PROPOSAL TEMPLATE

Forest Service use only.

Control Number: __1-C1-1-NA_

COVER SHEET

2016 U.S. Forest Service

National Urban and Community Forestry Challenge Cost-Share Grant Program

Pre-roposals are due by November 23, 2015, 11:59 PM Eastern

INNOVATION GRANT CATEGORY:

(An estimated total amount of $900,000, may be available, approximately $300,000 per category)

Check one category per application. More than one application may be submitted by an organization.

x Category 1: Analysis and Solutions for Development and Redevelopment Impacts on Urban and Community Forests

☐ Category 2: Building Human Health Through Urban and Community Forestry

☐ Category 3: Climate Change and Its Impact on Trees and Water

PROJECT CONTACT NAME, ORGANIZATION, ADDRESS, PHONE NUMBER, FAX NUMBER AND EMAIL ADDRESS:

Technical Contact: Dr. Charles Kroll, SUNY ESF, 1 Forestry Drive Syracuse NY 13210, 315-470-6699, 315-470-6958, cnkroll@esf.edu

Administrative Contact: Ms. Tanya Waite, The Research Foundation for SUNY, 35 State Street PO Box 9 Albany NY 12201, 518-434-7048, 518-434-8343, tanya.waite@rfsuny.org

PROJECT TITLE:

A Decision Support System to Develop, Analyze, and Optimize Urban and Community Forests

FUNDING REQUEST AND MATCH (Note: Matching amount must at a minimum equal requested amount.)

REQUESTED: $ + MATCHING: $ = TOTAL PROJECT: $ 300,000 + $307,697= $607,697, Full Proposa-Federal **285,340** Matching =$287,384 Total Project =$572,724

OUTREACH:

Note: if one check "Yes" in either of the boxes below, the applicant will be required to describe either how they plan to outreach to the identified population and/or provide a description of your underserved organization.

Is this project being developed to reach a minority or underserved population? _Yes X No

Is this pre-proposal being submitted by a minority or underserved population (owned/operated/ directed) business, organization or college/university? _Yes X No

Applicants should also address how the issue impacts underserved communities and how the proposal can address or minimize these impacts when applicable.

LIST PROJECT PARTNERS: Project Partner letters are to describe their role and contribution with the project.

[Provide: NAME, ADDRESS Phone Number and Email:]

LETTER OF SUPPORT INCLUDED: X YES _NO

1. Dave Nowak, Northern Research Station USDA Forest Service, 5 Moon Library 1 Forestry Drive Syracuse NY 13210, 315-448-3212, dnowak@fs.fed.us

2. Scott Maco, Davey Institute, Davey Expert Tree Company, P.O. Box 5193 Kent OH 44240, 330-673-5685, smaco@davey.com

LIST STAKEHOLDER SUPPORT: Support letters from stakeholders are to describe why the proposal end results are needed and how it will benefit them and their community.

[Provide: NAME, ADDRESS Phone Number and Email:]

LETTER OF SUPPORT INCLUDED: X YES _ NO

1. James Clark, Vice President, HortScience, 325 Ray Street Pleasanton CA 94566, 925-484-0211, jim@hortscience.com

2. Jere Jeter, Tennessee State Forester, Division of Forestry, P.O. Box 40627 Nashville TN 37207, 618-837-5520, jere.jeter@tn.gov

3. Stephen Harris, City Arborist, City of Syracuse, 412 Spencer Street Syracuse NY 13204, 315-473-4330, SHarris@ci.syracuse.ny.us

Abstract

We create a decision support system (DSS) for i-Tree Landscape that strategically manages the uncertainty in i-Tree Eco, Hydro, and Forecast predictions to increase the chance of managers achieving desired benefits and services from urban and community forests. Our challenge includes: increasing predictive accuracy of these i-Tree models while not creating undue data requirement burdens; and reporting predictive accuracy to inform and not confuse users. Our methods include identifying: a) drivers of model uncertainty; b) methods to estimate model uncertainty; and c) ways to view and reduce model uncertainty. Our expected outcomes are: uncertainty estimators for i-Tree Eco, Hydro, and Forecast; integration of this uncertainty in our DSS; case studies demonstrating the use of the DSS to minimize the impacts of development and redevelopment on urban and community forests; and dissemination of results. Our partners are the USDA Forest Service Northern Research Office and the Davey Tree Expert Company, urban forest modeling experts with a national scope (letters attached). The uncertainty management DSS is a post-project product that will be supported with other i-Tree tools. Technology transfer involves face-to-face and webinar trainings and outreach efforts to support new users of the uncertainty management DSS. The project is budgeted at $300,000.

Responses to Reviewers Comments 1-C1-1-NA Kroll SUNY Full Proposal Accepted Track Changes.

We appreciate the thoughtful and insightful comments of the proposal reviewers. Below we have listed the reviewer-identified areas of strength and areas requiring further explanation in the submitted pre-proposal. For each area requiring further explanation, we briefly discuss how we have addressed this in the full proposal, and indicate where in the full proposal this addition can be found.

Areas of Strength:

- Builds on existing tools with measures of uncertainty, which is valuable for influencing/decision making
- Good to have access via iTree tools website.
- Good job on project planning and timeline, structured by objective
- The proposal is well-written except for a few typos. It lays out a coherent conceptualization of the problems associated with uncertainties in the i-tree models and research suggested to address these problems. The logical hand off of study findings in the form of a decision support system for urban forest planners/managers is also very good. The proposal demonstrates critical thinking in that it suggests methods, which are grounded in the literature, to evaluate a popular urban forest inventory system. Designers of the model and users recognize that the various i-tree models contain unknowns and are attempting to address these with this research.
- Very thoughtful proposal that moves the iTree tools ahead. It has good and capable partners with valuable expertise.
- It's important to optimize the "go to" tool used by so many across the nation.
- It is an important innovation to existing product - iTree. Good fit to category; good lit review; proven team with good dissemination TT track record.

Areas Requiring Further Explanation:

- They could do a better job describing the potential impacts of this research.
- Discuss more how a decision maker would use this information.
- Why is this really important, or is it just incremental in terms of added impact?

  These comments are related to each other. To address this, we have added a brief example of the type of information that this proposal would generate and how urban planers and managers could use it. This is included on pages N-6 and N-7 of the full proposal.

- Specify how many workshops, trainings and webinars and other products
- Can you piggy back on existing i-Tree trainings?

  We are proposing 4 webinars (one focused on each of the study areas) and one conference-related workshop. This is included on page N-11.

- Spell out ABET evaluation criteria.

We mention ABET because we have extensive experience implementing assessment protocols as part of our program's ABET accreditation. We have included additional discussion of these protocols and how this experience improves our ability to assess our project as we advance towards our goals. This is on pages N-11 and N-12.

* Is any of the requested travel for travel to cities?

  No travel money is requested to travel to our study cities. We have developed relationships with stakeholders in each of our proposed study areas (letters from supporters in each proposed study area are now included with this proposal). Should our project team decide an in person visit to one or more of our study cites is necessary, we will divert conference travel money to this expense, and limit our conference travel.

* A major feature of this research is the development of a decision support system to aid users (municipalities principally) in determining the optimal places in urban areas to plant trees. Ideally, this optimization would help to promote environmental equity across a given city. This means equity in terms of human access to city trees and the benefits (and costs) they deliver. So it would seem that in order to approach such an ideal, any decision support system would necessarily include some form of human input into that decision system. I understand that the project designers are engineers and foresters whose science focuses on the physical aspects of urban forests, but I feel that in this case, an interdisciplinary approach to the decision support system is warranted; or a least some acknowledgement that the model does not contain any such input. Researchers will use the Atkinson index of social inequality to estimate how tree extent correlates with a measure of poverty. This is fine, but it is not the same as seeking input from local persons about their preferences for tree species, configurations, etc. It seems to me that the human response to any physical installation is key to the success of that installation, including tree plantings. Resentment can develop if people believe that programs or 'solutions to their problems' are developed without their input. So, I don't know enough about this science area to say whether the human response to urban tree plantings should be considered an uncertainty and somehow accounted for in the i-tree eco model, for instance or whether this element ought to be factored in to a decision support system independent of the modeling results, as something for managers to consider.

  This is an excellent comment. We completely agree that buy-in from local residents is critical to the success of any urban forestry initiative, and that input from these residents will strengthen the development of i-Tree tools. We will use our supporters in each city to help identify underrepresented communities within their city, and to help us better understand the urban forest needs of those communities as we develop our experimental design. After we have developed a prototype of our modeling system, we will run a webinar for stakeholders in the communities we have modeled. During this webinar, we will seek feedback on our products and how they could better serve these communities. There are also two important related issues. First, it's important to note that often our analyses are on a census block scale (though sometimes we work at smaller scales). In such an analysis, we are not indicating the exact location and configuration of a planting installation, but instead a general area of a city (a census block) where canopy should be either preserved or expanded. Second, the tools we are developing are screening tools. The goal is not to provide a single, absolute solution, but instead allow users to explore the tradeoffs between different urban forest initiatives, the uncertainty in assessing these systems, and provide recommendations of potential areas within a city to target for urban forest initiatives. This is discussed on page N-11 of the proposal.

* The following is more a question than a criticism. The tree demonstration sites selected are all in northern cities (I don't mean northeastern). I understand the reason for this selection, which is based on existing tree plot data and monitoring networks. Still, I'm aware of at least 1 study that has questioned whether urban trees are equally effective at pollution in all latitudes (Setala, H., Viippola, V., Rantalainen, A., & Pennanen, A. 2013. Does urban vegetation mitigate air pollution in northern conditions? Environmental Pollution, 183, 104-112). According to this article, i-tree result may be stronger in the lower latitudes. I wonder if model uncertainties may be better illuminated if the demonstration sites were in the U.S. southeast or southwest. I am aware that i-tree data have been collected in Florida (Tampa, Miami) and wonder about the possibility of one of those cities as a demonstration site.

  We have taken this suggestion and added Phoenix, AZ as an additional study area. Located in the southern US, Phoenix is a National Science Foundation Long Term Ecological Research (LTER) site. The LTER began in 1980 to conduct research on ecological issues, and provides many long-term datasets necessary to document environmental change. We have included a letter of support from Richard Adkins, Forestry Supervisor for the City of Phoenix, who has been involved with i-Tree urban forestry assessments in Phoenix. While we have considered adding either Miami or Tampa Bay as a fifth study area to further diversify our analysis, we are not proposing the addition of a fifth site at this time.

* The Davey consulting fee should be explained. What are the applicable rates as far as salaries or other services this company would provide? You should also be explicit about the faculty salary. How much is it? I could calculate it based on the information you provided, but it would be better if this were stated in a relevant note (similar to graduate student salary).

  The involvement of Davey Tree is critical to the success of the proposed project. Davey Tree provides technical and programming assistance, and supports the web interface and software development and updates for i-Tree tools. After further discussion with our Davey Tree partners, we have increased the total budget allocation to Davey Tree. During the first two years of this project, Davey will be used as a consultant when we develop and implement our experiment, helping with software questions and concerns, and providing general technical advice. During this 2-year period we have budgeted 5 hrs/month for Davey Tree at $60/hr. During year 3, Davey will integrate our new tools within i-Tree Eco, the “engine” of the i-Tree suite of tools. This will involve software development, testing, and documentation so that these tools are fully integrated within i-Tree Eco. This is far from a trivial task, and we have now allocated 40 hrs/week for 24 weeks at $60/hr. Note that the contracted rate for Davey Tree is $120/hr, and they have waived half of this fee as a match on this grant, as indicated in their updated letter of partnership. This is discussed on page N-13. In addition, the budgeted faculty salary is also included on page N-13.

* I was looking for specific examples as to how the tools would be used by lay people and the community of practice with practical examples of how it would help in the field. Reducing uncertainty may be good but how much more accurate and applicable might this make iTree, 1%, 10% or ??? This sounded like an exercise in statistics without a concrete applicable outcome. Would like to see a cost benefit outcome for the product.

  Our primary focus in the proposed work is to describe the uncertainty of output from i-Tree tools and how this uncertainty can be used within a decision support system to improve the use of i-Tree tools. The primary focus is not on developing more accurate models. We feel such uncertainty information is necessary to users to fully understand and assess i-Tree output and make more informed urban forestry decisions. Our uncertainty analyses will identify i-Tree output that is exceptionally uncertain and identify the drivers of this uncertainty, which allows us to make further improvements to these tools to both reduce uncertainty and improve accuracy.

* Objective 3 listed the wrong cities; unclear use of focus groups or beta testing with target users; expensive.

  We apologize for the typographic error in the pre-proposal under Objective 3. The 4 study cities (3 original and 1 additional) have been updated throughout the proposal.

  We have more fully described our use of focus groups for beta testing with target users. In each of our study areas, we will develop a training session with a case study from 2-4 different areas within each study city. These areas will be made up of census block groups. Our plan is to engage our local collaborators in the development of these study areas. This is discussed on page N-11 of the full proposal.

* While this tool can certainly be used to improve analysis of undeserved communities, the project does not specifically address this population. Which communities are served by this tool is up to the end user, not the researchers developing the tool. Perhaps the tech transfer could focus on these communities and solving problems specific to areas where undeserved communities reside.

  We agree that we need further discussion of how our analysis will address underserved communities. We have expanded this discussion on pages N-4 (Objective 1) and N-11 (National Distribution/Technology Transfer of Your Findings) of the proposal. In each study city, we will identify 2-4 different areas within each study city, with these areas made up of multiple census blocks. We will work with our supporters in each study area to identify areas that are underserved by inequitable financial and technical assistance as well as underserved by limited urban forest resources.

* We are asking applicants to look at their over-all budget to see if there are any areas that they can reduce their costs, since we will not be receiving the full amount of estimated funds.

  In response to this request, we have reduced our funding request by ~$15,000. We have reduced graduate student salaries and tuition during the first year, faculty summer salary, and travel expenses during the first year. These reductions also offset the increased compensation to Davey Tree. We proposed many integrated tasks to accomplish our project's goals (including increasing in the number of study sites); while we would consider further reductions in our requested budget, we hope to receive the amount requested.

1. Project Description

Urbanization can result in many detrimental environmental impacts including urban stream degradation, increased runoff and nutrient export, increased human exposure to air pollutants, increased temperatures, and increased material consumption and energy use. One way to alleviate these impacts is through urban greening, and many cities have launched large urban tree planting initiatives. At the same time, urban development pressures often reduce urban tree canopies and the ecosystem services they provide. Models of urban trees can help develop more efficient and effective planting schemes, identify areas where existing forests should be maintained, improve the overall management of urban forests, and better quantify the benefits of these forest resources.

This research focuses on the i-Tree suite of urban forest modeling tools. These tools quantify the structure, function and ecosystem benefits trees provide. Depending on the goals of the modeler, i-Tree tools work on a variety of urban scales. In addition, a new suite of distributed i-Tree tools has been developed which allow for a better characterization of the impact of urban trees on more local scales. These free public domain tools have been used by hundreds of researchers, urban planners, foresters, and others around the world to advocate for the benefits of urban trees.

While these tools have been extremely beneficial to the planning and management of urban trees, they have their limitations. Many of the models make assumptions that simplify the function of urban forests and the representation of urban landscapes. While such assumptions are often necessary to model these complex systems, they can increase the uncertainty of model output, and hinder the efficient and effective management of urban forests. The characterization of uncertainty from i-Tree models should be more fully explored. This research will develop methodology to characterize the uncertainty of i-Tree model output, improving the use of this urban forest modeling tool and providing urban managers more complete information about the structure, function, and value of their forest resources. It will then use output uncertainty information within a decision support system to allow i-Tree users to develop more effective urban forest management plans, better identify areas for tree planting and preservation, address inequities in ecosystem services and identify ways to improve urban canopies in underserved and disadvantaged communities, and more fully understand the benefits of urban forests.

Project objectives: The objectives of this research project are to:

1) Identify the drivers of output uncertainty for i-Tree models.

2) Develop and test methods for estimating the uncertainty of outputs from i-Tree models.

3) Design effective ways to present model uncertainty and to educate model users on how to use this information to improve forest planning and management.

4) Create a decision support system that allows users to identify improved urban forest planting and protecting schemes.

5) Disseminate our findings to a wide range of stakeholders using many different outreach techniques.

These objectives are fully described in Section 4 of this proposal (Project planning and timeline).

