contributing new research capabilities to the jurisdictions involved.
- ✓ The next wave of data collection will aim to capture patent applications or awards to demonstrate commercial potential and application of the tools being developed by the project (another indicator of enhanced research capacity in the region).

Interjurisdictional Collaborations and Partnerships

Question: To what extent has the project enabled researchers in the participating institutions to establish interdisciplinary collaborations?

- ✓ Robust research collaboration among project participants is illustrated by survey responses and the T2-DOP report. The majority of these collaborations are on research studies and proposals.
- ✓ The T2-DOP report shows that project teams are involved almost equally in intra- and inter-jurisdictional research collaborations.
- ✓ Senior faculty members (PIs and Co-PIs) continue to be central to collaborative efforts, as indicated by the number of connections reported to and from these individuals compared to other researchers. This is also indicated by the fact that these individuals continue to play a significant role in facilitating connection among other project researchers: the social network analysis shows that these individuals have high betweenness centrality, and potential influence in the network, probably because they control information and resources flow within the network. Given the continued prominent role of the PI and Co-PIs in the network, it will be important for the team to identify and prioritize how the connections established as a result of the INSPIRES project might be sustained or expanded in the long-term.

Questions: To what extent has the project enabled researchers in the participating institutions to establish partnerships with external stakeholders in industry, government, and non-profit sectors?

- ✓ More than 66% of the survey participants indicated that they have engaged in a research collaboration or partnership with an existing or new external stakeholder during 2021.
- ✓ 75% of the survey participants indicated that they plan to engage in a research collaboration or partnership with external stakeholders in a project-related area during the coming year.
- ✓ The project should consider ways in which external stakeholders might be engaged in evaluation activities to enable assessment of the effectiveness and outcomes of these collaborations and the broader societal impact of INSPIRES project activities.

Education and Workforce Development

Question: What progress has been made in achieving the project's education and workforce development benchmarks and milestones?

- ✓ There is evidence (based on the INSPIRES team composition) of a continued commitment to support early-career investigators as they work to establish an independent research path.
- ✓ A large number of students (graduate and undergraduate) are supported by the INSPIRES project with financial, technical, and/or mentoring support. Assuming positive training and career outcomes for these students, data suggests that the INSPIRES project has high potential to make a significant contribution to developing the STEM workforce in the participating jurisdictions.
- ✓ The addition of the supplement in 2021 to the project has enhanced the diversity of the INSPIRES project faculty researchers, and students.

Appendix I: Timeline for Evaluation Activities

Evaluation Activities	2020			
	Q1	Q2	Q3	Q4
Baseline Survey – Faculty and Researchers	√			
Baseline Survey – Graduate and Undergraduate Students				√
Annual Survey – Faculty and Researchers				√
	2021			
	Q1	Q2	Q3	Q4
Formative Expert Panel Assessment	√			
Annual Survey – Graduate and Undergraduate Students				√
Focus Group Interview – Graduate Students				√
Annual Survey – Faculty and Researchers				√
	2022			
	Q1	Q2	Q3	Q4
Baseline Survey – AAMU Faculty and Researchers				√
Exit Survey(s) – AAMU Graduate and Undergraduate Student Research Experiences			√	√
Annual Survey – Graduate and Undergraduate Students				√
Annual Survey – Faculty and Researchers				√
	2023			
	Q1	Q2	Q3	Q4
Summative Expert Panel Assessment	√			
Exit Survey(s) – AAMU Graduate and Undergraduate Student Research Experiences			√	√
Annual Survey – Graduate and Undergraduate Students				√
Annual Survey – Faculty and Researchers (incl AAMU)				√
	2024			
	Q1	Q2	Q3	Q4
Focus Group Interview(s) – External Stakeholders	√			
Exit Interviews – Faculty and Researchers; Graduate Students	√			
Longitudinal Data Analysis and Final Report			√	

Appendix II: Collaboration Analysis

Collaboration on Studies or Grants:

The social network analysis indicates that collaboration on research projects or grants is the most predominant mechanism, and reciprocity (both individuals indicate that a collaboration in this area exists) is more likely with collaborations on research projects or grants.

The density of the current collaboration network on INSPIRES-related studies or grants is 0.071, which means that 7.1% of all possible connections or relationships in this network are actualized (Figure Aii-1). The average number of connections reported by survey participants to other members of the project for this activity (studies or grants) is 5. Only 29% of these connections are reciprocated (connections reported in the opposite direction between the same people).

The following INSPIRES faculty and researchers have the highest number of connections for this activity:

- D'Amato, Anthony – UVM – Senior Faculty
- Toolin, Regina – UMaine – Senior Faculty
- Weiskittel, Aaron – UMaine – Senior Faculty
- Classen, Aimee– UVM – Senior Faculty

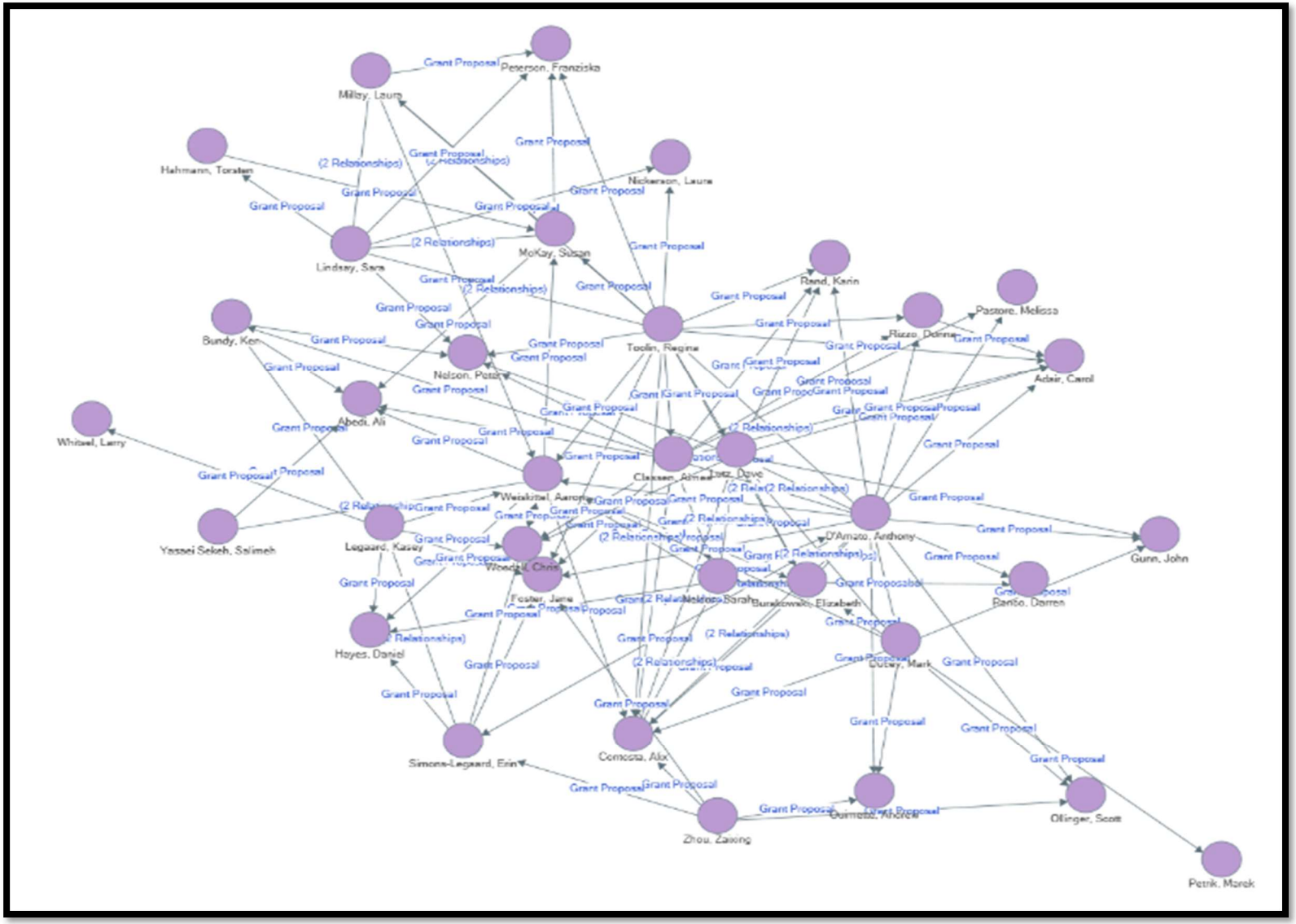


Figure Aii-1: Collaboration among INSPIRES Faculty & Researchers on Studies or Grants

Collaboration on Publications:

The density of the current collaboration network on INSPIRES-related publications is 0.028, which means that 2.8% of all possible connections or relationships in this network are actualized (Figure Aii-2). The average number of connections reported by survey participants to other members of the project for this activity (studies or grants) is 2. Only 33% of these connections are reciprocated (connections reported in the opposite direction between the same people).

The following INSPIRES faculty and researchers have the highest number of connections for this activity:

- Weiskittel, Aaron – UMaine – Senior Faculty
- D'Amato, Anthony – UVM – Senior Faculty
- Contosta, Alix – UNH – Early-Career Researcher
- Classen, Aimee – UVM – Senior Faculty

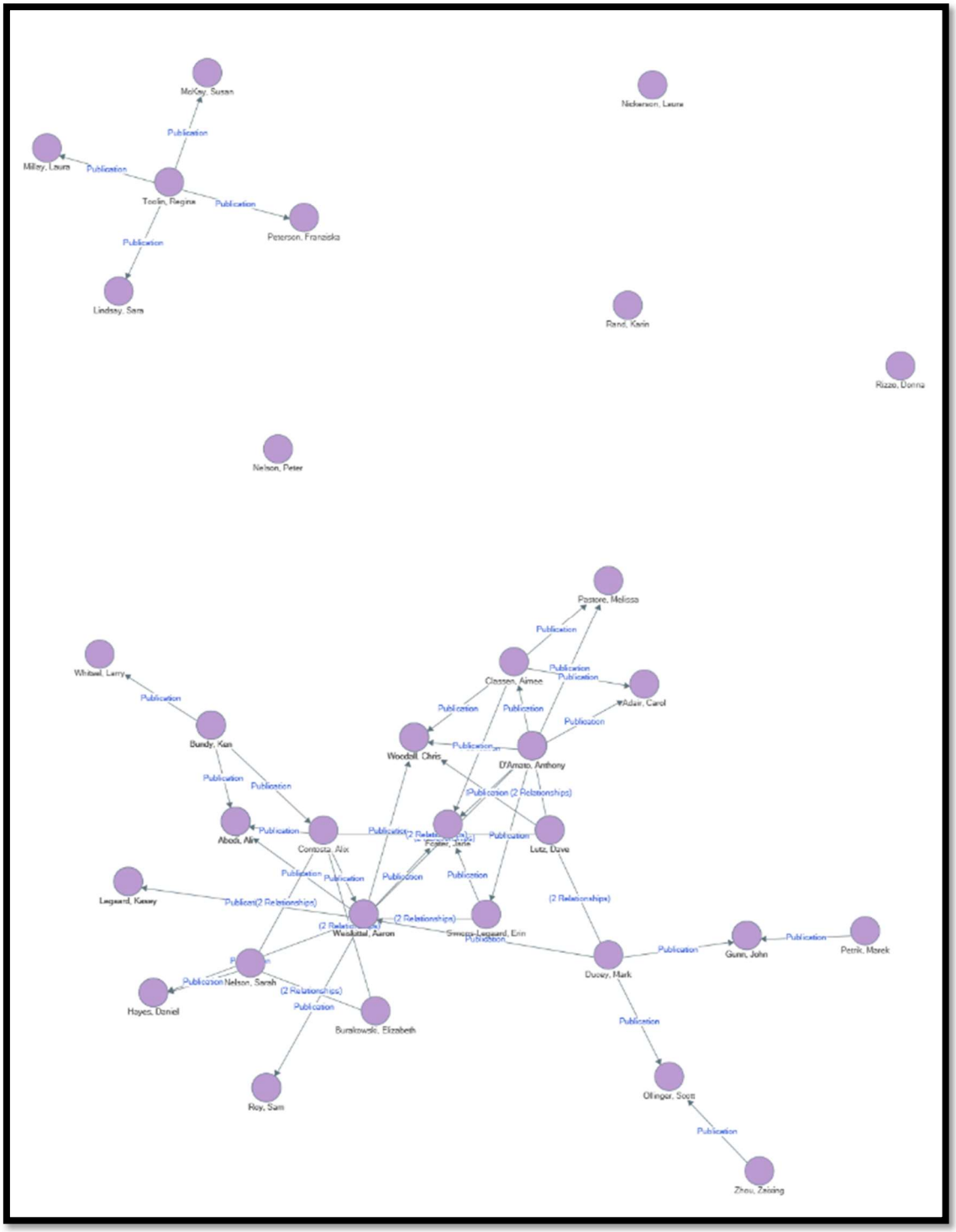


Figure Aii-2: Collaboration among INSPIRES Faculty & Researchers on Publications

Collaboration on Developing Models and Tools:

The density of the current collaboration network on INSPIRES-related model development is 0.031, which means that 3.1% of all possible connections or relationships in this network are actualized (Figure Aii-3). The average number of connections reported by survey participants to other members of the project for this activity (studies or grants) is 2.3. Only 18.5% of these connections are reciprocated (connections reported in the opposite direction between the same people).

