

SCRI Stakeholder Relevance Statement

a) Title: Mobile applications and virtual weather stations to improve fruit and vegetable adoption of IPM and crop management tools in the Network for Environment and Weather Applications (NEWA)

b) Type of project to be submitted: SREP

c) Anticipated amount of funding to be requested: \$2,928,050

d) Economic/environmental/social significance of the problem being addressed;

Fruit and vegetable farming in the Northeast is an important economic and social contributor to the local and regional economies. Farming practices are increasingly aimed towards improved sustainability through greater reliance on integrated pest management (IPM) practices. Consumer advocacy groups, retail grocers and international marketing agencies often dictate more rigid standards than mandated through US-EPA. It is essential for farmers to have tools to meet more rigorous standards in a way that does not detract from yield or quality. Over the past several decades agricultural scientists have developed models for predicting diseases and pests as well as crop development. Access to reliable meteorological data can be a major bottleneck to implementation of the models. The Network for Environment and Weather Applications (NEWA), through a partnership between agricultural scientists, climatologists, and farmers, provides a unique service where meteorological data is collected and analyzed to feed over 20 interactive crop, pest and disease forecast models at newa.cornell.edu. Recent expansion of this mesonet from New York (NY) into Connecticut (CT), Massachusetts (MA), New Jersey (NJ), Pennsylvania (PA) and Vermont (VT) now delivers NEWA's tools to a broad base of growers. The weather networks include grower owned weather stations, university and climatologist networks, as well as National Weather Service (NWS) data from airport locations. Integration of these existing weather networks with established predictive models provides a significant value-added product for farmers and field professionals. In a 2007 survey, NY apple, grape, potato and onion farmers reported they can save, on average, \$19,500 in spray costs and prevent, on average, \$264,000 in crop loss per year as a direct result of using NEWA forecast models; and 99% of NEWA users would recommend NEWA to farmers. It is critical to make these systems available and useful to our grower communities by developing a mobile platform using responsive web design and applying gridded forecast data to create virtual weather stations.

e) Potential economic/environmental/social benefit to solving the problem being addressed;

The information provided through NEWA is designed to inform users on prudent and efficacious pesticide use by applying environmental data to predict when the target organisms are vulnerable and management action, including pesticide sprays, should be taken. Furthermore, farming practices such as fruit thinning and irrigation are also informed using NEWA tools. Specifically, we will improve access to NEWA using modern communication methods such as smart phones and tablets, provide enhanced data quality control and geographic coverage, and pave the way for incorporating new tools targeting key production factors such as prediction of irrigation needs, frost and heat stress that will help improve the precision of water usage in crop production. By making NEWA more accessible, we anticipate increased use by farmers in the northeast quadrant of North America. Also, by developing methods for improved data quality control and through the use of virtual weather stations the reach of NEWA to growers without on-site weather stations will be facilitated. Once built, virtual weather stations are free of the inherent issues associated with maintenance and repair of weather station equipment. We project

that the user-friendly tools in NEWA are applicable to agricultural production across the geographic regions from Maine south to North Carolina, west to Tennessee, and north to Minnesota, underlining the benefit of virtual weather stations. We have seen positive results ranging from increasing pesticide efficacy to decreasing pesticide use. Increasing adoption and revenue streams to support NEWA will sustain this success. Through these advancements to the NEWA system it will be possible to integrate new tools and provide an incentive for scientists to develop models with the promise of an effective method for implementation.

f) How stakeholders were engaged in defining the problem being addressed and determining project objectives;