We are applying to NUCFAC **Grant Category 1: Analysis and Solutions for Development and Redevelopment Impacts on Urban and Community Forests**, since it focuses on improving decision-support to local governments, estimating gains and losses in tree canopy and the impacts of these changes, issues of urban forest sustainability, and cost/benefit of changes in green infrastructure at a variety of scales. This project will increase community understanding of how to best maintain existing urban forests while helping those communities develop new and improved urban infrastructure that incorporates urban trees and optimizes their benefits. As recommended in the RFP, we have communicated with our Forest Service Regional Urban Forestry Program Manager regarding the applicability of this proposal to this grant category.

The i-Tree tools have a diverse group of users, including scientists, university students, city planners and managers, community groups, consultants, non-profit organizations, and volunteers. The i-Tree tools have been applied to cities across the world, and as the tools and associated manuals are now freely available online, the number of applications of this modeling system is expanding. While the primary target audience of our work is urban planners and managers, we expect that all of the above groups will benefit from our project and the improved modeling toolset we develop, as well as related manuals and background information, which will be easily accessed online via the i-Tree tools website (www.itreetools.org).

Since we are improving i-Tree tools, which are developed to be applied seamlessly anywhere within the United States, the project is clearly national in scope and has the potential to serve all communities. We plan to perform demonstration projects in 4 cities, New York City, NY, Chicago, IL, Portland, OR, and Phoenix, AR, all of which have had prior applications of i-Tree tools, thorough tree plot information necessary for i-Tree, and extensive environmental monitoring networks.

The partnership collaboration for this project includes researchers at a public university (SUNY ESF), a private company (The Davey Tree Expert Company), and a federal agency (USDA Forest Service Northern Research Station). This group collaborated on a recently completed NUCFAC award (11-DG-11132544-340) which supported the recent launch of i-Tree Landscape (i-Tree's new spatially distributed modeling system), improved versions of i-Tree Eco and Hydro, and produced 7 journal articles published or in review (with more in development), 9 conference presentations, 1 conference session focused on urban ecosystem services, 3 i-Tree trainings and 3 webinars. This group's past collaborative success guarantees that this project will result in improvements to i-Tree tools that will benefit communities across the country.

2. Originality and Innovation

The i-Tree software suite is an incredible resource for urban planners and managers. It provides critical information regarding the structure and benefits of urban trees, how urban trees are changing over time, and how these changes may impact the ecosystem services and benefits urban trees provide. While this tool is being effectively used by a wide variety of stakeholders throughout the world, it has limits to how well it can describe the complexity of urban landscapes and ecosystems, and the impacts trees have on these ecosystems. The proposed project will improve i-Tree by developing estimators of model output uncertainty, and creating a decision support system that incorporates this uncertainty so that urban planners and managers can make more informed decisions regarding the impact of development and redevelopment on urban trees and the ecosystem services they provide.

We are aware of the recently funded NUCFAC project “Planning for equitable urban landscapes: Identifying communities underserved by urban forest green infrastructure, assessing future risks, and optimizing management strategies,” which primarily focuses on resiliency of urban forests to climate change, pests, and development using existing i-Tree tools. Here we are proposing improvements to i-Tree tools, developing new algorithms that will expand their functionality, improve their use, and better inform and develop optimal urban forest planning and management.

Our novel project develops measures of i-Tree output uncertainty, explores creative and effective ways to communicate to users the importance and use of this uncertainty, and integrates these measures within a decision support system to improve urban forest planning and management. Our project is particularly important not only for its direct results, but for the potential of improving all subsequent projects that utilize i-Tree tools.

3. Literature Review (See Appendix)

4. Project planning and timeline:
This section describes the logical steps that will be performed to reach our desired objectives and ultimate goals. The organization of this section is based on the objectives listed in Section 1.

Objective 1) Identify the drivers of output uncertainty for i-Tree models. The i-Tree models provide critical information regarding the structure, function, and benefits of urban forests on ecosystems and their inhabitants. Such environmental models describe the impact of changes in systems parameters (e.g. temperature, leaf area index, or ambient air quality) on model output (e.g. carbon sequestration, energy savings, or improvements in human health). While these models are simplifications of reality, they describe the primary processes impacting changes in state variables and fluxes within the model, as well as the effects of these changes. Not all input parameters have the same effect on model output. For this first objective, we aim to identify the most important drivers of i-Tree model output, and to characterize the uncertainty of these drivers.

In this project, we will focus on four i-Tree Models: i-Tree Eco, i-Tree Hydro, i-Tree Forecast, and i-Tree Landscape. i-Tree Eco is the “engine” of i-Tree, providing algorithms and inputs to other i-Tree models. i-Tree Eco provides users information on urban forest structure (e.g. tree species, cover, and health, leaf area and biomass), pollution removal by trees (e.g. ozone and particulate matter), effects of trees on energy use, net carbon sequestration, and the susceptibility of trees to pests and diseases. This is a lumped model, meaning that the study area functions as a whole, and estimates of output parameters are not location specific but instead for the entire study area. i-Tree Hydro is designed to simulate the effects of changes in tree and impervious cover characteristics within a watershed on stream flow and water quality. It simulates the water balance within a study area, and the impact of trees on interception, evapotranspiration, infiltration, and water quality. i-Tree Forecast is a new model that provides estimates of changes in tree cover and composition in the future, and changes in benefits due to these canopy changes. This involves both grow-out and die-back scenarios, and the impact of invasive species, pests, and development on urban trees. i-Tree Forecast provides future scenario inputs to i-Tree Eco and Hydro. i-Tree Landscape, released in November 2015, is a spatially explicit version of i-

Tree Eco, estimating many of the same output parameters at multiple locations within the study area. This model works within a Geographical Information System (GIS), and uses spatially varying inputs such as tree characteristics, land cover, meteorology, and air quality. Spatial outputs from i-Tree Eco, Hydro and Forecast provide inputs to i-Tree Landscape.

We will use simulation analyses to identify which model parameters and inputs lead to the greatest variability in i-Tree Eco, Hydro, and Forecast outputs, and then fully characterize the uncertainty of these parameters and inputs. There are a number of techniques and tools available to perform such an analysis. We will utilize global sensitivity methods that provide an analysis of the impact of input parameters over the entire parameter space. This will include Morris One-factor-At-a-Time (MOAT) (Morris, 1991; van Griensven et al., 2006) and Monte Carlo with Latin Hypercube Sampling (LHC-MC) (Zádor et al., 2005; Mészáros et al., 2009). Both of these methods have been successfully implemented for the dry deposition model within i-Tree Eco (Hirabayashi et al., 2011), where leaf area index, temperature, and ambient air quality were identified as the primary drivers of air pollutant dry deposition to urban trees. We will expand this analysis to other i-Tree models to better understand which inputs these models are most sensitive. In addition, we will also employ bootstrap resampling techniques (Efron, 1981) to characterize the uncertainty of these parameters and inputs. This is important, as uncertainty in model inputs often has a large impact on the uncertain of output parameters.

Objective 1) and subsequent objectives will be developed in 4 case study cities: New York City, NY; Chicago, IL; Portland, OR; and Phoenix, AZ. A letter of support from an urban forest stakeholder in each of these cities is provided with this proposal. i-Tree has been previously applied to each of these cities, and all have good tree plot data, a critical input to i-Tree. New York City was chosen due to its extensive environmental monitoring networks, extensive ongoing tree planting efforts, and previous case studies examining priority planting schemes. Chicago was chosen due to its extensive field plots, strong land use gradient from suburban to urban, and its location in the Midwestern United States. Portland was chosen to represent a western US study area of smaller scale and lower population than New York City or Chicago, but still has good environmental monitoring networks necessary to perform and assess our i-Tree analyses. Portland has many ongoing efforts to engage local communities in understanding and improving their urban forests. Phoenix is an additional study area in the southern US that was added to this proposal based on a reviewer's comment that vegetation may provide insignificant improvements to air pollution in northern conditions (Setala et al., 2013). Phoenix is a National Science Foundation Long Term Ecological Research (LTER) site. The LTER began in 1980 to conduct research on ecological issues, and provides many long-term datasets necessary to document environmental change.

Within each case study city, we will develop and test models in 2-4 different sub-areas within the city. Each of these areas will be comprised of several adjacent census block groups so that the distribution of demographic data within the areas can be determined and utilized in our study. These sub-areas will be developed with the participation of our local collaborators, who have provided letters of support for this proposal. We will specifically identify some areas within each study city where underserved populations are present. These groups may be underserved because they do not receive equitable financial and technical assistance as other communities, or they may be ecologically underserved due to limited local urban forest resources and the ecosystem services they provide. As discussed in Section 7 of this proposal (National Distribution/Technology Transfer of Your Findings), we will use our local collaborators to engage local stakeholders in the beta testing of tools developed from this project, and obtain feedback from these stakeholders on how to improve our products to better serve their communities.

Objective 2) Develop and test methods for estimating the uncertainty of outputs from i-Tree models. Outputs from environmental models are uncertain due to many factors including uncertainty of input parameters, model uncertainty, the natural variability and lack of stationarity of environmental processes which impact urban forests, the uncertainty in environmental measurements to which models are calibrated, and subjective judgment by the modeler. There are many different methods to describe the uncertainty of output from environmental models. We will explore a range of methods to better understand their applicability to i-Tree Eco, Hydro, and Forecast models, and develop recommended methodology for estimating output uncertainty of each model. We will focus on three methods that have been shown to be particularly useful for uncertainty analyses in environmental models: (1) gradient-based first-order error analyses, (2) resampling methods, and (3) Bayesian techniques (e.g. GLUE) (Matott et al., 2009).

Gradient-based first-order error analyses, which are sometimes referred to as the delta method, are based on a first-order Taylor series approximation to the variance of the output parameters. It requires estimators of the variance of the input drivers (Objective 1), as well as the partial derivative of the output parameter with respect to each of the input drivers. These partial derivatives can be analytically approximated (finite difference technique) using model simulation. This method sometimes performs poorly for highly nonlinear systems or if the input drivers are highly correlated, in which case higher order terms may be necessary.

Resampling methods require multiple model simulations, all of which are generally assumed to be equally likely, and then examine the distribution of the output parameter. In this method, input parameters are randomly chosen, often consistent with a preconceived notion of their probability distribution. This is sometimes referred to as ensemble forecasting, and has been widely applied in meteorology, hydrology, and many other fields (Toth and Kalnay, 1993; Wood et al., 2002). This method relies heavily on multiple model simulations, and thus may be too computationally intensive for some complex models. Unlike the delta method, this technique generates probability distributions of output parameters from which many alternative uncertainty statistics can be developed, such as the probability of exceeding an environmental quality threshold or not exceeding a specific financial savings.

Bayesian techniques, such as the Generalized Likelihood Uncertainty Estimators (GLUE) require the user to have a prior conception of the uncertainty of the input and how that uncertainty may translate into the uncertainty of the output (Beven and Binley, 1992). It first requires knowledge of the probability distribution of the model parameters and input variables (a prior distribution). Model parameters are then randomly chosen in a manner consistent with the prior distribution, and then for each parameter set, the model is simulated (similar to ensemble methods). These simulations are then evaluated and a posterior distribution of the output is developed, where each simulated output is weighted by the likelihood it occurred. From this distribution, the uncertainty of model output can be assessed. Stedinger et al. (2008) clearly show that when an informal likelihood measure is employed, the posterior distribution is incorrect; care must be taken to employ a statistically valid likelihood function.

Each of these methods to determine the uncertainty of model output will be explored in this project. Of interest will be whether simpler methods, such as the delta method, produce uncertainty estimators similar to those found with more complicated techniques. The tradeoffs between these methods will be explored, and recommendation for uncertainty estimators for each i-Tree model (Eco, Hydro, and Forecast) will be developed.

Objective 3) Design effective ways to present model uncertainty and to educate model users on how to use this information to improve forest planning and management. While developing estimators of the uncertainty of output from i-Tree models is important, equally important is conveying this information to i-Tree users to aid in urban forest planning and management. Without this, users of i-Tree output may incorrectly view this information as error free or incorrectly infer error magnitudes. Such concerns have arisen in fields such as climate forecasts (Morss et al., 2008), hydrology (Beven et al., 2015), and economics (Manski, 2015).

Here we will develop creative and effective ways to present model output uncertainty to i-Tree users. This will involve both graphical and numerical measures to more fully convey uncertainty. For each model, we will develop a graphical probability distribution of i-Tree output. We will provide estimates of the mean and variance of the output parameter based on this probability distribution. We will also allow the user to define thresholds from which exceedance probabilities can be estimated. For instance, a user may want to know the probability the economic savings from improving human health due to an urban forest planting scheme may be below the cost of that activity, the probability the quality in stormwater runoff exceeds a specific threshold, the probability of a specific tree loss from a proposed development activity, or the probability that a proposed urban tree planting activity will improve inequities in ecosystem services within a city.

To better explain how this information could be useful to urban planners and managers, the following example is presented. Assume inhabitants in a city have been suffering from a high rate of illness due to airborne contaminants. As part of a strategy to improve health and wellbeing, the city decides to increase canopy cover in areas where air pollutant concentrations are high and there is a large concentration of susceptible citizens. The city has allocated $200,000 for new tree plantings and $30,000/year for maintenance of these trees over the next 20 years. This results in a $46,000/year equivalent annual cost (assuming a 5% discount rate). An i-Tree analysis indicates that the proposed plantings within the city would result in a total expected (average) annual saving of $55,000/year, thus justifying the project.

Now assume that an uncertainty analysis within i-Tree, using methods from Objective 2), provides an estimate of the expected distribution of annual savings, as shown in Figure 1. This figure provides the probability distribution function (or frequency) of the expected annual savings. Areas under the curve represent probabilities. From this information, a more complete analysis of the proposed tree plantings can be made. For instance, while the expected (average) annual savings is $55,000, the median annual savings is estimated to be $60,000, indicating a higher than 50% chance of exceeding the expected annual benefit. In addition, the probability the annual savings is less than $46,000, the equivalent annual cost of the project, is estimated to be 27%. With this information, urban planners can better understand and assess the benefits of proposed plantings, and the tradeoffs between different planting schemes. This information could also be incorporated into a decision tree for assessing expected outcomes from the decision making process (Varis, 1997; Pock et al., 2004; Polasky et al., 2011).

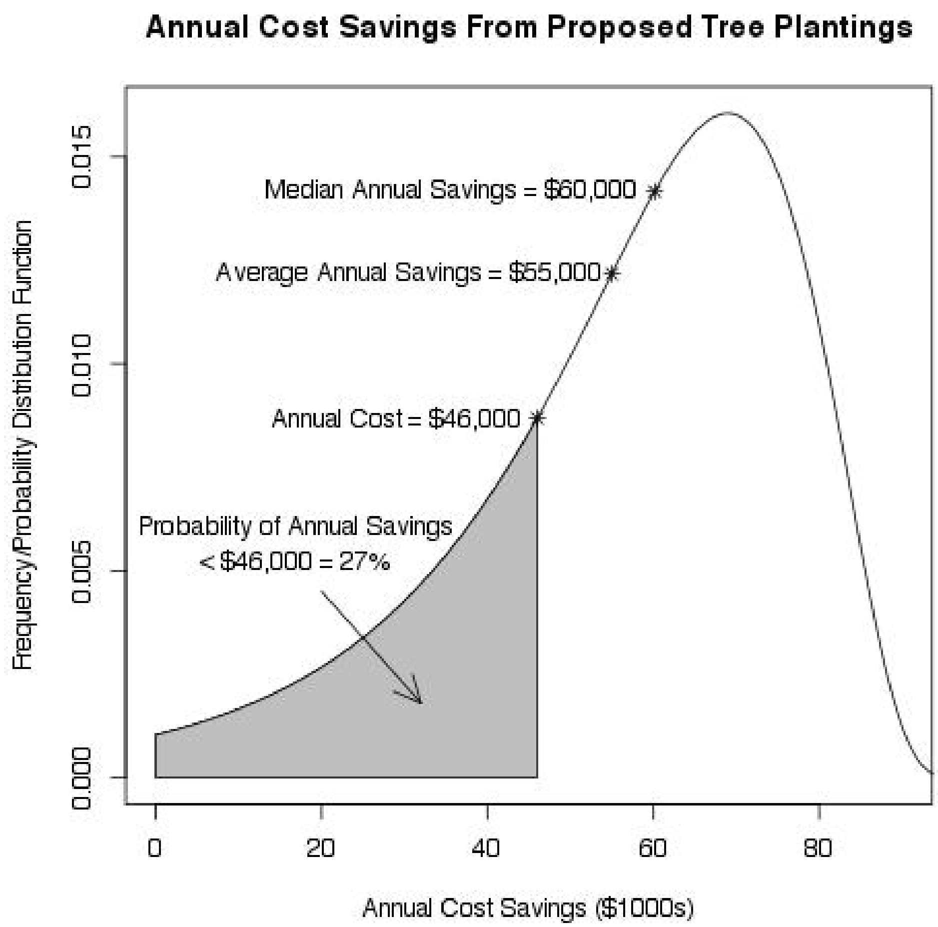


Figure 1: Distribution of annual cost savings ($1000s) from proposed tree plantings

In addition to these measures, we will also produce case studies that present ways in which uncertainty estimators of i-Tree output can be used for urban forest planning and management. This will be posted on the i-Tree web site (www.itreetools.org) so that users can explore ways in which this information can help improve the decision making process.