The following INSPIRES faculty and researchers have the highest number of connections for this activity:

- Lutz, Dave – Dartmouth-Early-Career Researcher
- D'Amato, Anthony – UVM – Senior Faculty
- Contosta, Alix – UNH – Early-Career Researcher
- Simons-Legaard, Erin – UMaine – Early-Career Researcher

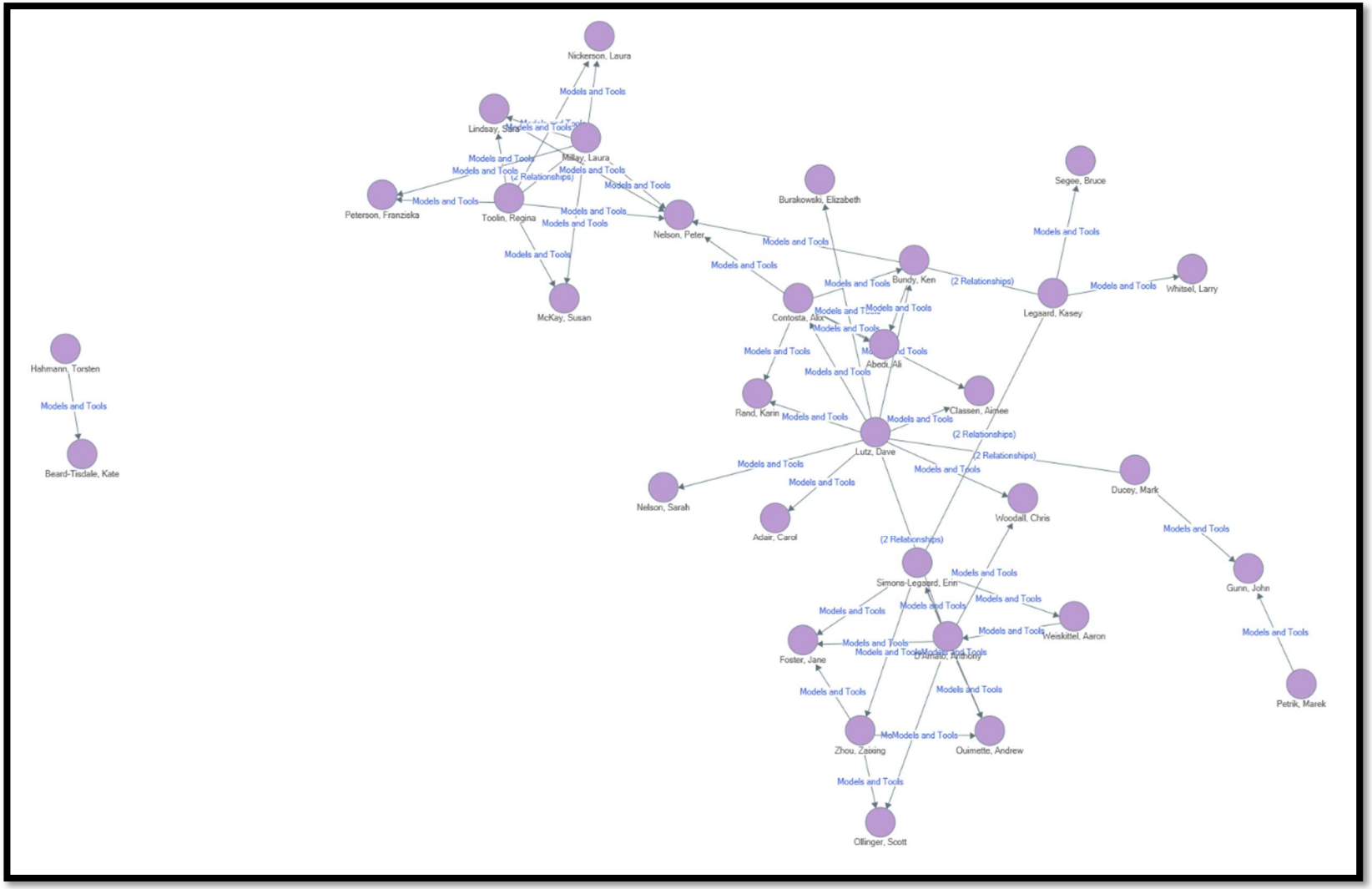


Figure Aii-3: Collaboration among INSPIRES Faculty & Researchers on Developing Models and Tools

Collaboration on Stakeholder Engagement:

The density of the current collaboration network on INSPIRES-related stakeholder engagement is 0.026, which means that 2.6% of all possible connections or relationships in this network are actualized (Figure Aii-4). The average number of connections reported by survey participants to other members of the project for this activity (studies or grants) is 2.1. Only 9% of these connections are reciprocated (connections reported in the opposite direction between the same people).

The following INSPIRES faculty and researchers have the highest number of connections for this activity:

- Millay, Laura – UMaine – Professional Staff
- D'Amato, Anthony – UVM – Senior Faculty
- Toolin, Regina – UMaine – Senior Faculty
- Lindsay, Sara – UMaine – Senior Faculty

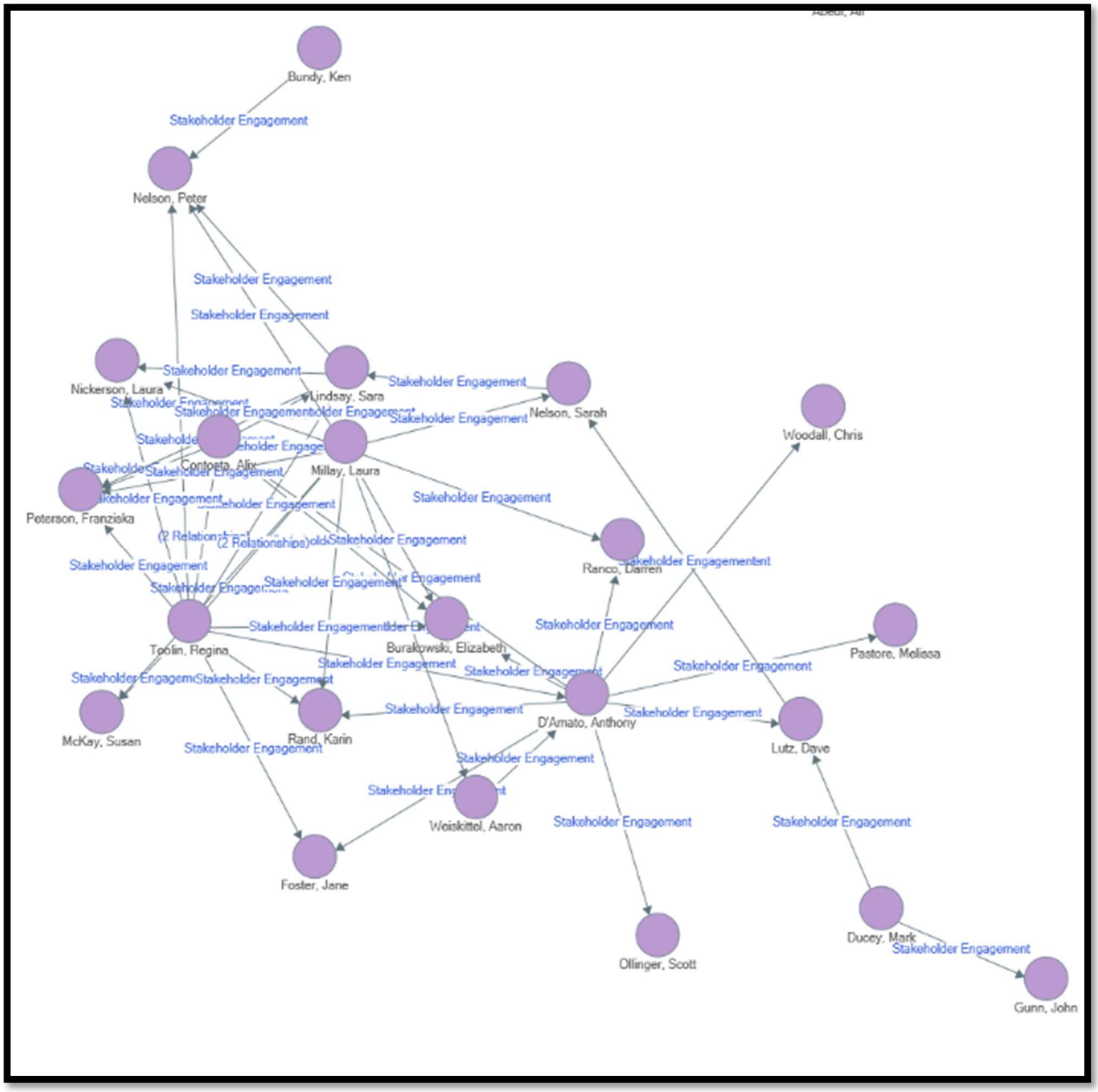


Figure Aii-4: Collaboration among INSPIRES Faculty & Researchers on Stakeholder Engagements

Collaboration on Developing Teaching Course:

The density of the current collaboration network on INSPIRES-related development of teaching courses is 0.012, which means that 1.2% of all possible connections or relationships in this network are actualized (Figure Aii-5). The average number of connections reported by survey participants to other members of the project for this activity (studies or grants) is less than 1. Only 19% of these connections are reciprocated (connections reported in the opposite direction between the same people).