Fruit and vegetable growers and processors in CT, MA, NJ, NY, PA and VT have identified increasing the implementation of, and access to, the information found on NEWA, newa.cornell.edu, as a priority through meetings, surveys and personal conversations with project staff. Requests from growers have prioritized the need for smart phone accessibility, more weather stations, more tools, and the ability to cache farm information. In the 2007 NY survey, putting more weather stations in the network was the top choice for how to improve NEWA. NEWA must keep pace with technologically savvy growers who utilize site specific tools for decision making and source information on mobile devices. Creating a responsive website that will display well on any device platform for NEWA accessibility is a clear opportunity for NEWA to increase impact to a larger number of growers. Growers' groups and Extension organizations are engaged in and contribute to NEWA's growth, including the Garden State Wine Growers Association, Lake Erie Grape Processors, NY Apple Growers Association, NY State Vegetable Growers Association, Outer Coastal Plain Vineyard Association, Pennsylvania Apple Growers Association, Seneca County NY Soil and Water Conservation District vineyards, Suffolk County NY Agricultural Stewardship Program, Vermont Tree Fruit Growers Association, etc. Email comments are received via newa@cornell.edu and improved smart phone access has been requested via this route, as well. Project objectives have been developed directly from interaction between the project team and the grower groups, industry members and extension staff who are the ultimate end users of NEWA.

g) How stakeholders will continue to be engaged in project development and evaluation;

We will partner with a grower-led advisory panel consisting of members from the apple, grape, berry and vegetable producer communities from the six Northeastern states currently participating in NEWA to allow for modification of priorities, extension outreach, and evaluation methods throughout the project. To accomplish the goals of this proposal we have assembled a strong and diverse team. The advisory panel and project team will meet at least once per year and also communicate via conference calls, email, the NEWA blog, Facebook and Twitter. Grower input will be collected throughout the project through project participant assessments, surveys and tracking of usage statistics. Focus groups of growers and project staff will participate in a technology strategy workshop and conduct responsive website user tests with ITX, NEWA's web hosting company, assist with evaluation of the virtual stations by comparison with their on-site weather stations with the project climatologists, help document and prioritize the need for new and improved NEWA tools with the project agricultural scientists, and investigate the value of and generating revenue from a customizable NEWA with the project economists. Because NEWA's mesonet is essentially built by growers who own weather stations, they are part of NEWA and have been and will continue to be instrumental in making the system useful and successful.

h) How information developed during the project will be translated into actionable recommendations or products and delivered to end-users;

NEWA is essentially a delivery system for products that include actionable recommendations. The products are web-based apps or tools including such things as insect degree day models, plant disease forecasts, and crop phenology models delivered to growers, consultants, Extension, research, and industry users via the NEWA website, newa.cornell.edu. As a result of information developed during this project, significant improvements to NEWA will result and include:

- **A mobile optimized user experience with a complete upgrade to responsive web design for NEWA**, making the user-interface more intuitive and NEWA tools easy to use and view whether on desktop or mobile devices. A technology strategy workshop will prioritize the website building blocks for NEWA, we will define the requirements for all components of the responsive NEWA, and we will user test and build a mobile-ready NEWA website for end-users.
- **Implementation of virtual weather stations**, such that NEWA data and model outputs can be served for any location as specified by geographic coordinates corresponding to the National Weather Service (NWS) grid. Current, on-site weather stations will be used to validate virtual stations and, if proven a viable alternative, will greatly expand NEWA's reach and value for agriculture. The research on utilizing the National Digital Forecast Database (NDFD) and Real-Time Mesoscale Analysis (RTMA) data will result in a virtual weather station location product that a grower can subscribe to along with the tools associated with NEWA and NEWA premium products.
- **A You're NEWA premium user interface** to set up farm profiles, cache crop information, subscribe to station locations, alerts and apps for faster, more efficient access to relevant NEWA products. For example, an apple grower would only be presented with weather data, model output, recommendations, alerts, etc. relevant to their orchard. This website will be built based on end-user preferences, recommendations, and pricing as identified by the economic research with surveys, focus groups and input from the project team.
- **A Developer Sandbox will be created for researchers** to test and improve new disease, insect and crop phenology models emerging from research. NEWA offers the best testing platform for new predictive models, notably the apple carbohydrate thinning model that has revolutionized apple fruit thinning. Upon implementation in NEWA, a model can immediately be used by stakeholders. The *Developer Sandbox* will be tested with two models, first with a blueberry phenology model <http://benedick.rutgers.edu/Blueberryweather/>, available at Rutgers, and then with a brown patch model for turf, at the University of Connecticut, expanding the NEWA audience base into ornamental crops. In addition, the project team and advisory group will develop and prioritize lists for new and improved NEWA fruit and vegetable tools and these will be slated for addition to the current array of end-user accessible NEWA tools.

i) Experience of PD and six key co-investigators in working with the specific stakeholder community and in dealing with the problem identified.