Objective 4) Create a decision support system that allows users to identify improved urban forest planting and protecting schemes. The PIs of this project have been developing new techniques to identify optimal locations to plant and preserve urban trees (Bodnaruk et al., 2015). This technique first identifies pervious and plantable impervious areas within the study area to determine the potential range of canopy cover (from the current to a maximum). This range is then discretized into regular intervals, and at each interval, i-Tree models are run and the ecosystem benefit for different canopy covers determined. Using this information, the localized gradient of the ecosystem service with respect to changes in canopy cover is estimated at different locations in the study area across the range of canopy cover. Priority planting areas are then identified as areas within the study area that have the greatest improvements in ecosystem services due to an increase in canopy cover. An initial analysis in Baltimore was performed to analyze the impact of changes in canopy cover on human health benefit from air quality improvements and temperature regulation. Maps of Baltimore were generated identifying sequential areas of priority plantings (from highest to lowest) up to Baltimore's goal of 40% canopy cover (Tree Baltimore, 2014); these methods will be used in our new study areas.

Here we will expand this analysis in a number of ways. Air quality data in Baltimore is limited due to the availability of only a single monitoring station, which limits the estimated spatial heterogeneity of air quality within this study area. We will initially analyze our methodology in New York City, which has a relatively large number of short- and long-term air quality monitoring stations. In addition, we will expand the ecosystem service benefits of increased canopy to include stormwater quantity and quality, and develop a modeling system that easily allows us to examine other ecosystem benefits.

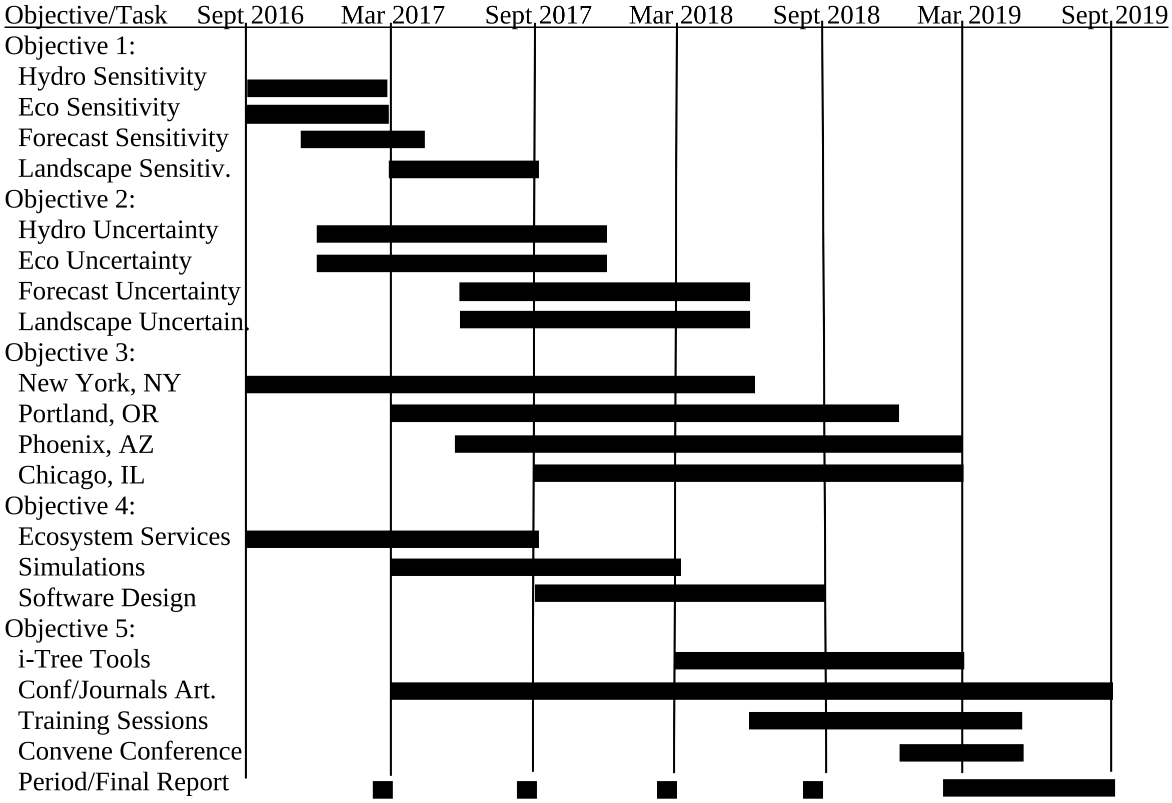
One further goal of this analysis will be to also consider the inequity in ecosystem system services provided by urban forests. Using a quantitative measure of inequality, the Atkinson index, we will be able to not only identify whether inequality of ecosystem services exists in areas of low income (or other social classes), but how urban tree planting efforts could be performed to reduce these inequalities, thus better providing benefits from urban forests to underserved populations. Urban tree planting can play a role in improving these communities.

In addition to these analyses, we plan to utilize the information obtained in Objectives 1), 2), and 3) to incorporate uncertainty estimators of ecosystem services into our decision support system. By integrating across probability distributions of ecosystem services, we will be able to better characterize expected ecosystem services and their variability. Our goal will be to develop a decision support system that fully utilizes this information, using a decision tree framework so that urban planners and managers can make more informed decisions regarding urban trees. This decision support system will be integrated into the newly released i-Tree Landscape.

Objective 5) Disseminate our findings to a wide range of stakeholders using many different outreach techniques. Disseminating our findings is not only an objective of this project, but also a required category of this proposal. See Section 7, National Distribution/Technology Transfer of Your Findings, for a discussion of how we will address this objective.

The timeline we will follow in this project is as follows:

Table 1: Timeline of task related to each objective



5. Product:

The product from this project will be a new set of methodologies that will be integrated within i-Tree Eco. We are focusing initially on the integration with i-Tree Eco, since Eco is the "engine" of the i-Tree suite of tools, providing inputs and algorithms for other i-Tree models. New uncertainty estimators designed for output from i-Tree Eco will be integrated within this software product. These uncertainty estimators will be presented in numerical and graphical ways to help users fully understand and utilize this information, and the methodology developed will help us integrate uncertainty analyses within other i-Tree tools in the future.

In addition, a decision support system will be developed to aid urban planners and managers optimize the ecosystem benefit of urban trees and explore the tradeoffs between competing ecosystem services. This will allow users to not only prioritize specific ecosystem services, but also examine the social implications of their management plans, and ways to reduce ecosystem inequities among underrepresented communities. The framework of a priority planting index is already part of i-Tree Landscape, i-Tree's new spatially explicit modeling platform. We will provide algorithms and methods from out decision support system to be integrated into this novel software package.

The products produced will be freely available to all stakeholders, as they will be integrated within i-Tree tools and disseminated via the i-Tree website. Stakeholders include urban planners and managers, educational institutions, consultants, and community groups. We will disseminate our findings and products using a wide range of methods as described in Section 7 of this proposal, including the i-Tree website, workshops, webinars, conference presentations, and journal articles. We will expand the current user base of i-Tree tools by developing ways to reach new stakeholders. For instance, similar to our previous NUCFAC award, we will expand i-Tree users by targeting some conferences and workshops whose participants are not current i-Tree stakeholders, raising the awareness of i-Tree tools and urban forest issues. These users will be educated on the importance of urban forests, and how the tools developed can help users better understand the costs and benefits of urban forests, and optimize urban green infrastructure.

6. Collaboration:
The primary collaborators are with the USDA Forest Service's Northern Research Station and the Davey Tree Expert Company. Both of these partners have a national scope and impact, and will help us reach the widest possible audience for our work. This partnership between an educational institution (SUNY ESF), a federal agency (USDA Forest Service) and a private company (Davey Tree) provide a unique combination of expertise, experience, and motivation. Together we can provide the best possible science to i-Tree tools, while developing and providing a public domain urban forestry tools that delivers critical information about the structure, function, and benefits of urban trees to users, regardless of their background.

Both PIs have ongoing research collaborations with Dr. Dave Nowak, Project Leader of the Northern Research Station. Dr. Nowak is a founding and on-going creator for i-Tree. He has a long history of advancing our understanding and ability to predict the benefits of urban and community forests. Dr. Nowak has been instrumental with the evolution of i-Tree, has provided support and mentorship to past and current SUNY ESF students, and provides leadership and expertise to make i-Tree tools the cornerstone of quantitative urban forest analyses. He will provide oversight on this project, and be involved with experimental design and interpretation.

We have been also working with the Davey Tree Expert Company, who is responsible for developing and maintaining the www.itreetools.org web site. Our primary contact will be with Davey Tree Expert Company's Scott Maco, Director of Research and Development, who focuses on developing tools that city foresters can use to convey the value and optimal management of urban trees. Maco leads development of the i-Tree Tools software suite and continues to expand Davey's leadership roles in federal, state, university and local research projects. Maco and Davey will be responsible for integrating the tools developed from this project into i-Tree products, and making these products freely available to i-Tree users.

We also have a wide variety of supporters of this project who will not only benefit from new uncertainty estimators and decision support tool within i-Tree, but also understand and support this novel evolution of i-Tree. Letters of support are included with this proposal.

7. National Distribution/Technology Transfer of Your Findings:
There will be many different methods used to distribute the findings from this project to critical stakeholders. Since we are teaming with the USDA Forest Service's Northern Research Station and Davey Tree Expert Company, our primary vehicle for technology transfer is via the i-Tree software suite. This public domain software product is freely available online, and has been widely disseminated to users across the United States. Our uncertainty methodology will be integrated within the i-Tree tools, and our decision support system will provide guidance to users

to determine more optimal urban forest management plans.

We will also run one i-Tree training workshop and four i-Tree webinars. Our last NUCFAC proposal resulted in multiple workshops where attendees were trained to understand and use i-Tree software. This occurred both as stand-alone workshops and as part of a pre-conference workshop session. These workshops not only aid in distributing i-Tree to users, but also provide critical feedback on model interfaces, problems users may encounter with the models, and the needs of users so that i-Tree can continue to evolve towards a more useful tool for its stakeholders. Here we will pursue one pre-conference workshop to train users on our new i-Tree tools and use of uncertainty analyses. This workshop will most likely occur during the annual Water Environment Federation Technical Exhibition and Conference (WEFTEC); our prior i-Tree training workshop at WEFTEC generated a strong interest in i-Tree tools, and the ability to engage a broader diversity of users than typical urban forest planners and managers.

Our proposed online training webinars will reach more remote i-Tree users who cannot attend workshops. We are proposing four webinars, one related to each of our study areas, to demonstrate use of the uncertainty analyses developed. With the coordination of our local supporters, we will mobilize local stakeholders in each of our study areas, and engage them in model testing to not only train them with our tools but also receive local feedback critical to the success of these tools. Discussions with our supporters have indicated a wide range of community involvement within some of our study cities. For instance, Portland, OR has over 100 local community groups actively involved with urban forestry efforts. Our goal is to engage some of these groups through webinars so that they can help us better develop i-Tree tools to be flexible to suit their needs. We are not looking to "force" solutions on these communities, but instead show them how i-Tree tools can be utilized to compare competing urban forest management plans and develop urban forest solutions to improve their health and well being. Morani et al. (2011) suggest that indicators such as the social acceptability of new tree plantings, community preferences, and aesthetic values could be added to improve decision support tools. People are a central component to understand the complex interactions between urban forests, human well-being, forest management decisions and associated benefits and costs (Dwyer et al., 1992; Gerhold and Porter, 2000; Wolfe and Kruger, 2007; Greene et al., 2011). Each of the webinars will be recorded and posted on the i-Tree website so that these resources can be available to those who cannot participate in the webinar.

In addition to this, the PIs will pursue traditional forms of academic scholarship, including peer-reviewed journal articles and conference presentations. Our last NUCFAC award resulted in 7 journal articles published or in review, and 9 conference presentations. We expect this award to be equally successful. In addition, we plan to convene a conference session on urban ecosystem services during the last year of this project so that we can present project results to a wide variety of scientists, i-Tree users, and other stakeholders.

Keyword for electronic searches include: urban forestry, ecosystem benefits, optimal urban planning, i-Tree tools, uncertainty in environmental models, environmental justice and inequity.

8. Project Evaluation:

Both PIs have extensive experience managing research projects and graduate students, and have a history of success with productive projects which results in well cited publications, well mentored graduate students, and increased knowledge and expertise in the fields of applied science and engineering. Both PIs are active in running an accredited engineering department, which requires them to maintain accreditation through the American Board of Engineering and Technology (ABET). We explain this process to illustrate how it prepared us to evaluate our NUCFAC research project. Our evaluations for ABET involve a rigorous assessment protocol, which provides feedback loops that continually improve our program. We assess outcomes on an annual basis, develop an annual assessment report, and review this report as a faculty. As part of this process we identify areas of concern and triggers that indicate the need for changes to our program. We then develop new approaches to address these areas of concern, and assess whether these approaches are helping us better achieve our outcomes. We will use this experience to develop a thorough project evaluation protocol for our NUCFAC research. We will use clear performance criteria and regular evaluations to monitor progress toward project objectives.

Project evaluation centers on attaining our objectives, which are described in Section 4. Project planning and timeline. As suggested, we will follow "SMART" goals for project evaluation. We have defined ***specific*** project objectives, each of which contributes to the final product. Our objectives are ***measurable***, and for each objective we define steps to obtain that objective (see Table 1). We have the ability, skills, oversight, and computational and financial resources to ***attain*** each of these steps. While our objectives are expansive, they are also ***realistic*** based on our past record of success. Finally, the steps in our project are ***timely***, with Table 1 outlining a timeline of steps for each objective.

For each biannual report, we will monitor our progress and outline short- and long-term goals. We will also have bi-weekly group meetings to provide continual project review and assessment. One year into our project, each of our PhD students will present their project-related PhD research proposal to a thesis research committee for evaluation and feedback. While this will involve some partners of this project, it will also involve faculty and researchers who are external to this project. This will provide another layer of oversight onto the research direction of this project, allow us the extend i-Tree's stakeholder groups, and further improve our products.

9. Experience/Personnel/Adequacy of Resources:

Both of the PIs and their partners have a long history of successfully integrating research, teaching, and outreach in their professional activities. Both also have experience successfully managing large research budgets. Each works on the integration of GIS tools and environmental modeling, with experience in both deterministic and stochastic modeling. We have a history of successfully working with our partners on this project, who will provide oversight and guidance.

The PI's home department, Environmental Resources Engineering, at SUNY ESF continues to upgrade their existing computational facilities. This includes high-end, multi-core servers, a 20-node Linux cluster, and multi-year research-grade software licenses. The purpose of these investments is to support projects exactly like that outlined in this proposal. Our department, at no cost to the project, will supply all computational requirements of this project. The department also has technical personnel resources to provide assistance with the upkeep and management of these computational resources.

10. Budget Justification:

A majority of the proposed budget involves personnel costs. We propose to have 2 PhD level graduate students working on this project for most of the 3-year project duration, with one student focusing on modeling i-Tree Eco and i-Tree Forecast, and the other advancing i-Tree Hydro and developing our decision support system in i-Tree Landscape. Both graduate students will be involved with algorithm development and software design. Both graduate students will begin their full-time work on this project in January 2017, and be completely supported by this project for the rest of its duration. They will be paid a prorated rate of $21,000/year stipend plus tuition in their 8 months; graduates student stipends are expected to increase $500/year in years 2 and 3. Both graduate students will reduce their tuition burden to 1 credit a semester at the beginning of year 2 (which is typical for post-candidacy exam PhD students). Principal Investigator (PI) Kroll has requested 3.5 weeks of summer salary a year (budgeted as $9658 during year 1 and rising 3%/year) to allow for management of this project. PI Endreny is a 12-month employee and requests no summer support.