The following INSPIRES faculty and researchers have the highest number of connections for this activity:

- Toolin, Regina– UMaine – Senior Faculty

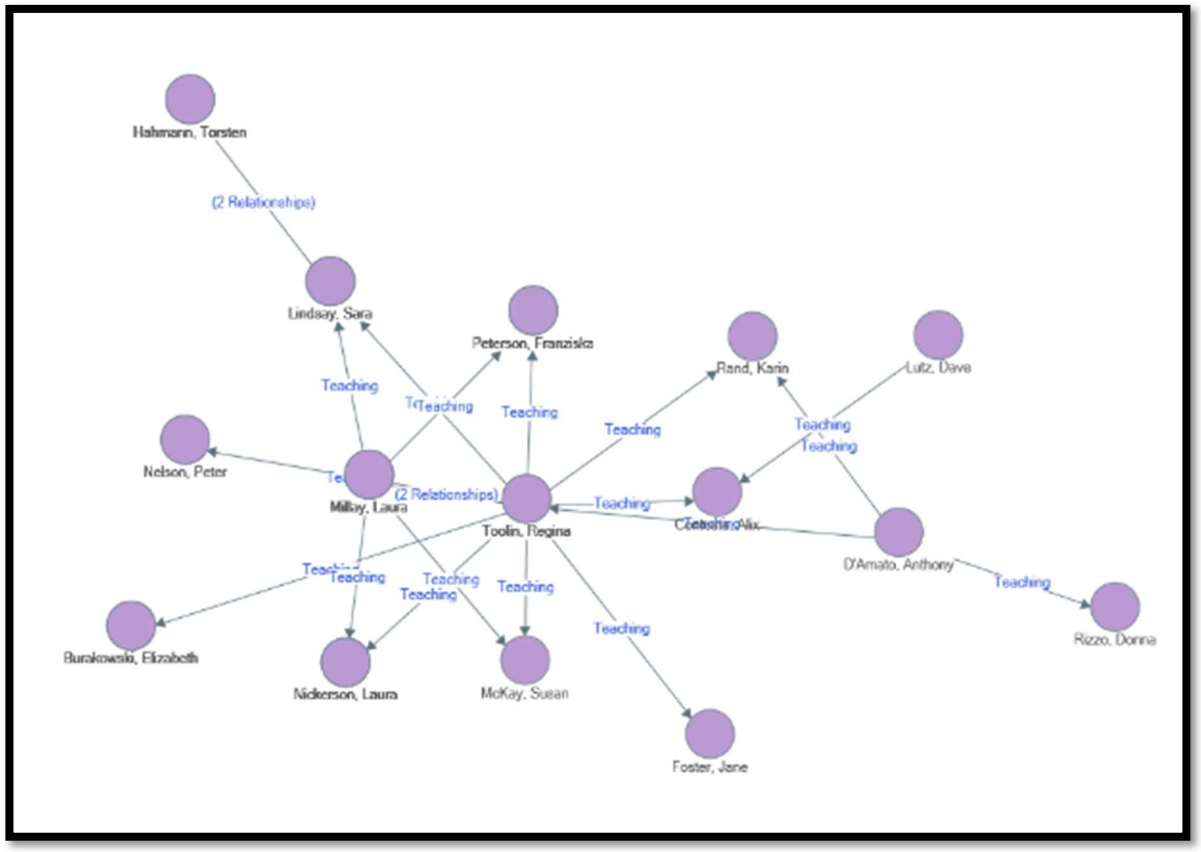


Figure Aii-5: Collaboration among INSPIRES Faculty & Researchers on Developing Teaching Course

Collaboration on Mentoring and Training:

The density of the current collaboration network on INSPIRES-related mentoring and training is 0.026, which means that 2.6% of all possible connections or relationships in this network are actualized (Figure Aii-6). The average number of connections reported by survey participants to other members of the project for this activity (studies or grants) is 2. Only 9% of these connections are reciprocated (connections reported in the opposite direction between the same people).

The following INSPIRES faculty and researchers have the highest number of connections for this activity:

- D'Amato, Anthony – UVM – Senior Faculty
- Classen, Aimee – UVM – Senior Faculty
- Contosta, Alix – UNH – Early-Career Researcher
- McKay, Susan – UMaine – Senior Faculty

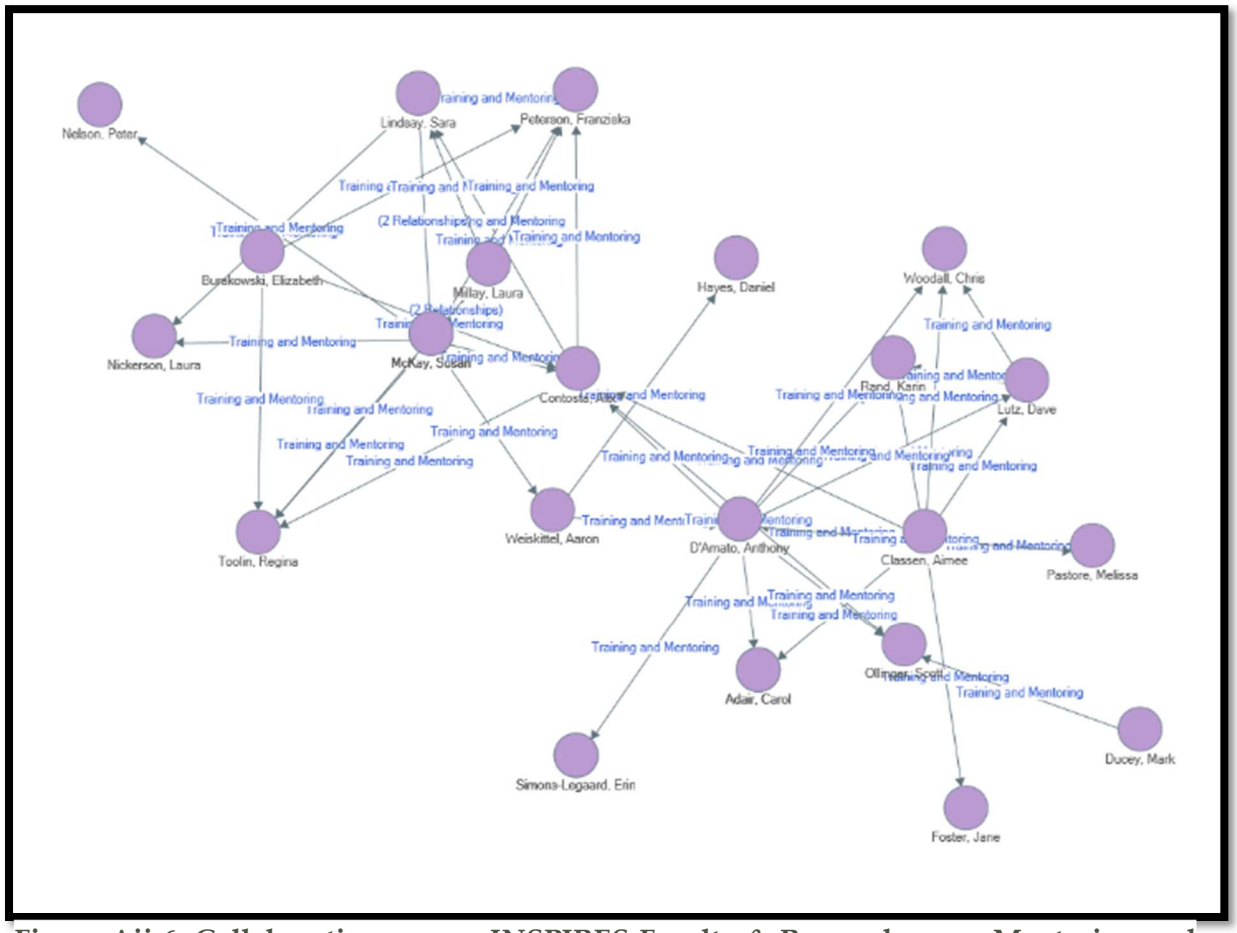


Figure Aii-6: Collaboration among INSPIRES Faculty & Researchers on Mentoring and Training

Collaborations among AAMU Faculty and Researchers

Studies or Grants

The density of the current collaboration network on INSPIRES-related studies or grants is 0.14, which means that 14% of all possible connections or relationships in this network are actualized (Figure Aii-7). Of these connections, approximately 46% are reciprocated (connections reported in the opposite direction between the same people).

The following AAMU faculty and researchers have the highest number of connections for this activity:

- Lemke, Dawn – AAMU -Early-Career Researcher

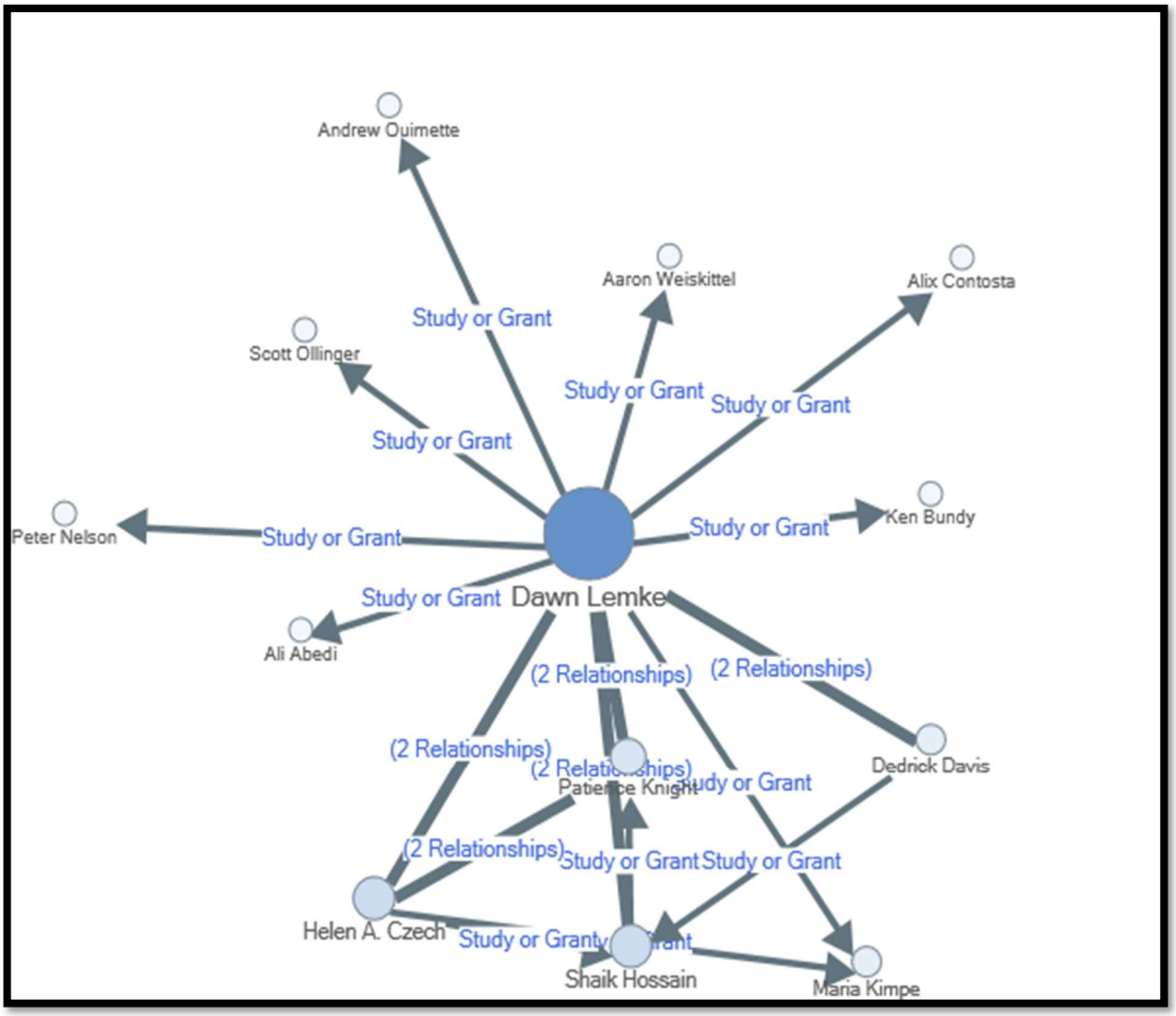


Figure Aii-7: Collaboration among AAMU Faculty & Researchers on Studies or Grants

Publications

The density of the current collaboration network on INSPIRES-related publications is 0.019, which means that 2% of all possible connections or relationships in this network are actualized (Figure Aii-8). Of these connections, approximately 67% are reciprocated (connections reported in the opposite direction between the same people).