PD, Juliet Carroll: Dr. Carroll coordinates the development and delivery of IPM practices for fruit growers in NY State with the goal of minimizing economic, health and environmental risks. She works closely with Cornell Cooperative Extension educators, faculty, legislators, the fruit industry, consultants, and growers. As Fruit IPM Coordinator she carries 20% research and 80% extension responsibilities. She has been Leader of the NEWA system since 2005. Under her leadership, NEWA has grown 6-fold, from 48 weather station locations in

NY to 295 in CT, MA, NJ, NY, PA, and VT. Recently, individuals in non-member states were invited to join and stations in Iowa, Maryland, Minnesota, Nebraska, New Hampshire, Virginia and Wisconsin are connecting to NEWA. Cloud computing supports weather data collection at 15-minute intervals, data archiving and processing by the Northeast Regional Climate Center (NRCC). Under her guidance, the current NEWA website, newa.cornell.edu, was built in 2009 with farmer input, focusing on end-user experience to freely deliver over 20 easy-to-use web applications for such things as growing degree days, IPM forecasts and crop production tools. In 2011, she received an award from the fruit growers of New York State for her outstanding and dedicated service.

Co PD, Arthur DeGaetano: Dr. DeGaetano has been at Cornell University since 1991. He is the director of the NOAA-supported Northeast Regional Climate Center (NRCC). The NRCC is part of the six-center Regional Climate Center Program that collectively serves all parts of the US. The NRCC has developed the Applied Climate Information System (ACIS) that integrates climate data from different federal and state networks and delivers a wide range of user-specified data products and decision tools. For example, ACIS powers software available to every county-level USDA NRCS field office in the country, providing standardized analyses for making wetlands determinations, evaluating field conditions, etc. The NRCC and NEWA have enjoyed over a decade of collaboration in linking weather data to specialty crop management models. In his role as professor of Earth and Atmospheric Science, Dr. DeGaetano's research interests are cross-disciplinary, focusing on the use of climate data in decision making. Recently, he has collaborated on numerous regional climate change assessment reports and has worked to identify climate impacts related to observed and projected future climate trends. Ongoing work has focused on extreme rainfall and frost occurrence. A native of the Northeast, Art received his interdisciplinary Ph.D. from Rutgers University focusing on meteorology and horticulture.

Co PD, Mary Concklin: Ms. Concklin is the Extension Fruit Production and IPM specialist at the University of Connecticut where she develops, conducts and evaluates IPM and fruit production educational programs for fruit growers statewide. She also conducts research involving fruit crop nutrition, alleviating soil compaction in established fruit plantings, spotted wing drosophila trap cropping, and hydroponic strawberries. She works with growers utilizing weather stations and NEWA in pest management decisions. She edits chapters in the New England Tree Fruit and New England Small Fruit Pest Management Guides; is on the planning committee, session chair and speaker at the New England Vegetable & Fruit Conference. Ms. Concklin is a member of the UConn IPM Team and is the CT NEWA state coordinator. She has been with UConn since 2010 and was previously with Penn State Cooperative Extension.

Co PD, Jon Clements: Jon Clements, M.S. has worked in the tree fruit industry for over 25 years in various roles, including research technician (University of Vermont), County Extension Horticulture Agent (Michigan State University), and Extension Tree Fruit Specialist (University of Massachusetts Amherst). In his current role as Extension Tree Fruit Specialist at UMass, he provides horticultural and integrated pest management education and recommendations via traditional (meetings, newsletter, etc.) and modern (e-mail, blog, YouTube, etc.) communication tools to tree fruit growers in Massachusetts, New England, and beyond. He also conducts applied research on pome and stone fruit at the UMass Cold Spring Orchard in Belchertown, MA. He is the MA NEWA state coordinator. Clements has received numerous awards, including USDA Group Honor Award for Excellence (Northeast Multi-State Research Project-183, 2001), International IPM Award of Excellence (7th International IPM Symposium,

2012), and International Fruit Tree Association Outstanding Service to Industry & Association (2006) and Extension (2013) Awards.