In addition, $2900 has been requested in travel costs in year 2, and $5800 in year 3. These are to support conference travel (with an anticipated cost of $1450/conference) for the PIs and the graduate students throughout this grant to present research results and obtain feedback from stakeholders who attend these conferences. It is expected during the 3rd year the PIs will convene a conference session related to urban ecosystem services and the impact and benefits of urban forestry.

15% of PI Kroll's academic year and 8% PI Endreny's academic year (both as a cost share) will be dedicated to this project. The college's indirect cost recovery rate has been reduced from 57% to 11.6% so that additional resources can be put directly into this project.

During the first two years of this project, the Davey Tree Expert Company will be used as a consultant when we develop and implement our experiment, helping with software support and providing general technical advice. During this 2-year period we have budgeted 5 hrs/month for Davey Tree at $60/hr. During year 3, Davey will integrate our new tools within i-Tree Eco. This will involve software development, testing, and documentation so that these tools are fully integrated within i-Tree Eco. We have now allocated 40 hrs/week for 24 weeks at $60/hr. Note that the contracted rate for Davey Tree is $120/hr, and they have waived half of this fee as a new match on this grant.

Budget Narrative:

	Federal Funds (requested)	Non-federal match Cash/ In-Kind	Total	Source of Matching Funds
Personnel	$172,375*	$82,181	$254,556	Academic year cost recovery of PIs/SUNY ESF
Travel	$8,700***	0	8,700	
Subaward	$64,800^	$64,800^	129,600	Davey Tree
Tuition	$15,562^^	0	15,562	
Total Direct Costs	261,437	$146,981	$408,418	
Indirect	$23,903^^^	$46,843	$70,746	Academic year cost recovery of PIs/SUNY ESF
Unrecovered Indirect	0	$93,560	$93,560	Academic year cost recovery of PIs/SUNY ESF
Total Cost	$285,340	$287,384	$572,724	

* 2 graduate students for 2.7 years with an average annual salary of $22,000 (1100 hr/yr at $20/hr) plus fringe benefits (average 19.6%), 3.5 weeks of summer salary for PI at academic year rate plus fringe benefits (15%).

** 10% academic year cost recovery for PI Kroll and 5% academic year cost recovery for PI Endreny.

*** Conference travel at approximately $1450/conference (2 attendees in year 2, and 4 attendees in year 3).

^ Subcontract to Davey Tree Expert Company (project partners) for project development and implementation. Davey Tree is providing a 100% match (dollar-for-dollar) for this subcontract work.

^^ 1/2-year tuition at $12592 for each student in year 1, and 1 credit/semester for each student in years 2 and 3.

^^^ Indirect cost recovery, lowered from 57% to 11.6%.

’ Indirect cost recovery at contracted federal rate of 57%.

’’ Recover from lowering indirect cost recovery rate on federal funds.

OMB Number: 4040-0004
Expiration Date: 8/31/2016

Application for Federal Assistance SF-424

*** 1. Type of Submission:**
- [ ] Preapplication
- [X] Application
- [ ] Changed/Corrected Application

*** 2. Type of Application:**
- [X] New
- [ ] Continuation
- [ ] Revision

* If Revision, select appropriate letter(s):

* Other (Specify):

* 3. Date Received: 11/23/2015

4. Applicant Identifier: 16052060;Kroll

5a. Federal Entity Identifier:

5b. Federal Award Identifier:

State Use Only:

6. Date Received by State:

7. State Application Identifier:

8. APPLICANT INFORMATION:

* a. Legal Name: The RF for SUNY with a place of business at SUNY ESF

* b. Employer/Taxpayer Identification Number (EIN/TIN): 14-1368361

* c. Organizational DUNS: 1526061250000

d. Address:

* Street1: 35 State Street, PO Box 9

Street2:

* City: Albany

County/Parish: Albany

* State: NY: New York

Province:

* Country: USA: UNITED STATES

* Zip / Postal Code: 12201-0009

e. Organizational Unit:

Department Name: SUNY ESF

Division Name:

f. Name and contact information of person to be contacted on matters involving this application:

Prefix: Ms.

* First Name: Justine

Middle Name:

* Last Name: Gordon

Suffix:

Title: Associate Director

Organizational Affiliation: The Research Foundation of SUNY

* Telephone Number: 518-434-7105

Fax Number: 518-434-8343

* Email: justine.gordon@rfsuny.org; esfaward@esf.edu

Application for Federal Assistance SF-424

*** 9. Type of Applicant 1: Select Applicant Type:**

M: Nonprofit with 501C3 IRS Status (Other than Institution of Higher Education)

Type of Applicant 2: Select Applicant Type:

Type of Applicant 3: Select Applicant Type:

* Other (specify):

*** 10. Name of Federal Agency:**

Forest Service

11. Catalog of Federal Domestic Assistance Number:

10.675

CFDA Title:

Urban and Community Forestry Program

*** 12. Funding Opportunity Number:**

USDA-FS-UCF-01-2016

* Title:

2016 National Urban and Community Forestry Challenge Cost Share Grant Program

13. Competition Identification Number:

USDA-FS-UCF-01-2016

Title:

14. Areas Affected by Project (Cities, Counties, States, etc.):

Areas Affected.pdf

Add Attachment | Delete Attachment | View Attachment

*** 15. Descriptive Title of Applicant's Project:**

A Decision Support System to Develop, Analyze, and Optimize Urban and Community Forests

Attach supporting documents as specified in agency instructions.

Add Attachments | Delete Attachments | View Attachments

Application for Federal Assistance SF-424

16. Congressional Districts Of:

* a. Applicant: NY-021

* b. Program/Project: NY-025

Attach an additional list of Program/Project Congressional Districts if needed.

Add Attachment | Delete Attachment | View Attachment

17. Proposed Project:

* a. Start Date: 09/01/2016

* b. End Date: 08/31/2019

18. Estimated Funding ($):

* a. Federal	285,340.00
* b. Applicant	287,384.00
* c. State	0.00
* d. Local	0.00
* e. Other	0.00
* f. Program Income	0.00
* g. TOTAL	572,724.00

*** 19. Is Application Subject to Review By State Under Executive Order 12372 Process?**

☐ a. This application was made available to the State under the Executive Order 12372 Process for review on ______.

☐ b. Program is subject to E.O. 12372 but has not been selected by the State for review.

☒ c. Program is not covered by E.O. 12372.

*** 20. Is the Applicant Delinquent On Any Federal Debt? (If "Yes," provide explanation in attachment.)**

☐ Yes ☒ No

If "Yes", provide explanation and attach

Add Attachment | Delete Attachment | View Attachment

21. *By signing this application, I certify (1) to the statements contained in the list of certifications and (2) that the statements herein are true, complete and accurate to the best of my knowledge. I also provide the required assurances** and agree to comply with any resulting terms if I accept an award. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 218, Section 1001)**

☒ ** I AGREE

** The list of certifications and assurances, or an internet site where you may obtain this list, is contained in the announcement or agency specific instructions.

Authorized Representative:

Prefix: Dr.

* First Name: Neil

Middle Name: H.

* Last Name: Ringler

Suffix:

* Title: Vice Provost for Research

* Telephone Number: 315-470-6606

Fax Number: 315-470-6779

* Email: nhringle@esf.edu; esfaward@esf.edu

* Signature of Authorized Representative: Lisa Schwabenbauer

* Date Signed: 11/23/2015

OMB Number: 4040-0007
Expiration Date: 06/30/2014

ASSURANCES - NON-CONSTRUCTION PROGRAMS

Public reporting burden for this collection of information is estimated to average 15 minutes per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding the burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the Office of Management and Budget, Paperwork Reduction Project (0348-0040), Washington, DC 20503.

PLEASE DO NOT RETURN YOUR COMPLETED FORM TO THE OFFICE OF MANAGEMENT AND BUDGET. SEND IT TO THE ADDRESS PROVIDED BY THE SPONSORING AGENCY.

NOTE: Certain of these assurances may not be applicable to your project or program. If you have questions, please contact the awarding agency. Further, certain Federal awarding agencies may require applicants to certify to additional assurances. If such is the case, you will be notified.

As the duly authorized representative of the applicant, I certify that the applicant:

1. Has the legal authority to apply for Federal assistance and the institutional, managerial and financial capability (including funds sufficient to pay the non-Federal share of project cost) to ensure proper planning, management and completion of the project described in this application.

2. Will give the awarding agency, the Comptroller General of the United States and, if appropriate, the State, through any authorized representative, access to and the right to examine all records, books, papers, or documents related to the award; and will establish a proper accounting system in accordance with generally accepted accounting standards or agency directives.

3. Will establish safeguards to prohibit employees from using their positions for a purpose that constitutes or presents the appearance of personal or organizational conflict of interest, or personal gain.

4. Will initiate and complete the work within the applicable time frame after receipt of approval of the awarding agency.

5. Will comply with the Intergovernmental Personnel Act of 1970 (42 U.S.C. §§4728-4763) relating to prescribed standards for merit systems for programs funded under one of the 19 statutes or regulations specified in Appendix A of OPM's Standards for a Merit System of Personnel Administration (5 C.F.R. 900, Subpart F).

6. Will comply with all Federal statutes relating to nondiscrimination. These include but are not limited to: (a) Title VI of the Civil Rights Act of 1964 (P.L. 88-352) which prohibits discrimination on the basis of race, color or national origin; (b) Title IX of the Education Amendments of 1972, as amended (20 U.S.C.§§1681-1683, and 1685-1686), which prohibits discrimination on the basis of sex; (c) Section 504 of the Rehabilitation Act of 1973, as amended (29 U.S.C. §794), which prohibits discrimination on the basis of handicaps; (d) the Age Discrimination Act of 1975, as amended (42 U. S.C. §§6101-6107), which prohibits discrimination on the basis of age; (e) the Drug Abuse Office and Treatment Act of 1972 (P.L. 92-255), as amended, relating to nondiscrimination on the basis of drug abuse; (f) the Comprehensive Alcohol Abuse and Alcoholism Prevention, Treatment and Rehabilitation Act of 1970 (P.L. 91-616), as amended, relating to nondiscrimination on the basis of alcohol abuse or alcoholism; (g) §§523 and 527 of the Public Health Service Act of 1912 (42 U.S.C. §§290 dd-3 and 290 ee- 3), as amended, relating to confidentiality of alcohol and drug abuse patient records; (h) Title VIII of the Civil Rights Act of 1968 (42 U.S.C. §§3601 et seq.), as amended, relating to nondiscrimination in the sale, rental or financing of housing; (i) any other nondiscrimination provisions in the specific statute(s) under which application for Federal assistance is being made; and, (j) the requirements of any other nondiscrimination statute(s) which may apply to the application.

7. Will comply, or has already complied, with the requirements of Titles II and III of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (P.L. 91-646) which provide for fair and equitable treatment of persons displaced or whose property is acquired as a result of Federal or federally-assisted programs. These requirements apply to all interests in real property acquired for project purposes regardless of Federal participation in purchases.

8. Will comply, as applicable, with provisions of the Hatch Act (5 U.S.C. §§1501-1508 and 7324-7328) which limit the political activities of employees whose principal employment activities are funded in whole or in part with Federal funds.

9. Will comply, as applicable, with the provisions of the Davis-Bacon Act (40 U.S.C. §§276a to 276a-7), the Copeland Act (40 U.S.C. §276c and 18 U.S.C. §874), and the Contract Work Hours and Safety Standards Act (40 U.S.C. §§327-333), regarding labor standards for federally-assisted construction subagreements.

10. Will comply, if applicable, with flood insurance purchase requirements of Section 102(a) of the Flood Disaster Protection Act of 1973 (P.L. 93-234) which requires recipients in a special flood hazard area to participate in the program and to purchase flood insurance if the total cost of insurable construction and acquisition is $10,000 or more.

11. Will comply with environmental standards which may be prescribed pursuant to the following: (a) institution of environmental quality control measures under the National Environmental Policy Act of 1969 (P.L. 91-190) and Executive Order (EO) 11514; (b) notification of violating facilities pursuant to EO 11738; (c) protection of wetlands pursuant to EO 11990; (d) evaluation of flood hazards in floodplains in accordance with EO 11988; (e) assurance of project consistency with the approved State management program developed under the Coastal Zone Management Act of 1972 (16 U.S.C. §§1451 et seq.); (f) conformity of Federal actions to State (Clean Air) Implementation Plans under Section 176(c) of the Clean Air Act of 1955, as amended (42 U.S.C. §§7401 et seq.); (g) protection of underground sources of drinking water under the Safe Drinking Water Act of 1974, as amended (P.L. 93-523); and, (h) protection of endangered species under the Endangered Species Act of 1973, as amended (P.L. 93-205).

12. Will comply with the Wild and Scenic Rivers Act of 1968 (16 U.S.C. §§1271 et seq.) related to protecting components or potential components of the national wild and scenic rivers system.

13. Will assist the awarding agency in assuring compliance with Section 106 of the National Historic Preservation Act of 1966, as amended (16 U.S.C. §470), EO 11593 (identification and protection of historic properties), and the Archaeological and Historic Preservation Act of 1974 (16 U.S.C. §§469a-1 et seq.).

14. Will comply with P.L. 93-348 regarding the protection of human subjects involved in research, development, and related activities supported by this award of assistance.

15. Will comply with the Laboratory Animal Welfare Act of 1966 (P.L. 89-544, as amended, 7 U.S.C. §§2131 et seq.) pertaining to the care, handling, and treatment of warm blooded animals held for research, teaching, or other activities supported by this award of assistance.

16. Will comply with the Lead-Based Paint Poisoning Prevention Act (42 U.S.C. §§4801 et seq.) which prohibits the use of lead-based paint in construction or rehabilitation of residence structures.

17. Will cause to be performed the required financial and compliance audits in accordance with the Single Audit Act Amendments of 1996 and OMB Circular No. A-133, "Audits of States, Local Governments, and Non-Profit Organizations."

18. Will comply with all applicable requirements of all other Federal laws, executive orders, regulations, and policies governing this program.

19. Will comply with the requirements of Section 106(g) of the Trafficking Victims Protection Act (TVPA) of 2000, as amended (22 U.S.C. 7104) which prohibits grant award recipients or a sub-recipient from (1) Engaging in severe forms of trafficking in persons during the period of time that the award is in effect (2) Procuring a commercial sex act during the period of time that the award is in effect or (3) Using forced labor in the performance of the award or subawards under the award.

SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL	TITLE
Lisa Schwabenbauer	Vice Provost for Research
APPLICANT ORGANIZATION	DATE SUBMITTED
The RF for SUNY with a place of business at SUNY ESF	11/23/2015

OMB Number: 4040-0006
Expiration Date: 06/30/2014

BUDGET INFORMATION - Non-Construction Programs

SECTION A - BUDGET SUMMARY

	Grant Program Function or Activity (a)	Catalog of Federal Domestic Assistance Number (b)	Estimated Unobligated Funds: Federal (c)	Estimated Unobligated Funds: Non-Federal (d)	New or Revised Budget: Federal (e)	New or Revised Budget: Non-Federal (f)	New or Revised Budget: Total (g)
1.	Urban and Community Forestry Program	10.675	$	$	$ 285,340.00	$	$ 285,340.00
2.	Urban and Community Forestry Program-Match	10.675				287,384.00	287,384.00
3.							
4.							
5.	Totals		$	$	$ 285,340.00	$ 287,384.00	$ 572,724.00

SECTION B - BUDGET CATEGORIES

6. Object Class Categories	GRANT PROGRAM, FUNCTION OR ACTIVITY				Total
	(1) Urban and Community Forestry Program	(2) Urban and Community Forestry Program-Match	(3)	(4)	(5)
a. Personnel	$ 144,852.00	$ 51,081.00	$	$	$ 195,933.00
b. Fringe Benefits	27,523.00	31,100.00			58,623.00
c. Travel	8,700.00	0.00			8,700.00
d. Equipment					
e. Supplies					
f. Contractual	64,800.00	64,800.00			129,600.00
g. Construction					
h. Other	15,562.00				15,562.00
i. Total Direct Charges (sum of 6a-6h)	261,437.00	146,981.00			$ 408,418.00
j. Indirect Charges	23,903.00	140,403.00			$ 164,306.00
k. TOTALS (sum of 6i and 6j)	$ 285,340.00	$ 287,384.00	$	$	$ 572,724.00
7. Program Income	$	$	$	$	$

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SECTION C - NON-FEDERAL RESOURCES				
(a) Grant Program	(b) Applicant	(c) State	(d) Other Sources	(e)TOTALS
8. Urban and Community Forestry Program	$ 0.00	$ 0.00	$ 0.00	$ 0.00
9. Urban and Community Forestry Program-Match	287,384.00	0.00	0.00	287,384.00
10.				
11.				
12. TOTAL (sum of lines 8-11)	$ 287,384.00	$	$	$ 287,384.00

SECTION D - FORECASTED CASH NEEDS					
	Total for 1st Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
13. Federal	$ 65,981.00	$ 16,495.25	$ 16,495.25	$ 16,495.25	$ 16,495.25
14. Non-Federal	$ 68,017.00	17,004.25	17,004.25	17,004.25	17,004.25
15. TOTAL (sum of lines 13 and 14)	$ 133,998.00	$ 33,499.50	$ 33,499.50	$ 33,499.50	$ 33,499.50

SECTION E - BUDGET ESTIMATES OF FEDERAL FUNDS NEEDED FOR BALANCE OF THE PROJECT				
(a) Grant Program	FUTURE FUNDING PERIODS (YEARS)			
	(b)First	(c) Second	(d) Third	(e) Fourth
16. Urban and Community Forestry Program	$ 65,981.00	$ 79,143.00	$ 140,216.00	$
17. Urban and Community Forestry Program-Match	68,017.00	78,009.00	141,356.00	
18.				
19.				
20. TOTAL (sum of lines 16 - 19)	$ 133,998.00	$ 157,152.00	$ 281,572.00	$

SECTION F - OTHER BUDGET INFORMATION	
21. Direct Charges: 261,437 on federal request	22. Indirect Charges: 23,903 on federal request
23. Remarks: 11.6% MTDC (base=$206,075); unrecoverable indirect included within match.	

CHARLES N. KROLL

Professor
Faculty of Environmental Resource Engineering
SUNY College of Environmental Science and Forestry
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Professional Preparation

Cornell University, Ph.D., Civil and Environmental Engineering, 1996
Tufts University, M.S., Civil and Environmental Engineering, 1987
Tufts University, B.S., Mechanical Engineering, 1983

Appointments

SUNY College of Environmental Science and Forestry, Faculty of Environmental Resource Engineering, Syracuse, NY
- Professor, 2009 - present
- Chair, 2008 - 2011
- Associate Professor, 2002-2009
- Assistant Professor, 1996-2002

Cornell University, Civil and Environmental Engineering, Ithaca, NY
- Lecturer, 1995-1996
- Teaching Assistant, 1991-1995

GZA GeoEnvironmental Inc., Norwood, MA 02062
- Staff Hydrologist and Staff Engineer, 1989-1991

Tufts University, Department of Civil and Environmental Engineering
- Research Assistant, 1987-1989

Selected Publications

Bodnaruk, E.W., Kroll, C.N., Hirabayashi, H., Yang, Y., Nowak, D.J., and Endreny, T.A. (2016). Urban forest ecosystem service optimization and tradeoffs: a spatially explicit localized gradient method, submitted to *Landscape and Urban Planning*, accepted (minor revisions), April 2016.

Kroll, C.N., Metz, K.A., and Vogel, R.M. (2015). Hypothesis Tests for Hydrologic Alteration, *Journal of Hydrology*, 530, 117-126.

Allaire, M.C., Vogel, R.M., and Kroll, C.N. (2015). The Hydromorphology of an Urbanizing Watershed Using Multivariate Elasticity, *Advances in Water Resources,* 86, 147–154, 2015.

Cabaraban, M.T.I., C.N. Kroll, S. Hirabayashi, and D.J. Nowak (2013), Modeling of air pollutant removal by dry deposition to urban trees using a WRF/CMAQ/i-Tree Eco coupled system, *Environmental Pollution*, 176, 123-133.

Kroll, C.N., and P. Song (2013), Impact of multicollinearity on small sample hydrologic regression models, *Water Resources Research*, 49, doi:10.1002/wrcr.20315.

Hirabayashi, S., C.N. Kroll, and D.J. Nowak (2012), Development of a distributed air pollutant dry deposition modeling framework, Environmental Pollution 171, 9–17.

Hirabayashi, S., C.N. Kroll, and D.J. Nowak (2011), Component-based development and sensitivity analyses of an air pollutant dry deposition model, *Environmental Modeling and Software,* 26(6), 804-816.

Matonse, A.H., and Kroll, C.N. (2009), Simulating low streamflows with hillslope-storage models, *Water Resources Research,* 45, W01407, doi:10.1029/2007WR006529.

Zhang, Z., and Kroll, C.N. (2007). A Closer Look at Baseflow Correlation, *Journal of Hydrologic Engineering*, ASCE, 12(2): 190-196.

Kroll, C.N., Luz , J.G., Allen, T.B., and Vogel, R.M. (2004). Developing a watershed characteristics database to improve low streamflow prediction, *Journal of Hydrologic Engineering*, ASCE, 9(2): 116–125.

Douglas, E.M., Vogel R.M., and Kroll C.N. (2000). Trends in floods and low flows in the United States: impact of spatial correlation, *Journal Of Hydrology*, 240(1-2): 90-105.

Kroll, C.N., and Stedinger, J.R. (1999). Development of Regional Regression Relationships with Censored Data, *Water Resources Research*, 35(3): 775-784.

Synergistic Activities

Chair of Environmental Resources and Forest Engineering, SUNY ESF, 2008 - present

Associate Editor of *Water Resources Research*, 2003 - 2005

Member of the Hydrologic Information Systems Subgroup for the Consortium of Universities to Advance Hydrologic Science, Inc. (CUAHSI)

Certified Professional Engineer, New York State, License Number 082971, 2005

Coordinator of International Association of Hydrological Sciences (IAHS) working group on Low Streamflow Prediction at Ungauged Basins (PUBs), 2006 – 2008

Collaborators & Other Affiliations

Graduate Advisors

Dr. Jery Stedinger, Cornell University (for PhD)

Dr. Richard Vogel, Tufts University (for MS)

Thesis Advisor (last 10 years)

Ibrahim Game, MS, 2015, Environmental Scientist, Lome, Togo

Kelly Metz, MS, 2015, Engineer, HDR, Syracuse, NY

Suzanne Ellsworth, MPS, 2015, Staff Scientist, ARCADIS, Syracuse, NY

Justin Dusseault, MPS, 2015, Health and Safety Coordinator, Corning Inc., Corning, NY

Maria Theresa Cabaraban, PhD, 2013, Professor, Xavier University, Philippines

Roman Yavich, MS, 2013, Dir. of Media and Dev., Azuero Earth Project, East Hampton, NY

Fred Agyeman, MPS, 2013, Environmental Consultant, Ghana

Peter Song, MS, 2011, Consulting Engineer, Anchor QEA, Syracuse, NY

Eben Pendleton, MS, 2009, Consulting Engineer, Anchor QEA, Montvale, NJ

Osman Ahmed, MS, 2009, Com. Dev. Officer, Northern Water Service Board, Kenya

Adão Matonse, MS, 2003, PhD, 2009, Senior Scientist, NYC DEP

Satoshi Hirabayashi, MS, 2005, PhD, 2009, Scientist and Engineer, Davey Tree, S, NY

Doreen Bwalya, MS, 2007, Senior Eng., Lusaka Water and Sewerage Company Ltd., Zambia

Andrew Korik, MPS, 2007, GIS Specialist, ARCADIS, Syracuse, NY

Zhenxing Zhang, PhD, 2005, Research Scientist, Illinois Water Survey, Urbana, IL.

Theodore A. Endreny, Ph.D., P.H., P.E.
State University of New York (SUNY), College of Environmental Science & Forestry (ESF)
402 Baker Labs, One Forestry Drive, Syracuse, New York 13210-2778
(tele) 315-470-6565, (fax) 315-470-6958, (email) te@esf.edu

Professional Preparation:

Cornell University	Natural Resources Management	B.S. 1990
North Carolina State University	Soil & Water Engineering	M.S. 1996
Princeton University	Water Resources Engineering	Ph.D. 1999
Channel Design Training	ASCE & FEMA courses	2wks 2001
Stream Restoration Training	US Fish & Wildlife courses	4wks 2002-3

Appointments:

Chair	SUNY, Environmental Resources Engineering	2011-present
Professor	SUNY, Environmental Resources Engineering	2009-present
Associate Professor	SUNY, Environmental Resources & Forest Engineering	2005-2009
Assistant Professor	SUNY, Environmental Resources & Forest Engineering	1999-2005
Research Scholar	National Aeronautics & Space Administration GSRP	1997-1999
Research Scholar	Environmental Protection Agency EMAP	1994-1996
Research Associate	Environmental Law Institute, Washington DC	1992-1994
Volunteer	U.S. Peace Corps & Honduras Forest Service	1990-1992

Products:

Relevant listing (indicates student)*

*Yang, Y., T.A. Endreny, and D.J. Nowak. "Simulating Double-Peak Hydrographs from Single Storms over Mixed-Use Watersheds", *ASCE Journal of Hydrologic Engineering*, DOI: 10.1061/(ASCE)HE.1943-5584.0001225, 2015. [citations]

*Yang, Y., T.A. Endreny, and D.J. Nowak. "Simulating the Effect of Flow Path Roughness to Examine how Green Infrastructure Restores Urban Runoff Timing and Magnitude", *Urban Forestry and Urban Greening*, DOI: 10.1016/j.ufug.2015.03.004, 2015. [citations]

*Decker, T. J., and T.A. Endreny, SUNY College of Environmental Science and Forestry Humanitarian Engineering: Small Scale College Components and Analysis, *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship, Special Issue: University Engineering Programs That Impact Communities: Critical Analyses and Reflection*, *Fall 2014*, 191-204, 2014. [citations]

*Haas, N.A., B.L. O'Connor, J.W. Hayse, M.S. Bevelhimer, and T.A. Endreny, "Analysis Of Daily Peaking And Run-of-river Operations With Flow Variability Metrics, Considering Subdaily To Seasonal Time Scales", *Journal of the American Water Resources Association*, 50(6): 1622-1640, DOI: 10.1111/jawr.12228, 2014.

Smidt, S.J., J.A. Cullin, A.S. Ward, J. Robinson*, M.A. Zimmer, L.K. Lautz, and T.A. Endreny. "A Comparison of Hyporheic Transport at a Cross-Vane Structure and Natural Riffle", *Groundwater*, DOI: 10.1111/gwat.12288, 2014. [citations]

*Han, B. and T.A. Endreny. "Comparing MODFLOW Simulation Options for Predicting Intra-Meander Flux", *Hydrological Processes*, *28*(11), 3824-3832, DOI: 10.1002/hyp.10186, 2014. [citations]

*Han, B. and T.A. Endreny. "Detailed River Stage Mapping and Head Gradient Analysis During Meander Cutoff In A Laboratory River", *Water Resources Research*, 50: 1–15, DOI: 10.1002/2013WR013580, 2014. [citations]

*Han, B. and T.A. Endreny. "River Surface Water Topography Mapping at Sub-Millimeter Resolution and Precision With Close Range Photogrammetry: Laboratory Scale

Application", *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 7(2): 602–608, DOI: 0.1109/JSTARS.2014.2298452, 2014. [citations]

*Zhou, T. and T.A. Endreny. "Reshaping of the Hyporheic Zone Beneath River Restoration Structures: Flume and Hydrodynamic Experiments", *Water Resources Research*, 49(8): 5009–5020, DOI: 10.1002/wrcr.20384, 2013. [1]

*Yang, Y., T.A. Endreny, and D.J. Nowak. "A Physically Based Analytical Spatial Air Temperature and Humidity Model", *Journal of Geophysical Research: Atmospheres*, 118(18): 10,449-10,463, DOI: 10.1002/jgrd.50803, 2013. [citations]

Synergistic Activity:

- Advisor for SUNY ESF Engineers without Borders Chapter - using sustainable design theory for outreach in water supply and ecological restoration for Latin America: 2003-present.
- Developed and maintain iTree Hydro application used by city and regional planners to quantify benefits of watershed restoration (www.itreetools.org/hydro): 2001-present.
- Developed and maintain fluvial geomorphology teaching and training modules for NOAA UCAR and NWS (http://www.fgmorph.com): 2003-present.
- Report SUNY ESF daily weather observations for NWS Cooperative Observers Program, and use data in outreach with *ESF in the High School* outreach activities: 2000-present.
- Serve as technical advisor to Onondaga County Save the Rain and USDA Forest Service on stormwater benefits of trees: 2001-present.

Collaborators and Co-Editors:

Davidson, Cliff (Syracuse), Driscoll, Charles (Syracuse), Chandler, David (Syracuse), Kroll, C. (ESF), Lautz, L. (Syracuse U), McGrath, K (ESF), Nowak, D. (USDA Forest Service), O'Connor, B.L. (U of Illinois), Ward, A. (Indiana)

Graduate Advisors:

Eric Wood, Princeton University, Greg Jennings, North Carolina State University

Thesis Advisor & Postgraduate-Scholar Sponsor:

- Past Advisees (15 MPS, 15 MS, 4 PhD) / Current Advisees (1 MPS, 8 MS, 4 PhD)
- Current and Last 5 Years: Becker, J. (ESF); Bodnaruk, E. (ESF); Calderon, M. (ESF); Chao, P. (Consultant); Chu, H. (ESF); Eichorn, D. (ESF/OCC); Fabian, M. (QEA Consultant); Fay, M. (ESF); Fello, K., (ESF); Fortman, A (ESF); Gonzalez, L. (ESF); Han, B. (U Idaho); Imbeah, N. (Ministry of Water, Ghana); Jeffords, B. (Consultant); Kadambi, H. (ESF); Khan, S. (Peace Corps); Kulkarni, S. (Ministry of Irrigation, India); Kwon, P. (ESF); Robinson, J. (ESF); Stephan, E. (ESF); Stires, A (ESF); Taggart, T. (ESF); Thapa, K. (ESF); Thomas, K. (NSE Consultant); Wagner, B. (ESF); Wolcott, S. (ESF, RIT); Y. Yang (ESF); Zhou, T. (U Washington Lettenmaier Lab)

Licenses:

Professional Hydrologist (PH) 1559, American Institute of Hydrology, 2002-present
Professional Engineer (PE) 079912, The State of New York, 2002-present

Biographical Sketch – DAVID J. NOWAK

USDA Forest Service, 5 Moon Library, SUNY-ESF, Syracuse, NY 13210
315-448-3212 dnowak@fs.fed.us

Professional preparation

SUNY College of Environ. Science & Forestry	Dual: Forestry & Biology	BS	1984
SUNY College of Environ. Science & Forestry	Urban Forestry	MS	1986
University of California, Berkeley	Urban Forest Ecology	PhD	1991

Appointments

2015 – present	i-Tree Team Leader / Research Forester, Northern Research Station, USDA Forest Service
1997 – 2015	Project Leader / Research Forester, Northern Research Station, USDA Forest Service (Project: Urban Forests, Human Health and Environmental Quality)
1997 – present	Adjunct Professor, SUNY College of Environmental Science and Forestry
1995 – 1997	Deputy Project Leader / Research Forester, Northeastern Research Station, USDA Forest Service
1991 – 1995	Research Forester, Northeastern Research Station, USDA Forest Service
1989 – 1991	Forestry Technician, Northeastern Research Station, USDA Forest Service
1986 – 1989	Research Assistant, University of California, Berkeley
1985 – 1986	Research Assistant, Research Foundation of the State University of New York

Select Publications (total publications = 267)

Nowak, D.J., K.L. Civerolo, S.T. Rao, G. Sistla, C.J. Luley, and D.E. Crane. 2000. A modeling study of the impact of urban trees on ozone. Atmospheric Environment. 34:1610-1613.