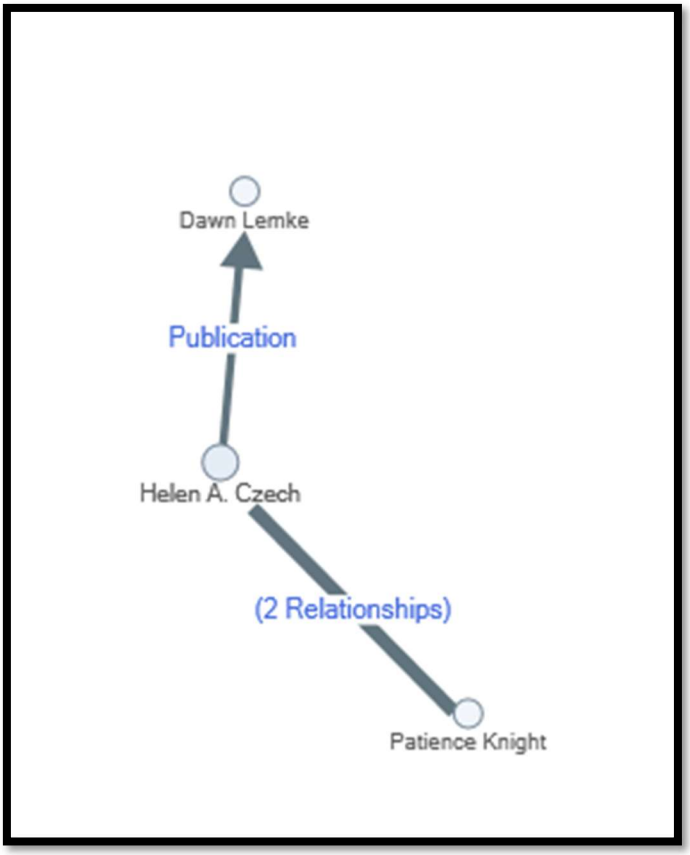


Figure Aii-8: Collaboration among AAMU Faculty & Researchers on Publications

Mentoring or Training

The density of the current collaboration network on INSPIRES- mentoring and training is 0.045, which means that 4.5% of all possible connections or relationships in this network are actualized (Figure Aii-9). Of these connections, approximately 57% are reciprocated (connections reported in the opposite direction between the same people).

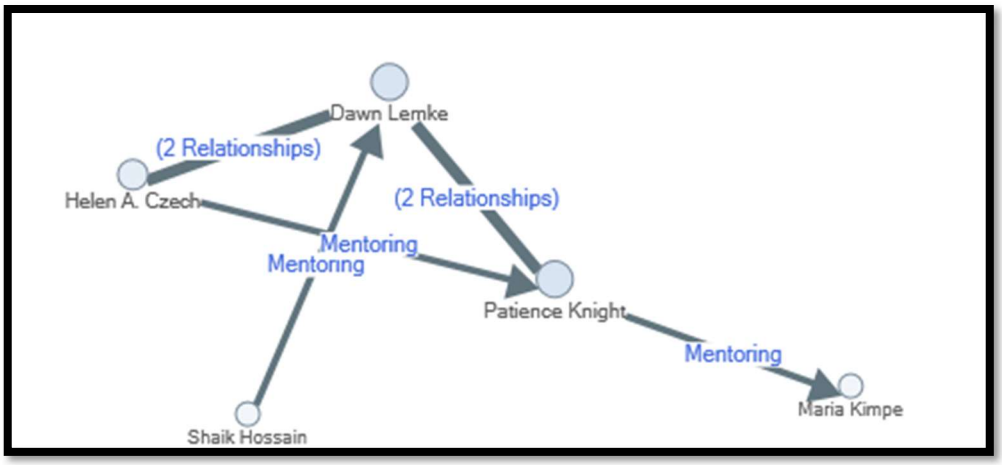


Figure Aii-9: Collaboration among AAMU Faculty & Researchers on Mentoring & Training

Developing and Teaching a Course

The density of the current collaboration network on INSPIRES- mentoring and training is 0.013, which means that 1.3% of all possible connections or relationships in this network are actualized (Figure Aii-10).

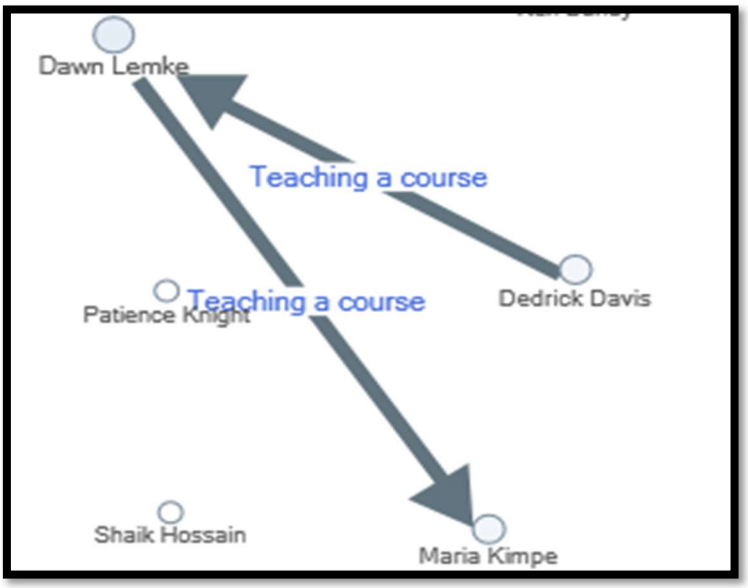


Figure: Aii-10 Collaboration among AAMU Faculty & Researchers on Developing a Teaching a Course

Appendix 3. 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	3	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
Emily Uhrig	ALL	UMaine, Center for Research on Sustainable Forests	Professional Staff
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-Noyes	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 4. INSPIRES Team Profiles

Profiles by Stefania Irene Marthakis

Additional team profiles are available on the New England Sustainability Consortium (NEST) INSPIRES website. New profiles are added regularly.

INSPIRES
Team Profiles

Alix Contosta

Research Assistant Professor
University of New Hampshire
Research Interests: Soil carbon, land use-climate feedbacks, winter ecology, ecosystem ecology

Dr. Alix Contosta's home base is in the Earth Systems Research Center at the University of New Hampshire (UNH), although she is often also in the field year-round. She is an ecosystem ecologist whose focus is on changing winters and their effects on ecosystems and people.

Contosta's academic interest in changing winters started during her Ph.D. at UNH, where she was stucying the effect of climate change on soils, soil organisms, and soil nutrient cycling. Trying to find unique questions to ask for her research project, Contosta started thinking about the importance of winters since there had been limited research that focused on the so-called "dormant season."

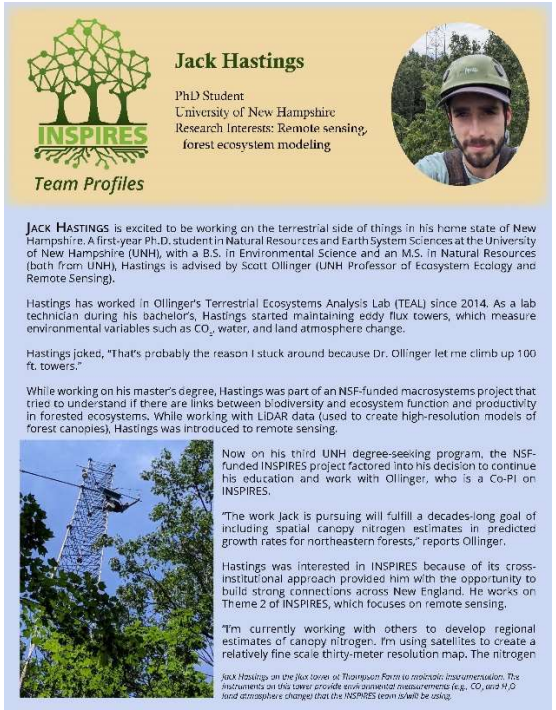
Her personal interest in winter began years earlier when Contosta moved to New England for her master's degree. She is originally from Philadelphia, where winters are shaped by the city's landscape and often result in dirty snow neighboring lanes of traffic. The forests and fields of Massachusetts, Vermont, and New Hampshire offered a stark contrast to her urban experience, and she realized how beautiful winters could be.

"It was amazing to me that it could be so beautiful in the woods, it could be so quiet, the trees looked totally different without leaves and you could really see their personalities in a different way," Contosta said. "This fascination I had with this forgotten season aligned with the research questions that I was interested in pursuing, and so my focus in winter ecology started then, something that has stuck with me ever since."

Contosta is one of the leads of INSPIRES Theme 1, a team focused on designing and installing a network of cutting-edge sensor suites across the northern forests of Maine, New Hampshire, and Vermont. Within this framework, Contosta and Theme 1 colleagues are trying to understand changing winter conditions, specifically changes in the winter to spring transition period called the vernal window (i.e., the timeframe between snow melt and when forest canopies 'leaf-out' or 'green-up').

Contosta is part of another NSF-funded grant as the Principal Investigator of Winter Weather Whiplash and its Impacts on Socio Ecological Systems. Her project is looking at not only winters getting warmer, but the variability of winter conditions. For example, she is exploring extreme cold snaps in winter that

Contosta and INSPIRES team members Regina Toolin, Liz Burakowski, Peter Nelson, Travis Peterson, Marcus van der Erb and Sara Lyndsay with STEM teachers from Maine and Vermont.



INSPIRES
Team Profiles

Jack Hastings

PhD Student
University of New Hampshire
Research Interests: Remote sensing, forest ecosystem modeling

Jack Hastings is excited to be working on the terrestrial side of things in his home state of New Hampshire. A first-year Ph.D. student in Natural Resources and Earth System Sciences at the University of New Hampshire (UNH), with a B.S. in Environmental Science and an M.S. in Natural Resources (both from UNH), Hastings is advised by Scott Ollinger (UNH Professor of Ecosystem Ecology and Remote Sensing).

Hastings has worked in Ollinger's Terrestrial Ecosystems Analysis Lab (TEAL) since 2014. As a lab technician during his bachelor's, Hastings started maintaining eddy flux towers, which measure environmental variables such as CO_2, water, and land atmosphere change.

Hastings joked, "That's probably the reason I stuck around because Dr. Ollinger let me climb up 100 ft. towers."

While working on his master's degree, Hastings was part of an NSF-funded macrosystems project that tried to understand if there are links between biodiversity and ecosystem function and productivity in forested ecosystems. While working with LiDAR data (used to create high-resolution models of forest canopies), Hastings was introduced to remote sensing.

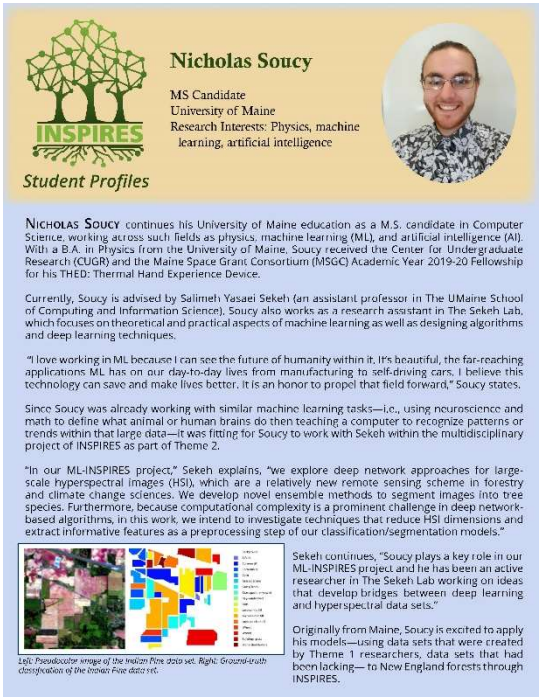
Now on his third UNH degree-seeking program, the NSF-funded INSPIRES project factored into his decision to continue his education and work with Ollinger, who is a Co-PI on INSPIRES.

"The work Jack is pursuing will fulfill a decades-long goal of including spatial canopy nitrogen estimates in predicted growth rates for northeastern forests," reports Ollinger.

Hastings was interested in INSPIRES because of its cross-institutional approach provided him with the opportunity to build strong connections across New England. He works on Theme 2 of INSPIRES, which focuses on remote sensing.