Co PD, David Robinson: Dr. Robinson is a Rutgers University professor in the Department of Geography and, since 1991, serves as New Jersey's State Climatologist in the NJ Agricultural Experiment Station. The mission of the Office of the NJ State Climatologist (ONJSC) is to provide environmental data and products to interested parties, conduct applied research in cooperation with stakeholders, and reach out to all within the state regarding weather and climate related issues. The ONJSC operates the NJ Weather and Climate Network, a constellation of close to 60 electronic weather stations where key atmospheric variables (e.g. temperature, precipitation, humidity, wind and solar radiation) and soil temperature and moisture are reported every five minutes. Data are used within the NEWA program. The ONJSC also coordinates the NJ Community Collaborative Rain, Hail and Snow Network, which is composed of over 250 citizen scientists who contribute daily reports of precipitation. Robinson is a contributor to the Intergovernmental Panel on Climate Change and to the National Climate Assessment, and sits on the National Academy of Sciences' Board on Atmospheric Sciences and Climate. Dr. Robinson is a Fellow of the American Meteorological Society and has been named a NOAA Environmental Hero.

CoPD, Robert Crassweller: Dr. Crassweller has been at Penn State University since 1984 with a 15% research and 85% extension position in tree fruits. He is the state Extension Specialist for tree fruits and his duties include developing educational programs for fruit growers throughout the state. Other extension duties include serving as the department's extension coordinator, acting as leader of the tree fruit plan of work, coordinating the state-wide program in extension for tree fruit, the plant and soil analysis recommendations for tree fruit, Cultural and Horticultural Section chair for the Pennsylvania Commercial Tree Fruit Production Guide. Research expertise is in applied tree fruit culture and includes rootstock and compound genetics systems for apples, cultivar evaluation and acceptance. Dr. Crassweller was a member of the Penn State decision support systems for tree fruit, AppLES in the 1990's. For the last three years he has worked with the fruit growers in Pennsylvania in evaluating the Apple Carbohydrate Thinning model on the NEWA site. He is the PA NEWA state coordinator. The work has been supported by the State Horticultural Association of Pennsylvania's Extension Committee.

CoPD, Terence Bradshaw: Mr. Bradshaw is the Tree Fruit & Viticulture Specialist at the University of Vermont with 25% each of Experiment Station research, extramural research, undergraduate teaching, and administrative farm director duties. Although not Extension-funded, 20% of his extramurally-funded effort is dedicated to providing state-wide grower outreach, including IPM program information and as coordinator of the Vermont NEWA network. Research expertise is in pest and horticultural management in organic and conventional apple and grape production systems, including assessment of organic management strategies, cultivar and rootstock evaluation, biological control of apple replant disease, and evaluation of production strategies for growers of (hard) cider apples. He provides interpretation of soil and foliar tissue analysis for fruit growers in Vermont, and contributes annually to authoring of the New England Tree Fruit Management Guide. He was President of the Vermont Tree Fruit Growers Association (VTFGA) from 2009-2014, and continues to serve as an advisor to that group as well as the Vermont Grape and Wine Council. Since 2013, Terry's research has been funded by USDA NIFA/SCRI & CPPM, AMS/FSMIP, & SARE; Vermont Agency of Agriculture; VTFGA; and private industry.

j) List of project objectives with corresponding hypotheses to be tested

(1) Develop NEWA into a responsive website to improve user experience and accessibility.

Hypotheses: (i) Most stakeholders access internet resources on smart phones and would rely on NEWA's web-based apps more if they could utilize mobile devices for access. (ii) Stakeholder focus groups and user testing during web development will result in user-friendly web design.

(2) Create virtual weather station locations by implementing freely available climate and forecast digital data into a NEWA map layer to allow for efficient and fast network expansion.