Nowak, D.J. and D.E. Crane. 2002. Carbon storage and sequestration by urban trees in the USA. Environmental Pollution. 116(3):381-389.

Nowak, D.J., J.C. Stevens, S.M. Sisinni, and C.J. Luley. 2002. Effects of urban tree management and species selection on atmospheric carbon dioxide. Journal of Arboriculture. 28(3):113-122.

Nowak, D.J., D.E. Crane and J.C. Stevens. 2006. Air pollution removal by urban trees and shrubs in the United States. Urban Forestry and Urban Greening. 4:115-123.

Nowak, D.J. and J.F. Dwyer. 2007. Understanding the benefits and costs of urban forest ecosystems. In: Kuser, J. (ed.) Urban and Community Forestry in the Northeast. Springer, New York. p. 25-46.

Nowak, D.J., R.E. Hoehn, D.E. Crane, J.C. Stevens, J.T. Walton, and J. Bond. 2008. A ground-based method of assessing urban forest structure and ecosystem services. Arboriculture and Urban Forestry 34(6):347-358.

Wang, J., T.A. Endreny, and **D.J. Nowak**. 2008. Mechanistic simulation of urban tree effects in an urban water balance model. Journal of American Water Resource Association. 44(1):75-85.

Nowak, D.J. 2010. Urban biodiversity and climate change. In: Urban Biodiversity and Design. Muller, N., Werner, P. and Kelcey, J.G. (eds). Wiley-Blackwell Publishing. Hoboken, NJ. p. 101-117.

Nowak, D.J. and E.J. Greenfield. 2012. Tree and impervious cover change in U.S. cities. Urban Forestry and Urban Greening. 11:21-30.

Nowak, D.J. and E.J. Greenfield. 2012. Tree and impervious cover in the United States. Landscape and Urban Planning. 107: 21– 30

Nowak, D.J. 2012. Contrasting natural regeneration and tree planting in 14 North American cities. Urban Forestry and Urban Greening. 11: 374– 382

Nowak, D.J., E.J. Greenfield, R. Hoehn, and E. LaPoint. 2013. Carbon storage and sequestration by trees in urban and community areas of the United States. Environmental Pollution. 178: 229-236.

Nowak, D.J., S. Hirabayshi, A. Bodine and R. Hoehn. 2013. Modeled $PM_{2.5}$ removal by trees in ten U.S. cities and associated health effects. Environmental Pollution. 178: 395-402.

Nowak, D.J. S. Hirabayashi, E. Ellis and E.J. Greenfield. 2014. Tree and forest effects on air quality and human health in the United States. Environmental Pollution 193:119-129

Presentations (total = 491)

Synergistic activities

1. Co-Principal Investigator, NSF-sponsored Baltimore Ecosystem Study (BES) Long Term Ecological Research (LTER) site
2. Leader of Forest Service National Urban Forest Resource Policy Act (RPA) Assessments
3. Co-leader of team to test and implement pilot projects regarding a national urban forest inventory and health monitoring network.
4. Leader of team developing the UFORE and i-Tree model software. i-Tree is a suite of public domain urban forest assessment and management tools (www.itreetools.org) that assess urban forest structure and ecosystem services and values.

Select awards

2015 - L.C. Chadwick Award for Arboricultural Research - one of ISA's Awards of Distinction and highest honors, this peer-nominated award recognizes individuals for research that has contributed valuable information toward the advancement of arboriculture

2011 - R.W. Harris Author's Citation – International Society of Arboriculture award for outstanding publications and sustained excellence in publications

2010 - J. Sterling Morton Award – National Arbor Day Foundation's highest honor recognizing positive impacts on the environment due to their lifelong commitment to tree planting and conservation at a national or international level

2010 - US EPA Office of Research and Development Honor Award

2009 - New York State Arborists, ISA Chapter Research Award

2008 - Forest Service Chief's Honor Award for Engaging Urban America (i-Tree Team)

2007 - Contributing member of Noble Peace Prize winning Intergovernmental Panel on Climate Change

2016 NUCFAC Project Team: The Davey Tree Expert Company

Project Lead

Scott Maco – Director of Research and Development

Scott Maco provides management and leadership for Research and Development at the Davey Institute. His focus on applied research and development of urban forest assessment and management tools. Specifically, Scott works to create new technologies that provide better access and understanding of trees' environmental benefits and how ecosystem services can be enhanced by managing urban forest structure. Scott has 15 years of experience in planning, design, and implementation of urban forestry enhancement projects and developing the tools to facilitate effective resource management. Scott collaborates to lead development of the i-Tree Tools software suite and provides leadership for many ongoing federal, state, university and private sector cooperative research projects for Davey. Scott is the author of several peer-reviewed articles on urban forest assessment and a frequent contributing writer for industry journals and magazines. Amongst other awards, Scott was a recipient of the 2008 Forest Service Chief's Honor Award for "Engaging Urban America." Scott holds a Master of Science in Horticulture and Agronomy from the University of California, Davis and a Bachelor of Science in Urban Forestry from the College of Forest Resources, University of Washington.

Primary Staff

Satoshi Hirabayashi – Coordinator, Environmental Modeling

Satoshi Hirabayashi is an Environmental Modeler with 10 years of experience in solving urban environmental issues with computer- and GIS-based models as well as several analytical techniques such as statistical, sensitivity and time-series analyses. In addition, Satoshi brings skills and experience in a broad range of software development and project management from his past career at Motorola, Sony, and Accenture. Currently with the Davey Institute, based at the USDA Forest Service, his primary responsibility is development of core computer models of i-Tree Tools software suite, including atmospheric stability, solar radiation, mixing height, evapotranspiration, leaf area index, air pollutant concentration, dispersion, deposition, and biogenic emission, precipitation interception, and public health benefits. He is also engaged in several US nationwide assessments of air quality improvement by urban forests such as the EnviroAtlas project lead by US EPA. Satoshi published several research papers on environmental modeling and GIS applications in peer-reviewed technical journals. Satoshi earned a Ph.D. and Master of Science degrees in Environmental Resource Engineering from the State University of New York College of Environmental Science and Forestry, and a Bachelor of Science degree in Electronics and Communication Engineering from Tokyo City University in Japan.

Mike Binkley – Manager of Technology Development

Mike Binkley is a Manager of Technology Development with 15 years of experience whose primary responsibility is the application of new technology to Davey endeavors. Past projects include the use of GIS analysis to resolve environmental and natural resource management issues, the development of Davey's GIS-based Asset Manager software and handheld field data collection software, as well as online mapping and web design, GPS vehicle tracking, satellite derived land cover classification, and cartographic design. As such, he strives to maintain extensive knowledge of contemporary GIS software as well as common operating system software and hardware platforms. In addition, he teaches GIS programming part-time at Kent State University. Mr. Binkley holds a Master of Arts in Geography – GIS from Kent State University and a Bachelor of Science with Honors in Natural Resource Conservation with minors in Climatology and Geography from the same institution.

Lianghu Tian - Research and Development Analyst, IT

Lianghu Tian brings 14 years of expertise in information technology, digital image processing, remote sensing and Geographic Information Systems (GIS) to Davey. Currently, Lianghu is a Research & Development Analyst. He manages IT activities, application design, and research and development projects for The Davey Institute. Tian specializes in computer programming, network administration, SQL database server administration, remote sensing satellite image processing, neural networks, web design and GIS. Before joining Davey, Tian completed various research projects in the United States (including Managing Urban Sprawl and Land Resource Changes by Remote Sensing and Geographic Information Systems; Great American Secchi Dip-in Program and Satellite Image Processing and Geographic Information Systems), as well as research projects in China including Gold Mine Detection by Remote Sensing, Urban Information Systems and Land Resource Information Systems. He has published numerous articles in his fields of expertise and has won several distinguished awards. Tian holds a PhD from Kent State University, a Master of Arts from Kent State University and earned both Master and Bachelor of Science degrees in information and image processing and remote sensing from Zhejiang University in China.

Al Zelaya - Research Urban Forester

Al Zelaya is a Research Urban Forester for The Davey Tree Expert Company. His primary responsibilities include development, research, training, website administration and providing technical support for urban forestry environmental service projects. His current focus includes support and integration tasks related to i-Tree, IPED (pest detection protocol) and SDAP (storm damage assessment protocols) initiatives. Al has more than 10 years experience working in urban forestry, arboriculture and natural areas management. Most recently, he was a Regional Urban Forestry Coordinator for the Wisconsin Department of Natural Resources and a County Forestry Crew Chief in Northern Illinois. He is also a graduate from the Municipal Foresters Institute (MFI) program and currently is a member of the MFI instructor cadre. Mr. Zelaya has a Bachelor of Arts Degree from DePaul University in Chicago, Ill., and is currently working on completing a master's degree in Natural Resources and Environmental Sciences from the University of Illinois. Al is an ISA certified arborist and a member of the Society of Municipal Arborists, the International Society of Arboriculture and the Society of American Foresters.

David Ellingsworth – Lead i-Tree Programmer

David Ellingsworth is a lead programmer for the i-Tree development team. His primary responsibilities include the development and maintenance of i-Tree Streets. David has experience developing with variety of programming languages including Java, .Net, C++, C, PHP, Perl, HTML, and CSS. He holds a Bachelors of Science in Computer Science from The University of Akron, an Associates of Business in Software Development and an Associates of Business in Network Communications Technology from Lorain County Community College. Prior to joining the i-Tree team, he developed web-based applications in .Net and ASP for Software Answers.

Michael Kerr – Lead i-Tree Programmer

Michael Kerr is a lead programmer for the i-Tree development team. His primary responsibilities include development for i-Tree Eco, i-Tree Hydro, and i-Tree's Pocket PC applications. He also develops and maintains the i-Tree Installation package. Michael studied Computer Science at Youngstown State University. He specializes in programming C#, VB.NET, VB6, and VBA applications along with configuration, installation, and software maintenance. Past projects include converting i-Tree Eco and i-Tree Streets to the .NET Compact Framework, the i-Tree Eco Report Generator, an XML to MDB conversion library, and a Pocket PC communication library.

Jason Henning – Research Urban Forester

Jason Henning is a Research Urban Forester with the USDA Forest Service and The Davey Tree Expert Company. He has a Ph.D. in Forestry and an M.S. in Statistics from Virginia Tech. Jason has 15 years of experience in teaching and research involving the quantitative assessment and modeling of forest resources. He has published peer reviewed research on forest growth modeling, silviculture, forest ecology, and remote sensing. He spent six years at the University of Tennessee teaching courses in forest and natural resource inventory, and researching methods for quantifying and modeling forest resources. Recently, he returned to his home state of Pennsylvania and his current position at the Forest Service's Philadelphia Urban Field Station. His current work focuses on applied scientific research and communication of scientific topics to support the informed management of urban forests. He also contributes to support and outreach involving the i-Tree suite of tools and manages projects employing i-Tree software in the Philadelphia area.

Allison Bodine – Research Forester

Allison Bodine is a Research Forester with the USDA Forest Service and The Davey Tree Expert Company. Her contributions to the development of i-Tree include providing application testing and feedback, as well as data mining to update species and location databases. She has also worked specifically with i-Tree Eco to develop methods to analyze pest risk, identify invasive tree and shrub species, and quantify the impacts of air pollution removal on human health using the U.S. EPA's Environmental Benefits Mapping and Analysis Program (BenMAP). Allison has a master's degree in Natural

Resource Management from the SUNY College of Environmental Science and Forestry in Syracuse, NY and a Bachelor of Arts in Environmental Design and Geography from the University at Buffalo.

Alexis Ellis – Research Urban Forester, GIS

Alexis Ellis is a research urban forester with 17 years of experience in the fields of forestry, information technology and Geographic Information Systems (GIS). In her current position with Davey and the USDA Forest Service she is responsible for projects relating to software development, database management, geospatial analysis, image processing and environmental modeling. Currently, her chief responsibilities include; developing the iTree Forecast model, energy modeling for iTree Design and analyzing temperature patterns following changes in tree canopy. In addition, she teaches GIS part-time at SUNY College of Environmental Science and Forestry (ESF). Alexis has a Master of Science in Forest and Natural Resource Management from SUNY ESF and a Bachelor of Arts Degree in Geography from Queen's University. Previously, Alexis worked for the US Geological Survey as a Remote Sensing and GIS Specialist developing web mapping applications, software, and map products in support of various natural hazards support, hydrologic analysis and natural resource conservation projects.

Kevin Whalen – Software Developer

Kevin Whalen is a software developer for the i-Tree team. His primary responsibilities are the engineering, and development of i-Tree Landscape. Kevin has experience writing in a variety of programming languages including C/C++, Java, C#, Javascript, Python, PHP, and Bash. He also has experience working with differing web technologies, frameworks, and libraries. Kevin has an Associate of Science in Computer Information Services from the National Institute of Technology, and a Bachelor of Science in Computer Science from Kent State University. He is perusing a Master of Science in Computer Science, with a focus on high performance computing, at Kent State University. Prior to working for the Davey Tree Expert Company, Kevin worked as a Database Analyst for CVS Caremark, and a Hardware Technician for the CVS Business Integration Center Repair Shop.

Literature Review

This literature review provides background material and information to explain how the proposed study builds upon previous work of the PIs and their Partners, as well as additional information pertinent to the study. The National Urban and Community Forestry Advisory Council (NUCFAC) describes the need for innovative grant proposals, which they define as new, cutting-edge or builds upon existing studies. We firmly believe that the proposed project fits all of these criteria.

This literature review is developed around 3 topics related to this proposal:
1) Uncertainty analyses in environmental modeling
2) Urban forest decision support systems
3) Ways to describe and utilize uncertainty in environmental modeling
Each of these topics is briefly discussed below. This is followed by a list of references for this proposal.

<u>1) Uncertainty analyses in environmental modeling</u>
Modeling techniques have become popular in the environmental sciences. Two common motivations for environmental modeling analysis are to gain understanding of interactions and complexities in environmental systems (Omlin and Reichert, 1999), and to predict future scenarios of environmental systems' behaviors under various parameters ranges, and changing scale and spatio-temporal settings (Wood et al., 1988). Examples include hydrologic (Mishra, 2009), ecologic (Clark, 2003a) and climatic (Held, 2005) models, and natural resources management decision making, risk and policy development (Herrera and Herrera-Viedma, 1996; Hallegatte, 2009).

A critically important component of environmental modeling is assessing the sensitivity of model output to model inputs, and developing estimators of the uncertainty of model outputs (Halpern, 2003). Uncertainty typically exists in every component of a model (e.g. input data, model parameters, and model structure) (Beck, 1987; Draper, 1995; Beven and Binley, 1991), as well as during the entire model building process and calibration process (e.g. calibration datasets, modeling assumptions, communicating outputs, and making decisions) (Helton et al., 2006; Beven et al., 2014; Hallegatte, 2009; Ascough et al., 2008). In addition, challenges arise when applying models to real world application. Environmental systems are highly complex, and spatial heterogeneity requires calibration of model to local conditions that may differ from those on which the model was based and developed (Hill, 1998). Temporal heterogeneity requires validation tests to assess how well models predict outputs (Legates and McCabe, 1999). Scale effects require re-verification of model structure and re-estimation of initial and boundary conditions and coefficient thresholds (Narasimhan et al., 2005). Given these issues, uncertainty analysis should be regarded as important as model outputs, and become a formal practice of model building effects (Pappenberger and Beven, 2006; Gallagher and Doherty, 2007).

In order to grasp meaningful interpretation from model uncertainty, it is necessary to characterize and distinguish various kinds of uncertainties. In the ecology community, Clark (2005) classifies uncertainty in two categories: (1) knowledge uncertainty (e.g. model and parameter uncertainty), which declines asymptotically with sample size; and (2) natural variability (e.g. spatial and temporal variability), which can be more accurately approximated with an increase in sample size. Loucks et al. (2005) adopted a similar classification of uncertainty when analyzing hydrologic systems. Apart from knowledge uncertainty and natural variability, Loucks et al. (2005) added a third category: decision uncertainty. Decision uncertainty is based on people's future desires, and includes changes in nature, human goals, interests, activities, demands and impacts. Interestingly, Beven et al. (2015) recently outlined a different approach to partition uncertainty: aleatory uncertainty and epistemic uncertainty. Aleatory uncertainty is "traditional" uncertainty, which is generally treated statistically and arises from random variability. Epistemic or "Knightian 'real uncertainties'" (Rougier and Beven, 2013), arise from a lack of knowledge about boundary conditions, processes and model structures, parameters, observational data used to calibrate and verify models.