"I'm currently working with others to develop regional estimates of canopy nitrogen. I'm using satellites to create a relatively fine scale thirty-meter resolution map. The nitrogen

Jack Hastings on the flux tower at Thompson Farm to maintain instrumentation. The instruments on this tower provide environmental measurements (e.g., CO_2 and H_2O land atmosphere change) that the INSPIRES team is/will be using.



INSPIRES
Student Profiles

Nicholas Soucy

MS Candidate
University of Maine
Research Interests: Physics, machine learning, artificial intelligence

Nicholas Soucy continues his University of Maine education as a M.S. candidate in Computer Science, working across such fields as physics, machine learning (ML), and artificial intelligence (AI). With a B.A. in Physics from the University of Maine, Soucy received the Center for Undergraduate Research (CUGR) and the Maine Space Grant Consortium (MSGC) Academic Year 2019-20 Fellowship for his THED: Thermal Hand Experience Device.

Currently, Soucy is advised by Salimeh Yasaei Sekeh (an assistant professor in The UMaine School of Computing and Information Science). Soucy also works as a research assistant in The Sekeh Lab, which focuses on theoretical and practical aspects of machine learning as well as designing algorithms and deep learning techniques.

"I love working in ML because I can see the future of humanity within it. It's beautiful, the far-reaching applications ML has on our day-to-day lives from manufacturing to self-driving cars. I believe this technology can save and make lives better. It is an honor to propel that field forward," Soucy states.

Since Soucy was already working with similar machine learning tasks—i.e., using neuroscience and math to define what animal or human brains do then teaching a computer to recognize patterns or trends within that large data—it was fitting for Soucy to work with Sekeh within the multidisciplinary project of INSPIRES as part of Theme 2.

"In our ML-INSPIRES project," Sekeh explains, "we explore deep network approaches for large-scale hyperspectral images (HSI), which are a relatively new remote sensing scheme in forestry and climate change sciences. We develop novel ensemble methods to segment images into tree species. Furthermore, because computational complexity is a prominent challenge in deep network-based algorithms, in this work, we intend to investigate techniques that reduce HSI dimensions and extract informative features as a preprocessing step of our classification/segmentation models."

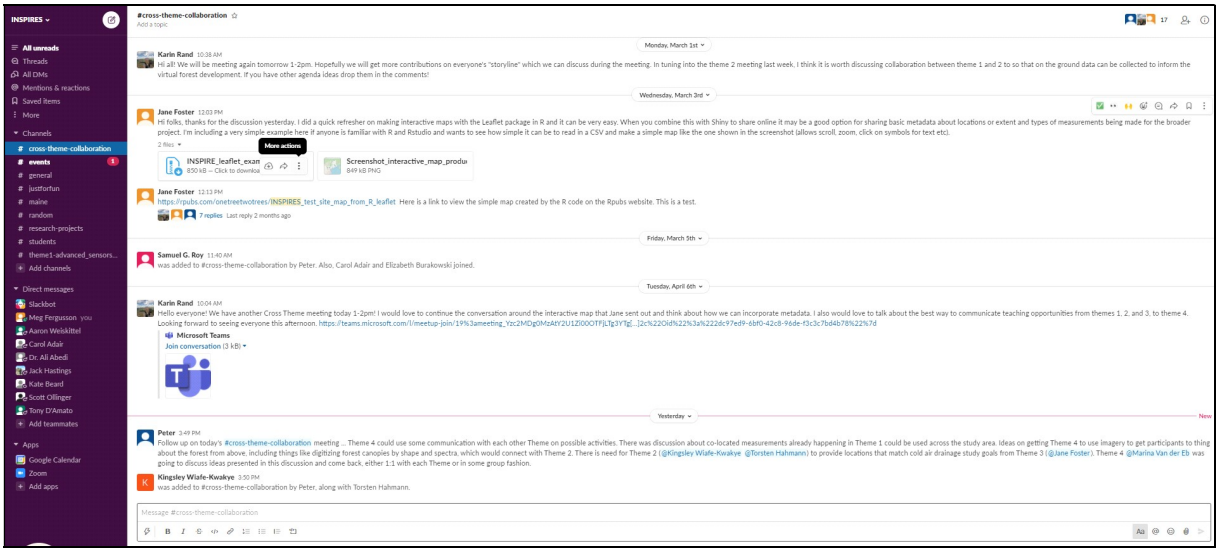
Left: Pseudocolor image of the Indian Pine data set. Right: Ground-truth classification of the Indian Pine data set.

Sekeh continues, "Soucy plays a key role in our ML-INSPIRES project and he has been an active researcher in The Sekeh Lab working on ideas that develop bridges between deep learning and hyperspectral data sets."

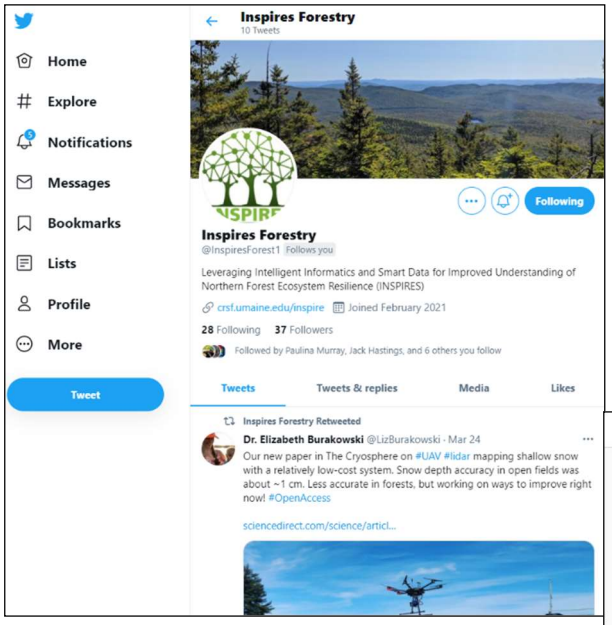
Originally from Maine, Soucy is excited to apply his models—using data sets that were created by Theme 1 researchers, data sets that had been lacking— to New England forests through INSPIRES.

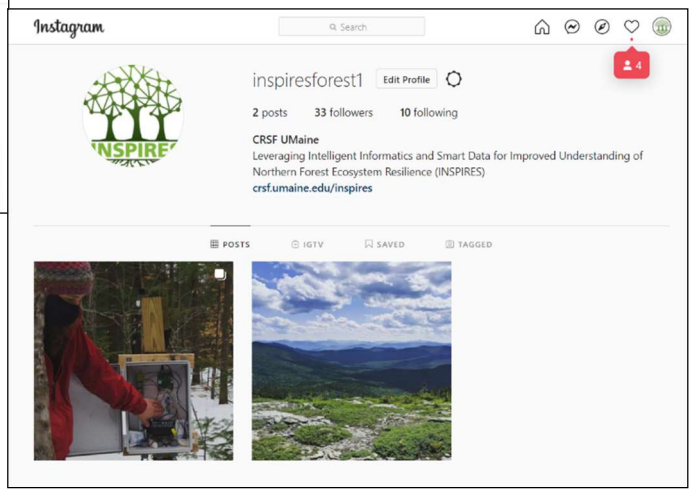
Appendix 5. INSPIRES Communications and Resources

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



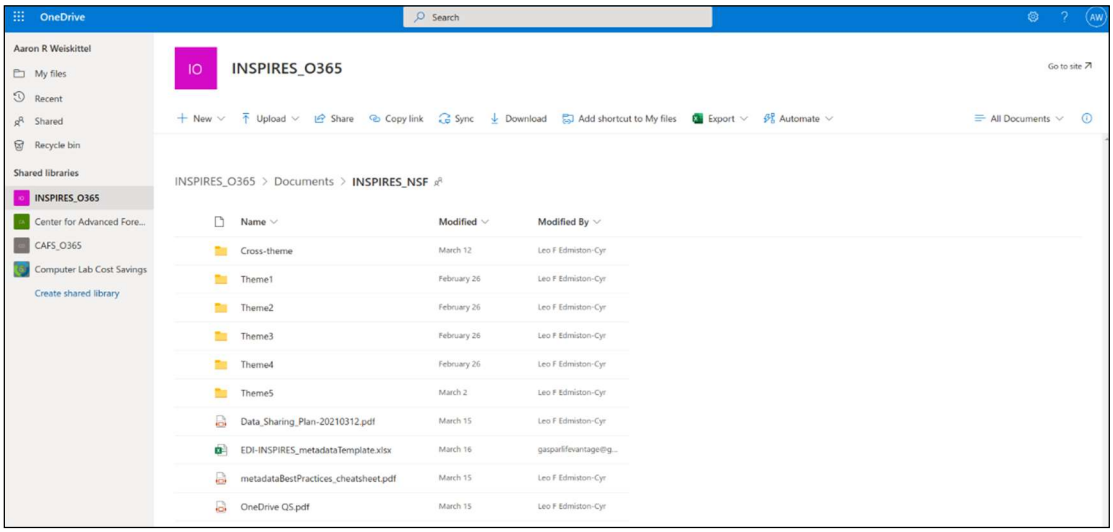
INSPIRES Slack Channel





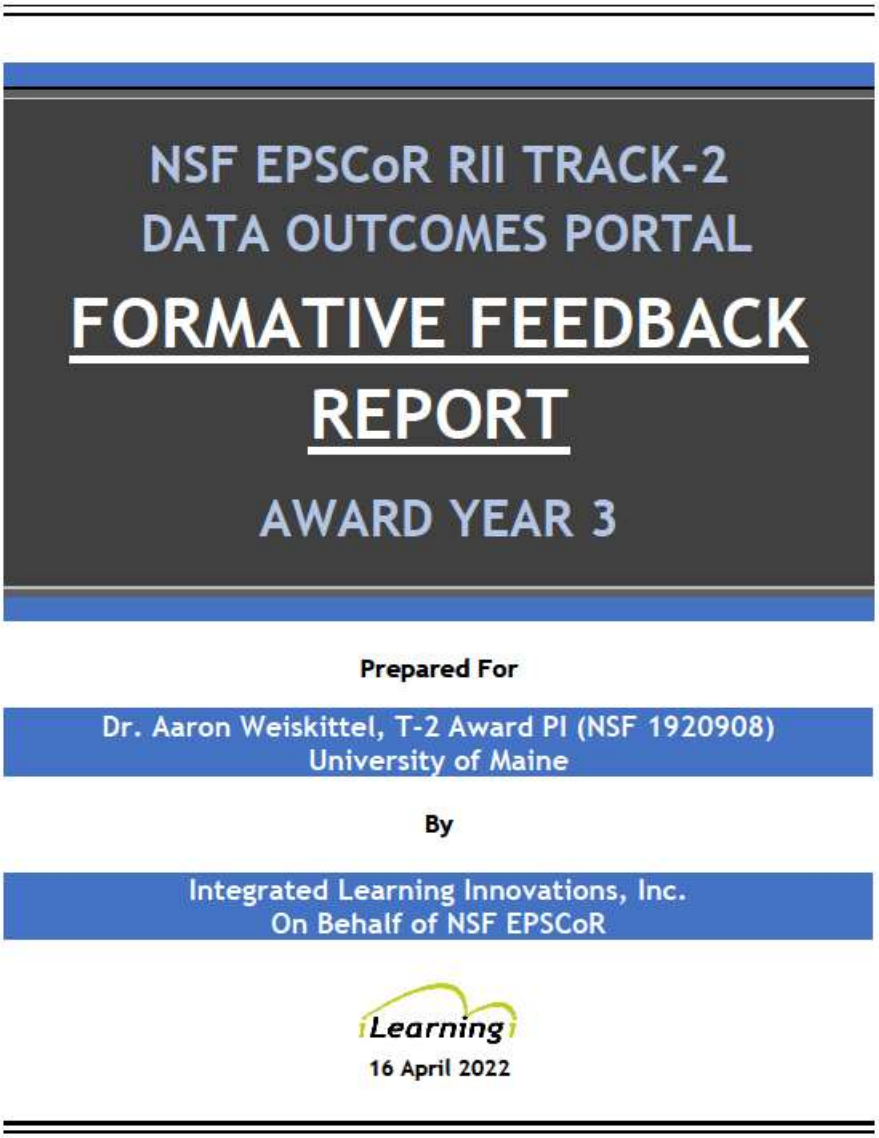
INSPIRES Twitter and Intagram accounts

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



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

Appendix 6: Data Outcomes Portal Formative Feedback Report



NSF EPSCoR RII TRACK-2
DATA OUTCOMES PORTAL

FORMATIVE FEEDBACK REPORT

AWARD YEAR 3

Prepared For

Dr. Aaron Weiskittel, T-2 Award PI (NSF 1920908)
University of Maine

By

Integrated Learning Innovations, Inc.
On Behalf of NSF EPSCoR

iLearning

16 April 2022

PREPARED FOR

This Formative Feedback Report was prepared, at the request of the NSF EPSCoR, for Dr. Aaron Weiskittel, Principal Investigator of the NSF EPSCoR RII Track-2 award to the University of Maine the award's collaborating researchers and institutions in partner jurisdictions of Maine, New Hampshire, and Vermont.