Hypotheses: (i) Virtual stations based on the National Digital Forecast Database (NDFD) and Real-Time Mesoscale Analysis (RTMA) can deliver precise weather data for use in NEWA tools. (ii) Virtual weather stations can be calibrated from NEWA's on-site stations.

(3) Investigate and build *You're NEWA*, a website to subscribe to virtual stations, alerts (e.g. infection events), customized apps, and user profiles (e.g. bloom dates) to support NEWA.

Hypotheses: (i) Revenue from subscription products will support NEWA, eliminating yearly fees. (ii) Farmers of fruits and vegetables will subscribe to *You're NEWA* products and profiles.

(4) Enhance IPM and crop production tools in NEWA with innovative tools, tools implemented by partner institutions and similar networks (e.g. Enviro-weather), and create a *Developer Sandbox* to validate tools that emerge from applied and basic research. *Hypotheses:* (i) Incorporating end-user suggestions for new and improved NEWA tools will result in high impact web applications. (ii) It is possible to share tools across networks and regions in temperate North America. (iii) A web utility can be created to ingest the building blocks of models and display them in NEWA end-user format via automated database programming.

k) Outline of methodology to be used to achieve project objectives

To develop the NEWA responsive website, we will engage the project group and our grower advisory panel in a technology strategy workshop conducted by ITX, NEWA's web hosting company, to prioritize components of the website. We will define the requirements for the responsive, *You're NEWA*, and *Developer Sandbox* websites with ITX and then engage a web development company to build them. End user testing will be done with focus groups consisting of the advisory panel, project members and others who have stations in NEWA.

The basis for virtual weather stations will be the freely available NDFD and RTMA. For virtual stations, the shortest forecast periods (i.e. the forecast for 1 hour in advance) will serve as surrogates for observed data. Thus, each forecast would become the "observed" data for the virtual station. We will validate this approach, quantifying the differences between virtual weather station data and actual observations. NEWA uses the NDFD dataset in tools that require forecasts. Our efforts will provide a means for calibrating these forecasts at NEWA weather stations. Through this research, we also propose to validate the NDFD forecast information and establish a way to quantify forecast uncertainty and identify systematic forecast biases.

Mobile platforms provide a premium experience with the potential to generate revenue. We will survey growers' willingness to pay to provide information in structuring the cost of using mobile NEWA tools. We will explore the potential for generating revenue through app sales, ad sales and freemium apps to fund continuing NEWA operations.

The advisory panel, project members and others who have stations in NEWA will be surveyed to provide input on new tools and suggested improvements. These will be formally documented and prioritized. We will communicate with similar networks in temperate North America to determine how to offer NEWA tools on their platforms and use their tools within NEWA. Existing models, for blueberry phenology at Rutgers and brown patch of turf at the University of Connecticut, will be used as test models for the NEWA *Developer Sandbox*.

1) Logic model chart

Program: NEWA Mobile Applications & Virtual Stations to Improve Fruit & Vegetable Adoption of IPM and Crop Management Tools in the Network for Environment and Weather Applications (NEWA) Logic Model
Situation: NEWA apps on mobile platforms and more weather station locations are needed by stakeholders for optimum access to IPM and crop risk management tools.