The advancement of computer science has led to the availability of new data analysis and modeling techniques, and various methods for uncertainty analysis have been developed. These methods range from classical frequentist analysis (Omlin and Reichert, 1999) to complex Bayesian networks (Bishop, 2006), and can be either subjective (e.g. expert assessment) (Uusitalo et al., 2015) or objective (e.g. probability theory) (Pearl, 2013). Among various uncertainty analysis techniques, Bayesian and its derivations have received increased attention due to their flexibility and capacity to integrate diverse sources of uncertainties (Clark, 2005). Bayesian methods, like Markov Chain Monte Carlo (MCMC) (Godsill, 2001; Clark, 2003b), and Generalized Likelihood Uncertainty Estimation (GLUE) (Beven and Binley, 1991; Beven et al., 2000; Beven and Freer, 2001), are gaining wide acceptance in hydrologic modeling (Vrugt et al., 2009; Shen et al., 2012), ecological modeling (Cressie, 2009), soil erosion modeling (Brazier et al., 2001), and among many other applications.

Different methods are not mutually exclusive, and instead they can be integrated together to achieve higher accuracy and efficiency. 'Ensemble' (Tebaldi and Knutti, 2007; Duan et al., 2007) and 'Equifinality' (Beven, 2002; Beven, 2006) are two important concepts with regards to model integration. For example, multiple models within an ensemble forecasting framework have been employed to forecast species distribution under future climate change scenarios, and the results indicate that ensemble forecasting has clear advantages over single-model forecasts, and can enable more robust decision making in the face of uncertainty (Araújo and New, 2007). Contrary to the idea of select an optimal or best model structure and parameter set, applying 'equifinality' can allow different models to contribute to the prediction interval at different time steps (Beven and Freer, 2001).

Given these competing estimators of model output and uncertainty, it's often challenging to choose a method to employ for your application. Simple estimators are easy to understand, implement, and communicate while complex estimators allow for integrating multiple sources of uncertainty and data sets at different scales (Clark, 2005). Complex estimators, such as Hierarchical Bayesian and Bayesian networks (Gelman et al., 2014), have gained more and more popularity; however, these complex estimators are not necessary superior than simpler methods. For example, as long as the underlying assumptions are satisfied, classical frequency approaches can provide accurate uncertainty estimation (Omlin and Reichert, 1999). Another paradox with regard to uncertainty analysis is between single-model and multi-model ensembles. Whether the combined information of several models is superior to a single-model forecast depends on scientific field, research objectives and questions, and data and parameter characteristics (Araújo and New, 2007). Guidance for uncertainty analyses in environmental science generally is to integrate theoretical and process understanding into estimator choices (Clark, 2005).

The application of i-Tree tools in urban area is subject to multiple sources and kinds of uncertainty. First, i-Tree tools use relatively simple mathematical equations to conceptualize and aggregate forest ecosystem processes and services (UFORE Methods: https://www.itreetools.org /eco/resources/UFORE%20Methods.pdf). This simplicity contributes to model uncertainty. In addition, the uncertainty of input datasets due to sampling processes and limited record length also contribute to output uncertainty. Most i-Tree models also have numerous model parameters, many of which must be estimated by the users. These parameters are also uncertain, and this may impact the uncertainty of model output. i-Tree models, such as i-Tree Hydro, rely on model calibration to obtain parameter estimates. While this may improve model fit, there is also uncertainty as the data to which a model is calibrated also contains uncertainty. i-Tree landscape allows users to explore the tradeoffs and synergies between multiple objectives, and our decision support tool will allow users to further explore multi-objective optimization, such as optimizing for improving air quality for human health benefits while reducing environmental inequities amongst underserved communities. Competing objectives also create output uncertainty. The spatial heterogeneity of urban landscapes, and integration of natural variability and anthropogenic activities (Cadenasso, Pickett, and Schwarz, 2007), make the model representation of urban area and process extremely difficult. In addition, increases in urbanization often results in more frequent extreme events (e.g., more floods due to the increase in impervious surface; increasing urban warming due to exacerbated urban heat island effect) (Burian and Shepherd, 2005; Grimmond, 2007). This increases not only the ranges of parameter values, but also the difference between future conditions and the conditions for which the model was calibrated.

Within i-Tree Eco, i-Tree users use uncertainty in field plot data to determine the minimum number of field plots for a study area. This uses plot size and number of plots to determine the precision of urban forest assessments (Nowak et al., 2008). Based on the criterion of standard error and relative standard error, as well as tradeoffs between cost and precision, the optimal number of plots and plot size are set to be approximately 200 one-tenth acre plots (Nowak et al., 2008). The limitations of this approach is that: 1) it only evaluates the input dataset uncertainty due to field sampling while ignoring other sources of uncertainty; (2) it only shows uncertainty of total tree number while ignoring other outputs; (3) it only provides a simple point estimate of lumping model rather than spatial details of models under various scales; and (4) it narrows down the uncertainty expression to a single number or even to a range of numbers, which may convey less interpreted meaning for decision maker. However, the relative standard error approach serves as a good starting point for further investigating uncertainty in i-Tree models.

2) Urban forest decision support systems

Trees can be strategically planted and managed to optimize desired ecosystem services using knowledge of the heterogeneous urban landscape and human demographics. For instance, a location with high levels of air pollutants and high population density could be an optimal location to plant trees to improve health (Cabaraban et al., 2013; Hirabayashi et al., 2011; Morani et al., 2011). Incomplete knowledge of the spatial and temporal variation of environmental parameters, ecosystem services, and human demographics and activities poses a challenge to more effective urban forest management (Jenerette et al., 2011; Pataki et al., 2011; Thomas and Geller, 2013).

Priority planting methodologies have been developed (Locke et al., 2010; Locke et al., 2013; Morani et al., 2011), but have not quantified ecosystem services, benefits, or tradeoffs needed for the decision-making context (Haase et al. 2014). Locke et al. (2010) employed a GIS-based methodology to identify priority plants of trees in urban areas. Priority planting was based on a combination of need-based criteria (e.g. air quality, public health, etc.) and suitability-based criteria (e.g. areas not building, road, water or existing canopy). These were standardized and weighted, and general maps of priority planting were developed. While Locke et al.'s (2010) methodology was excellent, they did not attempt to quantify the costs and benefits of these ecosystem services using common scales. For the next step in the evolution of urban forest decision support systems, it is critical to integrate this system with a spatially explicit modeling methodology that can explore multiple ecosystem services, benefits, costs, and the complex nature of tradeoffs (Carpenter et al., 2009; Rodríguez et al., 2006).

3) Ways to describe and utilize uncertainty in environmental modeling

There are many ways in which uncertainty can be described and communicated in environmental models. The most common way is numerically, where one employs statistics to describe the uncertainty. The most common numerical uncertainty measure is the variance of the parameter, output or estimator, the 2nd moment about the mean (Devore, 2015). There are many ways to estimate the variance of an estimator, including empirically from a sample, theoretically from a distributional hypothesis (Stedinger et al., 1993), using bootstrap resampling of the sample (Efron, 1979), or one of the many methods described in section 1) of this literature review. Instead of variance, sometimes the mean squared error is presented, which is the 2nd moment about the observations (Kroll and Stedinger, 1993). The mean squared error is equal to the variance plus the square of the bias. Bias, the expected value minus the observed or "true" value, is a common measure of systematic error, and so reporting the mean squared error represents both variability and systematic error.

Since variance has the same units as the original data squared, it can be difficult to compare variances of noncommensurate outputs (such as different ecosystem services and benefits). To address this one could divide the standard deviation (square root of variance) by the expected value (mean), creating the unitless coefficient of variation (CV), a common metric to compare samples (Stedinger et al., 1993). Alternatively, when dealing with the variance from commensurate outputs, one can divide all variances by the smallest variance, producing an estimator of the efficiency of an estimator (Kroll and Stedinger, 1996).

There are many other ways to describe and communicate the uncertainty of a phenomenon. One way is via a probability distribution function (pdf), which could be thought of as a continuous histogram with the variable on the x-axis and its frequency of occurrence on the y-axis. The pdf is a visual way to describe variability, but can be employed to derive many useful statistics. For instance, you can integrate across the pdf above or below a threshold to estimate the probability of exceeding a human health target or a monetary ecosystem benefit, or below a threshold to determine the probability of being below a target cost or environmental standard. Another common way to graphically describe uncertainty is via a box-plot, which visually describes the range, median, and quartiles of phenomenon.

Regardless of the method employed to estimate uncertainty, it is often challenging for scientists to communicate uncertainty to practitioners (Faulker et al, 2007). We expect an effective way to describe uncertainty to i-Tree users will be to combine numerical uncertainty into spatially explicit 2-dimension maps of a study area. The mapping of uncertainty has been shown to be a very effective tool for communicating flood inundation (Beven et al., 2015).

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Date: November 20, 2015

Nancy Stremple
National Urban & Community Forestry Advisory Council
U.S. Forest Service
201 14th Street SW
Sidney Yates Building (MS-1151)
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Re: Support of 2016 U.S. Forest Service National Urban & Community Forestry Challenge Cost-Share Grant Program Proposal

Dear Nancy:

This letter is in strong support of the NUCFAC proposal titled: "A Decision Support System to Develop, Analyze, and Optimize Urban and Community Forests" with SUNY College of Environmental Science and Forestry. This research and development will help advance i-Tree tools in relation to improving both science and management related to urban forests.

For years we have worked closely with Drs. Kroll and Endreny on several projects and they have always come through and provide excellent work. We hope to continue working closely with this team on this proposed project, which will greatly advance i-Tree. This project will help develop a decision support system that will allow users to identify areas to plant trees that will optimize ecosystem services and help distribute these services equitably across the urban landscape to provide benefits to communities and areas that need them the most.

I and my research staff will work closely with the research team and contribute to the project at no cost to NUCFAC. I hope NUCFAC will fund this important project.

Sincerely,

David J. Nowak
i-Tree Team Leader

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April 15, 2016

Subject: Letter of Partnership

To Whom It May Concern:

On behalf of the Davey Institute Team, I am writing to inform you of our interest and willingness to collaborate on and support the project entitled *A Decision Support System to Develop, Analyze, and Optimize Urban and Community Forests* with Drs. Charles Kroll and Theodore Endreny at the Department of Environmental Resources Engineering, SUNY ESF. This important project will help urban planners and natural resource managers—amongst others—to make better decisions on how to best minimize the impacts of development and redevelopment on urban and community forests while promoting integration of new canopy as part of the planning process.

Preserving our existing urban forest canopy is critical to maintaining community livability, human health, and environmental quality. Urban development pressures, however, threaten our established urban forests and compete for space needed to expand this critical resource. For nine years, i-Tree Tools have provided thousands of urban forest managers and urban planners with information to plan and advocate for urban forest stewardship. While the current i-Tree models are a tremendous asset for urban forest analyses, they lack a full accounting of the uncertainty of model output and how this uncertainty can be used to improve urban forest management. This project proposes to overcome this limitation by developing methodology and application functionality that allows users to better understand the impacts of urban planning and management decisions. With this system in place, i-Tree users will be able to better understand how to optimize for ecosystem benefits under competing development objectives, thereby encouraging more informed planning for urban forest preservation and expansion to meet community needs.

With the team of partners assembled for this project, we have the opportunity to leverage the highest level of expertise and collaboration with respect to developing and disseminating the science and management tools proposed in this project. We will leverage a unique network of scientists, engineers, software developers and science delivery specialists for the benefit of the urban forest community. I have no doubt that the results of this project will provide critical information and timely tools that are needed to better manage our nation's urban forests in the face of increasing urban development.

As project collaborators, we will be responsible for 1) consulting with the project Team to ensure the uncertainty methods and calculations are developed for i-Tree compatibility; 2) integration of the model output uncertainty estimators into the i-Tree Eco application, including the coding of developed algorithms, user-interface functions, and reporting features; and 3) the dissemination of the new products through the i-Tree platform. Davey is providing a 100% match to all funds received.

Thank you for your consideration.

Sincerely,

/s/ *Scott Maco*

Scott Maco
Director of Research & Development
Davey Tree Expert Company
Phone: 425-605-0383
Email: scott.maco@davey.com

Jennifer Greenfeld
Chief of Forestry, Horticulture,
& Natural Resources

T 212-360-1488 | 718-760-6800 **E** Jennifer.greenfeld@parks.nyc.gov

City of New York
Parks & Recreation

Arsenal North
1234 Fifth Avenue
2nd Floor
New York, NY 10029
www.nyc.gov/parks

Friday, April 15, 2016

National Urban and Community Forestry Advisory Council
USDA Forest Service
201 14th. St. SW, Sidney Yates Bldg. 3SC-01C
Washington, DC 20024

Re: Letter of Support for SUNY-ESF/The Davey Tree Expert Company Proposal – A Decision Support System to Develop, Analyze and Optimize Urban and Community Forests

Dear National Urban and Community Forestry Advisory Council,

This letter is in support of the NUCFAC proposal entitled "A Decision Support System to Develop, Analyze, and Optimize Urban and Community Forests" by Chuck Kroll and Ted Endreny of the State University of New York College of Environmental Science and Forestry (SUNY ESF) and Scott Maco of the Davey Tree Expert Company. i-Tree is a suite of urban forestry tools that have been used by New York City to characterize and assess current canopy cover, and to plan for future plantings. These tools have been absolutely critical to our program as a method in justifying our funding needs for tree planting and management. The proposed project will develop methods to assess the uncertainty of output from i-Tree tools, and develop a decision support system to help urban planners better understand the tradeoffs between different urban forest planting schemes and develop more optimal management plans.

We are aware that the proposed project has recommended modeling parts of New York City as one of their case studies. We welcome this analysis and will provide support by discussing plans for current and future tree plantings, helping identify areas of New York City that may be underrepresented in terms of urban forest ecosystem services, and providing publically available data on the current inventory of trees in New York City. We look forward to this collaboration.

Sincerely,

Jennifer Greenfeld
Chief of Forestry, Horticulture & Natural Resources

DEPARTMENT OF Streets & Sanitation
CITY OF CHICAGO

National Urban and Community Forestry Advisory Council
USDA Forest Service
201 14th. St. SW, Sidney Yates Bldg. 3SC-01C
Washington, DC 20024

Dear National Urban and Community Forestry Advisory Council:

This letter is in strong support of the NUCFAC proposal entitled "A Decision Support System to Develop, Analyze, and Optimize Urban and Community Forests" by the State University of New York College of Environmental Science and Forestry (SUNY ESF) and the Davey Tree Expert Company. This work will allow Urban Forestry professional such as me to assess the risks to our urban forest that is posed by natural disasters and challenges associated with climate change.

Since 1990, the City of Chicago has conducted assessments of it street trees through 100% tree counts and Random Sample Inventories roughly on a 10 year basis. We have also worked with the USDA Forest Service on the Chicago Urban Forest Climate Project (1994) and more recently a UFORE analysis completed in 2010. Utilizing data from Chicago's urban forest will help guide our future planting efforts which will be critical when we enter our restoration following the anticipated loss of nearly 20% of our forest to the Emerald Ash Borer. We realize the importance of making our forest more resilient by improving our species selection, maintenance practices and whenever possible improving the growing conditions created on capital projects by increasing soil volumes and space allocated for trees.

I and my staff will aid the research team in any way we can. This includes facilitating access to our inventory data and anticipated tree planting locations. We look forward to the results produced so that we can actively implement them in future inventories and management decisions. I hope the Council will fund this important project.

Sincerely,

Malcolm Whiteside Jr
Department of Streets and Sanitation
Bureau of Forestry

2352 South Ashland Avenue, Third Floor, CHICAGO, ILLINOIS 60608

April 8, 2016

Dear National Urban and Community Forestry Advisory Council grant selection committee,

This is an enthusiastic letter of support for the proposal entitled, "A Decision Support System to Develop, Analyze, and Optimize Community Forests," which is being submitted to the US Forest Service's Urban and Community Forestry Challenge grant by Dr. Charles Kroll and colleagues.