CONTACT INFORMATION

The secondary contacts for this report are Integrated Learning Innovation's co-principals.

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and/or
Walter E. "Skip" Bollenbacher, Ph.D.
Vice President
Professor Emeritus of Biology, University of North Carolina at Chapel Hill

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INTRODUCTION

The Research Infrastructure Improvement Program Track-2 Focused EPSCoR Collaborations (RII Track-2 FEC) builds inter-jurisdictional collaborative teams of EPSCoR investigators in scientific focus areas consistent with NSF priorities. Based upon this goal, the RII Track-2 FEC has four objectives. These objectives and the research outcomes that indicate awardee progress toward them include:

- **Objective 1:** *Developing capabilities to create and disseminate new knowledge:* Metrics include the overall number of peer-reviewed journal publications, funding proposals, presentations, and patents by participants.
- **Objective 2:** *Building collaborations, with an emphasis on inter-jurisdictional collaborations:* Metrics include the total number of collaborative inter-/intra-jurisdictional publications, funding proposals, and patents by participants.
- **Objective 3:** *Enhancing the research development of researchers, with an emphasis on early-career researchers:* Metrics include number of individual, collaborative, and inter-/intra-jurisdictional publications, funding proposals, and presentations by early-career researchers.
- **Objective 4:** *Increasing engagement in NSF strategic activities (e.g., funding) for all researchers, with an emphasis on early career researchers:* Metrics include NSF, Other Federal, Non-Federal, and Total funding activity (submissions, awards, dollar amounts) overall, collaboratively, inter-jurisdictionally, by research participants, and especially by early-career researchers.

For each year of an NSF EPSCoR RII T-2 project, Integrated Learning Innovations (ILI) prepares for a project's PI a Formative Feedback Report (FFR) that presents a cumulative overview (e.g., after 1 year, after 2 years) of the research outcomes achieved in relationship to the metrics that reflect progress toward achieving the NSF EPSCoR's T-2 program's 4 objectives.

For this RII Track-2 FEC Award entitled Multi-scale Integrative Leveraging Intelligent Informatics and Smart Data for Improved Understanding of Northern Forest Ecosystem Resiliency (INSPIRES) with Aaron Weiskittel as PI and involving 3 NSF EPSCoR jurisdictions (Maine, New Hampshire, and Vermont) this year's FFR covers research outcomes for 3 T-2 DOP project years, August 1, 2019 through March 31, 2022.

This FFR includes the following two sections.

I. Researchers and Trainees Participating in the T-2 Project

II. Research Outcomes Achieved for the T-2 Program's 4 Objectives

NOTE

- ***Year Definition:*** For this report a Year refers to each time period that T-2 DOP data are collected for annual Formative Feedback Reports and End-of-Award Summative Report, which the NSF EPSCoR has defined as follows: Year 1 = 08.01.19 – 03.31.20, Year 2 = 04.01.20 – 03.31.21, Year 3 = 04.01.21– 03.31.22, Year 4 = 04.01.22 – 07.31.23.
- ***Analytics:*** The analysis of research outcomes is based upon each participant logging into the DOP and entering demographic information and appropriate outcomes (e.g., publications) by completing all required fields. If fields are not completed (e.g., publications' month and year publication dates) the algorithm will not include the item in an analysis.
- ***Footnotes:*** For clarity, tables include footnotes that provide important information regarding definitions of terms and protocols for data analysis per NSF EPSCoR.

I. RESEARCHERS AND TRAINEES PARTICIPATING IN THE T-2 PROJECT

This T-2 award includes participants from NSF EPSCoR jurisdictions Maine, New Hampshire, and Vermont and involves 6 universities (Maine 3, New Hampshire 2, Vermont 1). The number and type of researcher and trainee participants are summarized in this section in order to assist awardees with fulfilling the *Broadening Participation* section of NSF EPSCoR's T-2 award *Final Reporting Guidelines*. To this end, the data on the T-2 project's participants are presented as follows:

- Total number of participants by career stage after 3 years.
- Diversity of participants by career stage and participating institutions after 3 years.

I.A. Total Number of Participants by Career Stage after 3 Years.

The researchers and trainees that participated in the T-2 project after 3 years are presented in Table 1. The distribution of senior and early-career researchers among the project's participating jurisdictions is presented in Table 2. Beyond the reporting of participation to the NSF EPSCoR, these data are important for interpreting and understanding the research outcomes achieved by researchers and trainees that participated after 3 years.

Table 1: Total researcher and trainee participants after 3 years.[1]

Researchers			Trainees				
Total	Senior	Early-Career	Total	Postdocs	Grad Students	Undergrads	Other
46	21	25	31	3	24	4	0

[1] *Participants are individuals who have start dates that fall within the 3 year award period.*

Table 2: Breakdown of the total researcher participants by award jurisdiction and researcher classification (i.e., senior and early-career researchers) after 3 years.[1]

Alabama			Maine			New Hampshire			Vermont		
Total	Senior	Early-Career	Total	Senior	Early-Career	Total	Senior	Early-Career	Total	Senior	Early-Career
3	0	3	23	11	12	12	5	7	8	5	3

[1] *Participant universities included: Alabama A&M University, Dartmouth College, University of Maine Augusta Bangor, University of Maine Fort Kent, University of Maine Orono, University of New Hampshire, and University of Vermont.*

I.B. Diversity of Participants by Career Stage and Participating Institutions for Project Year 3.

The NSF EPSCoR has indicated that the diversity data described in the *Broadening Participation* section of *NSF EPSCoR's T-2 Award Final Reporting Guidelines* should describe participation for the current project year, in this case Year 3. Per NSF EPSCoR's guidance and approval, ILI has created two tables that present the diversity data for the project's current year that each PI can submit to the NSF EPSCoR, thus freeing the PIs from having to prepare these tables on their own.

- ***Researcher and Trainee Gender, Disability, Underrepresented Race, Ethnicity, Underrepresented Race/Ethnicity, Underrepresented Group (Female and/or with a disability) by Career Stage and Institution for Year*** 3: These data are presented in Table 3 (see Excel file) and this table can be used as is for the year 3 narrative report to the NSF EPSCoR.
- ***Researcher and Trainee Race by Career Stage and Institution for Year*** 3*:* These data are presented in Table 4 (see Excel file) and this table can be used as is for the awardee's year 3 narrative report to the NSF EPSCoR.

[THE TWO TABLES ARE PROVIDED AS AN EXCEL DOCUMENT]

2

II. RESEARCH OUTCOMES ACHIEVED FOR THE T-2 PROGRAM'S 4 OBJECTIVES

For this T-2 award, progress after 3 years toward achieving the T-2 program's four objectives (see Introduction) is summarized through descriptive analytics of: 1) numbers of research outcomes (peer-reviewed journal publications, funding activity, patents, and presentations); as well as 2) the percentages of researchers and trainees that contributed to building participating jurisdictions' research capacity overall and collaboratively through these outcomes.

II.A. Objective 1: Developing Capabilities to Create and Disseminate New Knowledge

The metrics for achieving this objective include percentage of researchers and trainees with one-or-more published peer-reviewed journal publications, proposals, patents, and presentations, and the number of each type of research outcome.

- **Publications:** Table 5 summarizes, for researchers and trainees, the: 1) percentage of researchers and trainees that have one-or-more published peer-reviewed journal publications; and 2) total number of published peer-reviewed journal publications.

Table 5: Peer-reviewed journal publication activity by T-2 award researchers and trainees after 3 years.[1]

Researchers' Journal Publications		Trainees' Journal Publications	
% w/≥1	Number	% w/≥1	Number
39%	27	10%	4

[1]Publications counted in this table are those entered as "journal articles print" or "journal articles electronic only," with statuses of "published" and "peer-reviewed."

- **Funding:** Table 6 summarizes, for researchers and trainees, the: 1) percentage of researchers and trainees with one-or-more proposals submitted; 2) total number of proposals submitted, awarded, and pending; and 3) percentage of proposals awarded of the proposals that had a funding decision after 3 years.

Table 6: Funding activity by T-2 award researchers and trainees after 3 years.[1]

Researchers' Proposals				Trainees' Fellowship Proposals (Postdocs, Grad Students)			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
50%	45	17 (55%[2])	14	0%	0	0 (0%[2])	0

[1]A researcher proposal is defined as one involving one or more T-2 award researchers as PI, Co-PI, or key personnel.
[2]The percentage of awarded proposals is determined for proposals that had a funding decision, i.e., funded or not funded.

- **Patents:** 0 patent applications were recorded after 3 years.
- **Presentations:** Table 7 summarizes, for researchers and trainees, after 3 years the: 1) percentage of the total number of researchers and trainees that have one-or-more presentations; and 2) total number of presentations.

Table 7: Presentation activity by T-2 award researchers and trainees after 3 years.[1,2]

Researchers' Presentations		Trainees' Presentations	
% w/≥1	Number	% w/≥1	Number
46%	31	16%	12

[1]A presentation is defined as a conference talk, poster, and other reported as a presentation by a T-2 participant.
[2]Presentations counted in this table are those entered with the status of "published" with a publication date within the T-2 DOP reporting period.

II.B. Objective 2: Building Collaborations, with an Emphasis on Inter-jurisdictional Collaborations

The metrics for achieving this objective include the percentage of researchers that had one-or-more collaborative intra- and inter-jurisdictional published peer-reviewed journal publications, proposals, patents, and presentations with other T-2 award researchers, as well as numbers of these outcome types.

- **Publications:** Table 8 summarizes, for researchers, the: 1) percentage of researchers with one-or-more published collaborative peer-reviewed journal publications, i.e., total, intra-jurisdictional, inter-jurisdictional; and 2) number of published collaborative peer-reviewed journal publications for the three categories.

  Collaborative publications accounted for 48% (13 collaborative/27 total) of all peer-reviewed journal publications. Intra- and inter-jurisdictional collaborative publications account for 26% (7 intra-/27 total) and 22% (6 inter-/27 total), respectively, of all peer-reviewed journal publications.

Table 8: Peer-reviewed collaborative intra- and inter-jurisdictional journal publications between T-2 award researchers after 3 years.[1,2]

Researchers' Collaborative Publications					
Total		*Intra*-jurisdictional		*Inter*-jurisdictional	
% w/≥1	Number	% w/≥1	Number	% w/≥1	Number
28%	13	24%	7	9%	6

[1]A collaborative publication is defined as one involving two or more of the T-2 award researchers as co-authors on the publication.
[2]Publications counted in this table are those entered as "journal articles print" or "journal articles electronic only," with statuses of "published" and "peer-reviewed."

- **Funding:** Table 9 summarizes, for researchers, the: 1) collaborative funding activity in total and for intra- and inter-jurisdictional proposals; 2) percentage of researchers that submitted one-or-more collaborative proposals; and 3) percentage of collaborative proposals awarded of the collaborative proposals that had a funding decision after 3 years.