Inputs	Outputs		Outcomes -- Impact		
	Activities	Participation	Short	Medium	Long
<p>NEWA state coordinators (CT, MA, NJ, NY, PA, & VT)</p> <p>Cornell, UMass, UVM, UConn, Penn State, Rutgers</p> <p>Northeast Regional Climate Center (NRCC) staff experience and knowledge</p> <p>Growers with weather stations</p> <p>Fruit & vegetable industry members</p> <p>Stakeholder advisory group</p> <p>Biologists, climatologists, economists, and IT specialists</p> <p>NEED-NERA Planning Grant</p> <p>USDA-NIFA-SCRI funding</p> <p>NEWA ITX website infrastructure supported by the NRCC and the NYS IPM Program</p> <p>Weather station mesonets and data acquisition infrastructure</p>	<p>Monthly conference calls with NEWA state coordinators</p> <p>Build project webpage, post NEWA blogs</p> <p>Establish project advisory group</p> <p>Yearly project team and advisory group meetings</p> <p>ITX holds technology strategy workshop with project team & advisory group</p> <p>Define the requirements for a responsive NEWA website</p> <p>Develop a responsive NEWA website</p> <p>Create and validate virtual weather stations</p> <p>Document and prioritize new and improved NEWA tools</p> <p>Develop 'You're NEWA' custom website and Developer Sandbox</p> <p>Evaluate responsive website, virtual stations</p> <p>Research value & price NEWA apps, alerts, and profiles</p> <p>Survey NEWA growers on willingness to pay for 'You're NEWA'</p> <p>Educational programs, written materials for industry on use of (1) predictive models, (2) virtual stations, (3) 'You're NEWA'</p> <p>Presentations at regional, national meetings.</p>	<p>Fruit & vegetable growers</p> <p>Agribusinesses</p> <p>Extension & research faculty and staff in CT, MA, NJ, NY, PA, & VT and potentially other states in the US</p> <p>Owners of NEWA on-site weather stations in CT, IO, MA, MD, MN, NC, NE, NH, NJ, NY, PA, RI, VA, VT, & WI</p> <p>Stakeholder advisory group</p> <p>State weather mesonets</p> <p>Internet consultants and architects from ITX, NEWA's web hosting company</p> <p>Northeast Regional Climate Center (NRCC)</p> <p>NY State IPM Program</p>	<p>NEWA priorities reflect and support grower needs</p> <p>The project webpage and NEWA blog keep the public informed on SCRI project outcomes</p> <p>A responsive NEWA website is available</p> <p>Growers access NEWA via smart phones for weather, crop production, and IPM information</p> <p>Virtual weather stations are available at NWS gridded forecast locations and calibrated with on-site stations</p> <p>New NEWA tools and improvements are based on grower input</p> <p>New and improved tools are available on NEWA</p> <p>Disease, pest, and crop research knowledge can be adapted into NEWA tools and tested via the NEWA Developer Sandbox</p> <p>NEWA email alerts are grower-approved and available</p> <p>'You're NEWA' subscription alerts, apps, profiles and a payment gateway become available</p> <p>Growers learn how to navigate the NEWA website and use NEWA crop and IPM tools</p> <p>NEWA instructional materials are available on the NEWA website</p>	<p>Additional states in the US join and benefit from NEWA</p> <p>State subscription fees are no longer necessary allowing free and open access to NEWA</p> <p>Growers save money by preventing crop loss and reducing unnecessary sprays</p> <p>Increase in number of growers utilizing NEWA on mobile devices</p> <p>Increase in number of NEWA station locations</p> <p>NEWA reaches across the entire Northeast quadrant of North America</p> <p>Increase in number of weather, crop and IPM tools on NEWA</p> <p>NEWA funding is sustained through NEWA apps, ads, profiles, and virtual station subscription services</p> <p>Smart phone access of NEWA website and customizable 'You're NEWA' alerts significantly increases use of IPM and crop tools</p>	<p>Growers are more profitable through savings in pest and crop management inputs</p> <p>Human health and environmental risks are minimized through reduction in inputs</p> <p>NEWA collaborates with agricultural weather and climate groups, websites, and hubs across the US and internationally</p> <p>NEWA continues to grow and has a sustained funding base</p> <p>Growers are more successful with managing disease, arthropod, and crop management inputs</p>

Assumptions
 Majority of stakeholders access internet resources on smart phones
 Stakeholders would utilize mobile platforms to access NEWA's web-based apps
 Virtual weather stations can be realistically used for crop model predictions & history
 Revenue from subscription products will allow NEWA to become self-supporting.
 Stakeholders will subscribe to 'You're NEWA' products.

External Factors
 USDA-NIFA-SCRI funding
 Stakeholder input
 Collaborations with similar systems in the US
 Climate change altering pest/disease life history
 Invasive species for which no models exist