As the municipal managers of 250,000 street trees, 1.3 million park trees, and innumerable private trees in Portland, Oregon, we are keen to support efforts to improve iTree. We use iTree products regularly to support and guide our management decisions, and have published 50+ neighborhood tree inventory reports using iTree analyses. In our experience, there are limitations to iTree – it often is too theoretical to provide practical information for management and to accurately answer stakeholder questions. We believe this proposal will greatly enhance the usability of iTree for practitioners. Specifically, the proposal will:

1. *Provide a measure for uncertainty of the iTree model.* iTree is great at producing numbers – but as a model it is required to rely on general assumptions without much specificity. Our experience is that when presented with iTree data (such as benefits of trees in dollars, or environmental services of trees) our stakeholders will question the data validity. They want to know how it was calculated and how accurate the information is. iTree users aren't able to answer these types of questions, as a measure of certainty is missing. By developing a certainty measure this proposal will greatly improve the product by giving users a way to evaluate the certainty of iTree's outputs.

2. *Develop a decision support tool*. Currently users are left to independently apply and interpret iTree findings to their individual situations. In reality, managers don't have time to make the jump from iTree findings to useful field application – they need easy an easy to use product that will help them make decisions. In Portland we are trying to determine where to plant trees to meet a variety of goals: to address inequities in canopy access, to

combat urban heat island effects, to improve air quality along transit corridors, etc. There are currently no tools available to do this easily. It would be an amazing, practical, and incredibly powerful tool for iTree to include a decision support tool where users could prioritize goals and use their data to the most important hotspots for both tree planting and tree preservation. Too often urban forest managers are forced to rely solely on their own professional experience to make these key decisions. Having a powerful product such as iTree to lend credibility to these decisions would greatly benefit managers.

Portland is thrilled to be considered as a case study for a project such as this. What a rare opportunity to have the developer's ear of a product that you use regularly! Our Urban Forestry Outreach and Science Supervisor can work directly with Dr. Kroll's team to coordinate efforts. We welcome the chance to begin a collaboration that will provide tools to benefit urban forestry managers across the globe.

Sincerely,

Jenn Cairo
City Forester
Jenn.Cairo@portlandoregon.gov

Angie DiSalvo
Outreach & Science Supervisor
Angie.DiSalvo@portlandoregon.gov

City of Phoenix

PARKS AND RECREATION DEPARTMENT
SPECIALIZED MAINTENANCE AND AQUATICS DIVISION

Chuck Kroll

Environmental Resources Engineering

SUNY ESF

Syracuse, NY 13210

April 5, 2016

Mr. Kroll,

The city of Phoenix would be pleased to participate as a potential study location for your "A Decision Support System to Develop, Analyze, and Optimize Urban and Community Forests" project. I would be happy to share and discuss information regarding our past iTree and iEco analysis, as well as our current inventory and proposed plans.

While I continue to utilize iTree data analysis to support the urban forestry efforts in the Phoenix area, and am confident in the numbers, I am occasionally questioned regarding model uncertainty. I think this project to assess any uncertainty and help define means to optimize benefits will be well-received by the urban forest management community.

Feel free to contact me at richard.adkins@phoenix.gov or 602.495.3762 should you have any further questions. Good luck on the proposal submittal. I look forward to opportunity to work with you and your team on this project.

Respectfully,

Richard Adkins

Forestry Supervisor

Parks and Recreation Department

City of Phoenix

Natural Areas Conservancy

April 13, 2016

National Urban and Community Forestry Advisory Council
USDA Forest Service
201 14th. St. SW, Sidney Yates Bldg. 3SC-01C
Washington, DC 20024

Re: Letter of Support for SUNY-ESF/The Davey Tree Expert Company Proposal – A Decision Support System to Develop, Analyze and Optimize Urban and Community Forests

Dear National Urban and Community Forestry Advisory Council,

On behalf of the Natural Areas Conservancy (NAC), I would like to extend my support of the NUCFAC proposal entitled "A Decision Support System to Develop, Analyze, and Optimize Urban and Community Forests" by Chuck Kroll and Ted Endreny of the State University of New York College of Environmental Science and Forestry (SUNY ESF) and Scott Maco of the Davey Tree Expert Company. i-Tree is a suite of urban forestry tools that has been used by New York City to characterize and assess current canopy cover, and to plan for future plantings. The proposed project will develop methods to assess the uncertainty of output from i-Tree tools, and develop a decision support system to help urban planners better understand the tradeoffs between different urban forest planting schemes and develop more optimal management plans.

We are aware that the proposed project has recommended modeling parts of New York City as one of their case studies. We welcome this analysis and will provide support by discussing plans for current and future tree plantings, helping identify areas of New York City that may be underrepresented in terms of urban forest ecosystem services, and providing publically available data on the current inventory of trees in New York City. We look forward to this collaboration.

Founded in 2012, the Natural Areas Conservancy is an independent, non-profit organization devoted to restoring and conserving 10,000 acres of New York City's forests, grasslands, and wetlands. We preserve and promote ecological diversity and resilience across the five boroughs in close partnership with the New York City Department of Parks & Recreation.

Thank you for the opportunity to voice our support of this important project.

Sincerely,

Sarah Charlop-Powers
Executive Director

November 20, 2015

National Urban & Community Forestry Advisory Council
US Forest Service
201 14th Street SW
Washington, D.C. 20250

Dear Sir or Madam:

I am writing to express my strong support for the proposal "A Decision Support System to Analyze and Minimize Development Impacts on Urban and Community Forests" submitted by Dr. Ted Endreny of the State University of New York (Syracuse), College of Environmental Science and Forestry.

The i-Tree suite of tree assessment and management programs has changed the way urban forests are evaluated and managed. i-Tree is now an integral part of urban forestry. It allows users like me to evaluate the structure and function of urban forests, and to determine the benefits provided. I've been fortunate to have used i-Tree in a number of urban forestry projects, as both an aid to planning and management and to describe how urban forests enhance human and environmental health.

I urge you to give this proposal your strongest consideration. My firm would be happy to assist in the development, testing and application of the proposed tools.

Thanks very much.

Sincerely,

James R. Clark, Ph.D.
Vice President

Lazarus Sims
Commissioner

Mary Beth Roach
Deputy Commissioner

PARKS, RECREATION AND YOUTH PROGRAMS

Stephanie A. Miner, Mayor

Drs. Chuck Kroll & Ted Endreny
Professors, Department of Environmental Resources Engineering
State University of New York, College of Environmental Sciences & Forestry
1 Forestry Drive, Syracuse, NY 13210

Re: NUCFAC Proposal

Date: November 17, 2015

Dear Drs. Kroll and Endreny

This letter serves to confirm that the Onondaga County / City of Syracuse Arborist is supportive of your NUCFAC proposal, *A Decision Support System to Analyze and Minimize Development Impacts on Urban and Community Forests*. Our local forest planning and management will benefit from the decision support system you are creating, allowing us to consider risk and uncertainty.

Please contact me or the Engineering Department if any additional information is needed.

Sincerely,

Stephen Harris
Onondaga County/City of Syracuse Arborist
Department of Parks, Recreation and Youth Programs

TN Department of Agriculture | Forestry

MEMORANDUM

To: National Urban and Community Forestry Advisory Council Committee

From: Jere Jeter, State Forester & Assistant Commissioner

Date: November 19, 2015

RE: Support for NUCFAC Proposal entitled *"A Decision Support System to Analyze and Minimize Development Impacts on Urban and Community Forests"*

I am in full support of the above identified NUCFAC proposal submitted by Dr. Theodore Endrey and partners The Davey Tree Expert Company and the USDA Forest Service Northern Research Station. This proposal appears to further strengthen and perfect the suite of i-Tree tools that have already proven to be very valuable to those of us interested in the sound management of our urban forests. While the results of this proposal, if approved, will have multiple benefits, the one most interesting to me is the provision of an improved decision support system that can be utilized by urban forest managers and others interested in the protection and enhancement of our urban natural resources.

I encourage you to vote favorably on this proposal.

JEJ

Division of Forestry • P.O. Box 40627 • Nashville, TN 37204

Tel: 615-837-5520 • Fax: 615-837-5003 • tn.gov/agriculture/section/forests

COLLEGES AND UNIVERSITIES RATE AGREEMENT

EIN: 1146013200L6

DATE:02/27/2015

ORGANIZATION:

RFSUNY and SUNY College of Environ.Sci. & Forestry
35 State Street
Albany, NY 12207-2826

FILING REF.: The preceding agreement was dated 02/21/2014

The rates approved in this agreement are for use on grants, contracts and other agreements with the Federal Government, subject to the conditions in Section III.

SECTION I: INDIRECT COST RATES

RATE TYPES: FIXED FINAL PROV. (PROVISIONAL) PRED. (PREDETERMINED)

	EFFECTIVE PERIOD				
TYPE	**FROM**	**TO**	**RATE(%)**	**LOCATION**	**APPLICABLE TO**
PRED.	07/01/2013	06/30/2017	57.00	On-Campus	Research
PRED.	07/01/2013	06/30/2017	26.00	Off-Campus	All Prog.ex.DOD Con
PRED.	07/01/2013	06/30/2017	59.00	On-Campus	Res. DOD Contract
PRED.	07/01/2013	06/30/2017	28.00	Off-Campus	Res. DOD Contract
PRED.	07/01/2013	06/30/2017	50.00	On-Campus	Instruction
PRED.	07/01/2013	06/30/2017	40.00	On-Campus	Oth.Spons.Progr
PRED.	07/01/2013	06/30/2017	12.00	On-Campus	IPA
PROV.	07/01/2017	Until Amended			Use same rates and conditions as those cited for fiscal year ending June 30, 2017.

*BASE

Modified total direct costs, consisting of all direct salaries and wages, applicable fringe benefits, materials and supplies, services, travel and up to the first $25,000 of each subaward (regardless of the period of performance of the subawards under the award). Modified total direct costs shall exclude equipment, capital expenditures, charges for patient care, rental costs, tuition remission, scholarships and fellowships, participant support costs and the portion of each subaward in excess of $25,000. Other items may only be excluded when necessary to avoid a serious inequity in the distribution of indirect costs, and with the approval of the cognizant agency for indirect costs.

ORGANIZATION: RFSUNY and SUNY College of Environ.Sci. & Forestry
AGREEMENT DATE: 2/27/2015

SECTION I: FRINGE BENEFIT RATES**

TYPE	FROM	TO	RATE(%)	LOCATION	APPLICABLE TO
FIXED	7/1/2014	6/30/2015	42.50	All	Regular Employees
FIXED	7/1/2014	6/30/2015	15.00	All	Summer Employees
FIXED	7/1/2014	6/30/2015	14.00	All	Graduate Students
FIXED	7/1/2014	6/30/2015	5.00	All	Undergraduate Students
FIXED	7/1/2015	6/30/2016	44.00	All	Regular Employees
FIXED	7/1/2015	6/30/2016	15.00	All	Summer Employees
FIXED	7/1/2015	6/30/2016	16.00	All	Graduate Students
FIXED	7/1/2015	6/30/2016	5.00	All	Undergraduate Students
PROV.	7/1/2016	6/30/2018	45.00	All	Regular Employees
PROV.	7/1/2016	6/30/2018	15.00	All	Summer Employees
PROV.	7/1/2016	6/30/2018	18.00	All	Graduate Students
PROV.	7/1/2016	6/30/2018	5.00	All	Undergraduate Students

** DESCRIPTION OF FRINGE BENEFITS RATE BASE:

Salaries and wages.

SECTION II: SPECIAL REMARKS

TREATMENT OF FRINGE BENEFITS:

The fringe benefits are charged using the rate(s) listed in the Fringe Benefits Section of this Agreement. The fringe benefits included in the rate(s) are listed below.

1. These Facilities and Administrative cost rates apply when grants and contracts are awarded jointly to Research Foundation of SUNY and SUNY College of Environmental Science and Forestry.

2. For all activities performed in facilities not owned or leased by the institution or to which rent is directly allocated to the project(s), the off -campus rate will apply. Actual costs will be apportioned between on-campus and off-campus components. Each portion will bear the appropriate rate.

3. The fringe benefit costs listed below are reimbursed to the grantee through the direct fringe benefit rates applicable to Research Foundation employees:

A. Retiree Health Insurance
B. Retirement Expense
C. Social Security
D. NYS Unemployment Insurance
E. NYS Disability Insurance
F. Group Health Insurance
G. Group Life Insurance
H. Long Term Dis. Ins.
I. Workers' Compensation
J. Dental Insurance
K. Vacation & Sick Leave*

*This component consists of payments for accrued unused vacation leave made in accordance with the Research Foundation Leave Policy to employees who have terminated, changed accruing status, or transferred. It also includes payments for absences over 30 calendar-days that are charged to sick leave.

The fringe benefit costs for State University of New York employees are charged utilizing the New York State fringe benefit rate for federal funds. This approved rate is contained in the New York State-Wide Cost Allocation Plan. This rate includes the following costs:

A. Social Security
B. Retirement
C. Health Insurance
D. Unemployment Benefits
E. Workers' Compensation
F. Survivors' Benefits
G. Dental Insurance
H. Employee Benefit Funds

4. Equipment means an article of nonexpendable, tangible personal property having a useful life of more than one year, and an acquisition cost of $5,000 or more per unit.

5. Treatment of Paid Absences: *Vacation, holiday, sick leave pay and other paid absences are included in salaries and wages and are claimed on grants, contracts and other agreements as part of the normal cost for salaries and wages. Separate claims for the cost of these paid absences are not made.

This rate agreement updates Fringe Benefit rates only.

SECTION III: GENERAL

A. LIMITATIONS:

The rates in this Agreement are subject to any statutory or administrative limitations and apply to a given grant, contract or other agreement only to the extent that funds are available. Acceptance of the rates is subject to the following conditions: (1) Only costs incurred by the organization were included in its facilities and administrative cost pools as finally accepted: such costs are legal obligations of the organization and are allowable under the governing cost principles; (2) The same costs that have been treated as facilities and administrative costs are not claimed as direct costs; (3) Similar types of costs have been accorded consistent accounting treatment; and (4) The information provided by the organization which was used to establish the rates is not later found to be materially incomplete or inaccurate by the Federal Government. In such situations the rate(s) would be subject to renegotiation at the discretion of the Federal Government.

B. ACCOUNTING CHANGES:

This Agreement is based on the accounting system purported by the organization to be in effect during the Agreement period. Changes to the method of accounting for costs which affect the amount of reimbursement resulting from the use of this Agreement require prior approval of the authorized representative of the cognizant agency. Such changes include, but are not limited to, changes in the charging of a particular type of cost from facilities and administrative to direct. Failure to obtain approval may result in cost disallowances.

C. FIXED RATES:

If a fixed rate is in this Agreement, it is based on an estimate of the costs for the period covered by the rate. When the actual costs for this period are determined, an adjustment will be made to a rate of a future year(s) to compensate for the difference between the costs used to establish the fixed rate and actual costs.

D. USE BY OTHER FEDERAL AGENCIES:

The rates in this Agreement were approved in accordance with the authority in Office of Management and Budget Circular A-21, and should be applied to grants, contracts and other agreements covered by this Circular, subject to any limitations in A above. The organization may provide copies of the Agreement to other Federal Agencies to give them early notification of the Agreement.

E. OTHER:

If any Federal contract, grant or other agreement is reimbursing facilities and administrative costs by a means other than the approved rate(s) in this Agreement, the organization should (1) credit such costs to the affected programs, and (2) apply the approved rate(s) to the appropriate base to identify the proper amount of facilities and administrative costs allocable to these programs.

BY THE INSTITUTION:

RFSUNY and SUNY College of Environ.Sci. & Forestry

(INSTITUTION)

Christopher J Wade

(SIGNATURE)

Christopher J. Wade

(NAME)

Sr. Director of Cost Accounting & Procurement

(TITLE)

3/5/2015

(DATE)

ON BEHALF OF THE FEDERAL GOVERNMENT:

DEPARTMENT OF HEALTH AND HUMAN SERVICES

(AGENCY)

Darryl W. Mayes -S Digitally signed by Darryl W. Mayes -S DN: c=US, o=U.S. Government, ou=HHS, ou=PSC, ou=People, 0.9.2342.19200300.100.1.1=2000131666, cn=Darryl W. Mayes -S Date: 2015.03.02 11:36:16 -05'00'

(SIGNATURE)

Darryl W. Mayes

(NAME)

Deputy Director, Cost Allocation Services

(TITLE)

2/27/2015

(DATE) 0133

HHS REPRESENTATIVE:

Telephone: (212) 264-2069