  Collaborative proposals accounted for 58% (26 collaborative/45 total) of all proposals submitted. Intra- and inter-jurisdictional collaborative proposals accounted for 36% (16 intra-/45 total) and 22% (10 inter-/45 total), respectively, of all proposals submitted.

Table 9: Collaborative funding activity by T-2 award researchers after 3 years: Total, intra-jurisdictional, and inter-jurisdictional.[1]

Researchers' Collaborative Proposals			
% w/≥1	Submitted	Awarded	Pending
41%	26 (58%[2])	6 (38%[3])	10

Researchers' Intra-jurisdictional and Inter-jurisdictional Collaborative Proposals							
Intra-jurisdictional				*Inter*-jurisdictional			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
30%	16	6 (55%[3])	5	28%	10	0 (0%[3])	5

[1]A collaborative proposal is defined as one involving two or more of the T-2 award researchers as PI, Co-PI, or key personnel.
[2]Percent of collaborative proposals submitted is the percent of all proposals submitted which are collaborative.
[3]The percentage of awarded proposals is determined for proposals that had a funding decision, i.e., funded or not funded.

- **Patents:** 0 collaborative patent applications were recorded after 3 years.
- **Collaborative Presentations:** Intra- and inter-jurisdictional collaborative presentations are not presented because of the NSF EPSCoR focus on the individuals actually making the presentations.

II.C. Objective 3: Enhancing the Research Development of Researchers, with an Emphasis on Early-Career Researchers

The metrics for achieving this objective include the percentage of senior and early-career researchers with one-or-more non-collaborative and collaborative published intra- and inter-jurisdictional peer-reviewed journal publications, funding proposals, patents, and presentations, as well as numbers of these outcome types.

- **Publications:** Table 10 summarizes, for senior and early-career researchers, the: 1) percentage of these researchers with one-or-more publications; and 2) total number of peer-reviewed journal publications.

Table 10: Total peer-reviewed journal publications by T-2 award senior and early-career researchers after 3 years.[1]

Senior Researchers' Publications		Early-Career Researchers' Publications	
% w/≥1	Number	% w/≥1	Number
43%	22	36%	13

[1]Publications counted in this table are those entered as "journal articles print" or "journal articles electronic only," with statuses of "published" and "peer-reviewed."

Table 11 summarizes, for senior and early-career researchers, the: 1) percentage with one-or-more collaborative peer-reviewed journal publications; and 2) percentage with one-or-more intra- or inter-jurisdictional peer-reviewed collaborative journal publications.

Table 11: Collaborative intra- and inter-jurisdictional peer-reviewed journal publications by senior and early-career researchers after 3 years.[1,2]

% Senior Researchers w/ ≥1 Pub			% Early-Career Researchers w/ ≥1 Pub		
Collaborative	Collaborative Intra-jurisdictional	Collaborative Inter-jurisdictional	Collaborative	Collaborative Intra-jurisdictional	Collaborative Inter-jurisdictional
29%	24%	14%	28%	24%	4%

[1]A collaborative publication is defined as one involving two or more of the T-2 award researchers as co-authors on the publication.
[2]Publications counted in this table are those entered as "journal articles print" or "journal articles electronic only," with statuses of "published" and "peer-reviewed."

- **Funding:** Table 12 summarizes, for senior and early-career researchers, the: 1) percentage that submitted one-or-more proposals or one-or-more collaborative proposals; 2) number of proposals (total, collaborative) submitted, awarded, and pending; and 3) percentage of proposals (total, collaborative) awarded of the proposals (total, collaborative) that had funding decisions after 3 years.

Table 12: Total funding activity and collaborative funding activity by T-2 award senior and early-career researchers after 3 years.[1,2]

Senior Researchers' Proposals				Early-Career Researchers' Proposals			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
Total Funding Activity							
100%	9	5 (71%[3])	2	25%	7	5 (83%[3])	1
Collaborative Funding Activity							
43%	20	5 (38%[3])	7	40%	22	4 (31%[3])	9

[1]A researcher proposal is defined as one involving one or more T-2 award researchers as PI, Co-PI, or key personnel.
[2]A collaborative proposal is defined as one involving two or more of the T-2 award researchers as PI, Co-PI, or key personnel.
[3]The percentage of awarded proposals is determined for proposals that had a reported outcome, i.e., funded or not funded.

Table 13 summarizes, for senior and early-career researchers, the: 1) percentage that submitted one-or-more collaborative intra- and inter-jurisdictional proposals; 2) number of collaborative proposals submitted, awarded, and pending; and 3) percentage of collaborative proposals awarded of the collaborative proposals that had funding decisions made after 3 years.

Of the total proposals submitted, collaborative intra- and inter-jurisdictional proposals by senior researchers accounted for 22% (10/45 total) and 22% (10/45 total) of all proposals submitted, respectively, and for early-career researchers they accounted for 27% (12/45 total) and 22% (10/45 total) of all proposals submitted, respectively.

Table 13: Collaborative intra- and inter-jurisdictional funding activity by T-2 award senior and early-career researchers after 3 years.[1,2]

Collaborative *Intra*-jurisdictional Proposals				Collaborative *Inter*-jurisdictional Proposals			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
Senior Researchers							
33%	10	5 (63%[3])	2	24%	10	0 (0%[3])	5
Early-Career Researchers							
28%	12	4 (50%[3])	4	32%	10	0 (0%[3])	5

[1]A researcher proposal is defined as one involving one or more T-2 award researchers as PI, Co-PI, or key personnel.
[2]A collaborative proposal is defined as one involving two or more of the T-2 award researchers as PI, Co-PI, or key personnel.
[3]The percentage of awarded proposals is determined for proposals that had a reported outcome, i.e., funded or not funded.

- **Patents:** After 3 years, 0 patent applications were recorded by senior researchers and 0 patents were recorded by early-career researchers.
- **Presentations:** Table 14 summarizes presentations reported by senior and early-career researchers after 3 years. Intra- and inter-jurisdictional collaborative presentations are not presented because of NSF EPSCoR focus on the researchers actually making the presentations.

Table 14: Presentations[1] by senior and early-career researchers after 3 years.[1,2]

Presentations	
% Senior Researchers w/≥1	% Early-career Researchers w/≥1
43%	88%

[1]A presentation is defined as a conference talk, conference poster, or an invited seminar.
[2]Presentations counted in this table are those entered with the status of "published" with a publication date within the T-2 DOP reporting period.

II.D. Objective 4: Increasing Engagement in NSF Strategic Activities (e.g., Funding) for all Researchers, with an Emphasis on Early-Career Researchers

Objective 4 focuses on the overarching goal of the NSF EPSCoR to facilitate jurisdictions' increase in NSF funding through enhancement of their research capacity and competitiveness. However, the NSF EPSCoR views as also important the ability of T-2 awardees to leverage their T-2 funding with research funding from non-NSF organizations, i.e., Other Federal and Non-Federal.

In this light, the descriptive analytics for Objective 4 address the impact of NSF EPSCoR T-2 funding on the funding metrics used for Objectives 1, 2, and 3 with a focus on: 1) NSF funding; 2) Other Federal funding; and 3) Non-Federal funding.

II.D.1. NSF Funding Activity

Proposals to the NSF accounted for 31% (14/45) of the total researcher proposals submitted during the 3 years.

- **Total NSF Funding per Objective 1:** Table 15 summarizes, for researchers' and trainees' NSF funding, the: 1) percentage of researchers/trainees submitting one-or-more proposals/fellowships; and 2) total proposal activity, i.e., number submitted, awarded, and pending; and 3) percentage of NSF proposals awarded of the NSF proposals that had a funding decision after 3 years.

  Of the researchers' NSF proposals that had a funding decision after 3 years, 44% were funded.

Table 15: Total NSF funding activity by T-2 award researchers and trainees after 3 years.[1]

Researchers' NSF Proposals				Trainees' NSF Fellowship Proposals (Grad Students/Postdocs)			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
28%	14	4 (44%[2])	5	0%	0	0 (0%[2])	#0

[1]A researcher NSF proposal is defined as an NSF proposal involving one or more T-2 award researchers as PI, Co-PI, or key personnel.
[2]The percentage of awarded proposals is determined for proposals that had a reported outcome, i.e., funded or not funded.

- **Collaborative NSF Funding per Objective 2:** Table 16 summarizes, for researchers' collaborative NSF funding, the: 1) collaborative funding activity in total and for intra- and inter-jurisdictional proposals; 2) percentage of researchers who submitted one-or-more collaborative proposals; and 3) percentage of NSF collaborative proposals awarded of NSF collaborative proposals that had a funding decision after 3 years.

  NSF collaborative proposals accounted for 71% (10/14 total) of NSF proposals submitted. NSF intra-jurisdiction and inter-jurisdictional collaborative proposals accounted for 50% (7 intra-/14 total) and 21% (3 inter-/14 total), respectively, of NSF proposals submitted.

Table 16: NSF collaborative funding activity by T-2 award researchers after 3 years: Total, intra-jurisdictional, and inter-jurisdictional.[1]

Researchers' NSF Collaborative Proposals							
% w/≥1	Submitted		Awarded		Pending		
26%	10 (71%[2])		2 (33%[3])		4		
Researchers' NSF Intra-jurisdictional and Inter-jurisdictional Collaborative Proposals							
Intra-jurisdictional				*Inter*-jurisdictional			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
26%	7	2 (50%[3])	3	9%	3	0 (0%[3])	1

[1]A collaborative proposal is defined as one involving two or more of the T-2 award researchers as PI, Co-PI, or key personnel.
[2]Percent of collaborative NSF proposals submitted is the percent of all NSF proposals submitted which are collaborative.
[3]The percentage of awarded proposals is determined for proposals that had a reported outcome, i.e., funded or not funded.

- **Senior and Early-Career Researcher NSF Funding per Objective 3:** Table 17 summarizes, for senior and early-career researchers' NSF non-collaborative proposals, the: 1) total funding activity; 2) percentage of these researchers who submitted one-or-more non-collaborative proposals; and 3) percentage of NSF non-collaborative proposals awarded of the NSF non-collaborative proposals that had a funding decision after 3 years.

Table 17: NSF non-collaborative funding activity for senior and early-career researchers after 3 years.[1]

Senior Researchers' Proposals				Early-Career Researchers' Proposals			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
5%	1	1 (100%[2])	0	8%	3	1 (50%[2])	1

[1]A non-collaborative proposal is defined as one that included only one T-2 award researcher PI, Co-PI, or key personnel.
[2]The percentage of awarded proposals is determined for proposals that had a reported outcome, i.e., funded or not funded.

Table 18 summarizes, for senior and early-career researchers' collaborative NSF proposals, the: 1) collaborative funding activity in total and for intra- and inter-jurisdictional proposals; 2) percentage of these researchers who submitted one-or-more collaborative proposals; and 3) percentage of NSF collaborative proposals awarded of the NSF collaborative proposals that had a funding decision after 3 years.

Table 18: NSF collaborative funding activity by T-2 award senior and early-career researchers after 3 years: Total, intra-jurisdictional, and inter-jurisdictional.[1]

Senior Researchers				Early-Career Researchers			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
Total NSF Collaborative Proposals[1]							
29%	7	2 (40%[2])	2	24%	8	1 (25%[2])	4
NSF Intra-jurisdictional Collaborative Proposals[1]							
29%	4	2 (67%[2])	1	24%	5	1 (50%[2])	3
NSF Inter-jurisdictional Collaborative Proposals[1]							
5%	3	0 (0%[2])	1	12%	3	0 (0%[2])	1

[1]A collaborative proposal is defined as one involving two or more of the T-2 award researchers as PI, Co-PI, or key personnel.
[2]The percentage of awarded proposals is determined for proposals that had a reported outcome, i.e., funded or not funded.

II.D.2. Other Federal Funding Activity

Proposals to Other Federal agencies accounted for 60% (27/45) of the total proposals submitted and thus these proposals are summarized below.

- **Total Other Federal Funding per Objective 1:** Table 19 summarizes, for researchers' and trainees' Other Federal funding, the: 1) total Other Federal proposal activity, i.e., number submitted, awarded, and pending; 2) percentage of researchers/trainees submitting one-or-more Other Federal proposals/fellowships; and 3) percentage of Other Federal proposals awarded of Other Federal proposals that had a funding decision after 3 years.

  Of the researchers' Other Federal proposals that had a funding decision made after 3 years 55% were funded.

Table 19: Total Other Federal funding activity by T-2 award researchers and trainees after 3 years.[1]

Researchers' Other Federal Proposals				Trainees' Other Federal Fellowship Proposals (Grad Students and Postdocs)			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
39%	27	11 (55%[2])	7	0%	0	0 (0%[2])	0

[1]A researcher Other Federal proposal is defined as an Other Federal proposal involving one or more T-2 award researchers as PI, Co-PI, or key personnel.
[2]The percentage of awarded proposals is determined for proposals that had a reported outcome, i.e., funded or not funded.

- **Collaborative Other Federal Funding per Objective 2:** Table 20 summarizes, for researchers' collaborative Other Federal funding, the: 1) total collaborative and collaborative intra- and inter-jurisdictional funding activity; 2) percentage of researchers who submitted one-or-more collaborative proposals; and 3) percentage of Other Federal collaborative proposals awarded of Other Federal collaborative proposals that had a funding decision after 3 years.

  Other Federal collaborative proposals accounted for 52% (14/27 total) of all Other Federal proposals submitted. Other Federal intra-jurisdiction and inter-jurisdictional collaborative proposals accounted for 30% (8/27 total) and 22% (6/27 total), respectively, of Other Federal Collaborative proposals submitted.

Table 20: Other Federal collaborative funding activity by T-2 award researchers after 3 years: Total, intra-jurisdictional, and inter-jurisdictional.[1]

Researchers' Other Federal Funding Collaborative Proposals			
% w/≥1	Submitted	Awarded	Pending
33%	14 (52%[2])	3 (33%[3])	5

Researchers' Other Federal Intra-jurisdictional and Inter-jurisdictional Collaborative proposals							
Intra-jurisdictional				*Inter*-jurisdictional			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
20%	8	3 (50%[3])	2	26%	6	0 (0%[3])	3

[1]A collaborative proposal is defined as one involving two or more of the T-2 award researchers as PI, Co-PI, or key personnel.
[2]Percent of collaborative Other Federal proposals submitted is the percent of all Other Federal proposals submitted which are collaborative.
[3]The percentage of awarded proposals is determined for proposals that had a reported outcome, i.e., funded or not funded.

- **Senior and Early-Career Researcher Other Federal Funding per Objective 3:** Table 21 summarizes, for senior and early-career researchers' Other Federal non-collaborative funding, the: 1) total funding activity; 2) percentage of these researchers who submitted one-or-more non-collaborative proposals; and 3) percentage of Other Federal non-collaborative proposals awarded of Other Federal non-collaborative proposals that had a funding decision after 3 years.

Table 21: Other Federal non-collaborative[1] funding activity for senior and early-career researchers after 3 years.[1]

Senior Researchers				Early-Career Researchers			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
19%	6	3 (75%[2])	2	20%	7	5 (71%[2])	0

[1]A non-collaborative proposal is defined as one that included only one T-2 award researcher PI, Co-PI, or key personnel.
[2]The percentage of awarded proposals is determined for proposals that had a reported outcome, i.e., funded or not funded.

Table 22 summarizes, for senior and early-career researchers' collaborative Other Federal funding, the: 1) total collaborative and collaborative intra- and inter-jurisdictional funding activity; 2) percentage of these researchers who submitted one-or-more collaborative Other Federal proposals; and 3) percentage of collaborative Other Federal proposals awarded of collaborative Other Federal proposals that had a funding decision after 3 years.

Table 22: Other Federal collaborative funding activity by T-2 award senior and early-career researchers 3 years: Total, intra-jurisdictional, and inter-jurisdictional.[1]

Senior Researchers				Early-Career Researchers			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
Total Other Federal Collaborative Proposals[1]							
33%	11	2 (29%[2])	4	32%	13	3 (33%[2])	4
Other Federal Intra-Jurisdictional Collaborative Proposals[1]							
19%	5	2 (50%[2])	1	20%	7	3 (50%[2])	1
Other Federal Inter-Jurisdictional Collaborative Proposals[1]							
24%	6	0 (0%[2])	3	28%	6	0 (0%[2])	3

[1]A collaborative proposal is defined as one involving two or more of the T-2 award researchers as PI, Co-PI, or key personnel.
[2]The percentage of awarded proposals is determined for proposals that had a reported outcome, i.e., funded or not funded.

II.D.3. Non-Federal Funding Activity

Proposals to Non-Federal agencies (e.g., institutions, foundations, state governments) accounted for 9% (4/45) of the total proposals submitted and thus these proposals are summarized below.

- **Total Non-Federal Funding per Objective 1:** Table 23 summarizes, for researchers' and trainees' Non-Federal funding, the: 1) total funding activity, i.e., number submitted, awarded, and pending; 2) percentage of researchers/trainees who submitted one-or-more proposals/fellowships; and 3) percentage of Non-Federal proposals awarded of Non-Federal proposals that had a funding decision after 3 years.

  Of the researchers' Non-Federal proposals that had a funding decision made after 3 years 100% were funded.

Table 23: Total Non-Federal funding activity by T-2 award researchers and trainees after 3 years.[1]

Researchers' Non-Federal Proposals				Trainees' Non-Federal Fellowship Proposals (Grad Students/Postdocs)			
% of w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
17%	4	2 (100%[2])	2	0%	0	0 (0%[2])	0

[1]A researcher NSF proposal is defined as a Non-Federal proposal involving one or more T-2 award researchers as PI, Co-PI, or key personnel.
[2]The percentage of awarded proposals is determined for proposals that had a reported outcome, i.e., funded or not funded.

- **Collaborative Non-Federal Funding per Objective 2:** Table 24 summarizes, for researchers' collaborative Non-Federal funding, the: 1) total collaborative and collaborative intra- and inter-jurisdictional funding activity; 2) percentage of researchers who submitted one-or-more collaborative proposals; and 3) percentage of collaborative Non-Federal proposals awarded of collaborative Non-Federal proposals that had a funding decision after 3 years.

Non-Federal collaborative proposals accounted for 50% (2/4 total) of all Non-Federal proposals submitted. Non-Federal intra-jurisdiction and inter-jurisdictional collaborative proposals accounted for 25% (1/4 total) and 25% (1/4 total), respectively, of Non-Federal Collaborative proposals submitted.

Table 24: Non-Federal collaborative funding activity by T-2 award researchers after 3 years: Total, intra-jurisdictional, and inter-jurisdictional.[1]

Researchers' Non-Federal Collaborative Proposals			
% w/≥1	Submitted	Awarded	Pending
15%	2 (50%[2])	1 (100%[3])	1

Researchers' Non-Federal Intra-jurisdictional and Inter-jurisdictional Collaborative Proposals							
Intra-jurisdictional				*Inter*-jurisdictional			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
4%	1	1 (100%[3])	0	11%	1	0 (0%[3])	1

[1]A collaborative proposal is defined as one involving two or more of the T-2 award researchers as PI, Co-PI, or key personnel.
[2]Percent of collaborative Non-Federal proposals submitted is the percent of all Non-Federal proposals submitted which are collaborative.
[3]The percentage of awarded proposals is determined for proposals that had a reported outcome, i.e., funded or not funded.

- **Senior and Early-Career Researcher Non-Federal Funding per Objective 3:** Table 25 summarizes, for senior and early-career researchers' Non-Federal non-collaborative proposals, the: 1) total funding activity; 2) percentage of these researchers who submitted one-or-more non-collaborative proposals; and 3) percentage of Non-Federal non-collaborative proposals awarded of Non-Federal non-collaborative proposals that had a funding decision after 3 years.

Table 25: Non-Federal non-collaborative[1] funding activity for senior and early-career researchers after 3 years.[1]

Senior Researchers				Early-Career Researchers			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
5%	1	0 (0%[2])	1	4%	1	1 (100%[2])	0

[1]A non-collaborative proposal is defined as one that included only one T-2 award researcher PI, Co-PI, or key personnel.
[2]The percentage of awarded proposals is determined for proposals that had a reported outcome, i.e., funded or not funded.

Table 26 summarizes, for senior and early-career researchers' collaborative Non-Federal proposals, the: 1) total collaborative and collaborative intra- and inter-jurisdictional funding activity; 2) percentage of these researchers who submitted one-or-more collaborative proposals; and 3) percentage of Non-Federal collaborative proposals awarded of Non-Federal collaborative proposals that had a funding decision after 3 years.

Table 26: Non-Federal collaborative funding activity by T-2 award senior and early-career researchers after 3 years: Total, intra-jurisdictional, and inter-jurisdictional.[1]

Senior Researchers				Early-Career Researchers			
% w/≥1	Submitted	Awarded	Pending	% w/≥1	Submitted	Awarded	Pending
Total Non-Federal Collaborative Proposals[1]							
19%	2	1 (100%[2])	1	12%	1	0 (0%[2])	1
Non-Federal Intra-jurisdictional Collaborative Proposals[1]							
10%	1	1 (100%[2])	0	0%	0	0 (0%[2])	0
Non-Federal Inter-jurisdictional Collaborative Proposals[1]							
10%	1	0 (0%[2])	1	12%	1	0 (0%[2])	1

[1]A collaborative proposal is defined as one involving two or more of the T-2 award researchers as PI, Co-PI, or key personnel.
[2]The percentage of awarded proposals is determined for proposals that had a reported outcome, i.e., funded or not funded.

II.E. Overall Funding Activity

The NSF EPSCoR has the mandate of helping jurisdictions increase their NSF funding to at least 0.75% of the NSF research funding. In this regard, the FFR includes an analysis of the extent that T-2 funding leveraged additional NSF funding, as well as Other Federal and Non-Federal funding. Thus, this analysis covers the funding dollars requested, awarded, and pending for all proposals, NSF proposals, Other Federal proposals, and Non-Federal proposals.

- **Overall Funding Activity by Funding Organization Type:** Table 27 summarizes the number and percentage of proposals submitted to the three funding organization classifications used for data collection, i.e., NSF, Other Federal, and Non-Federal.

Table 27: Number and percentage of submitted proposals that were to the NSF, Other Federal, and Non-Federal funding organizations after 3 years.

Total	NSF		Other Federal		Non-Federal	
#	#	% of Total	#	% of Total	#	% of Total
45	14	31%	27	60%	4	9%

- **Funding Activity by Dollars, Requested, Awarded and Pending:** The funding dollars that were generated by the T-2 award based upon research outcomes from the T-2 award were analyzed and Table 27 highlights the findings.

Table 28: The dollar amount of funds that were requested by project researchers and the dollar amount awarded for all proposals, NSF proposals, Other Federal proposals, and Non-Federal proposals after 3 years.

# Proposals			$ Amount			Awarded $ as a % of requested $ (for proposals with funding decisions)[1]	Ratio of Funding $ Generated to T-2 Award $[2]
Submitted	Awarded	Pending	Requested	Awarded	Pending		
Total Funding Activity							
45	17	14	$58,429,683	$11,789,408	$19,116,529	30%	2.32:1
NSF Funding Activity							
14	4	5	$26,242,368	$6,516,067	$15,594,706	61%	1.28:1
Other Federal Funding Activity							
27	11	7	$31,817,768	$5,187,341	$3,238,276	18%	1.02:1
Non-Federal Funding Activity							
4	2	2	$369,547	$86,000	$283,547	100%	0.02:1

[1]The percentage of dollars award is determined by dividing the awarded dollars by the requested dollars for which a funding decision was made (submitted minus pending) during the award period.
[2]The ratio of new funding leveraged with T-2 funding is determined by dividing the awarded dollars by the T-2 award total dollars.