TECHNICAL PROPOSAL

Selection No. 1270194

Develop guidelines and support country program in estimating the uncertainty of emission reductions from REDD+ programs using the Monte Carlo approach

A - Consultant's Organization

The Research Foundation of the State University of New York

Grants and contracts for research programs at SUNY College of Environmental Science & Forestry are awarded to the Research Foundation for SUNY. The Research Foundation (RF) is a private, non-profit 501c3 education corporation which exists to serve the State University of New York (SUNY) by providing essential research administration services. The RF is chartered to receive, hold and administer gifts or grants. The RF provides a central infrastructure of people, technology and processes that enable faculty to write and submit grant proposals to agencies, foundations and companies; establish contracts and manage funding that is awarded to run campus-based research projects; protect and commercialize intellectual property created within those projects; and promote transparency and accountability throughout the process.

B - Consultant's Experience

Assignment name: RCN: Quantifying Uncertainty in Ecosystem Studies (QUEST)	Approx. value of the contract (in current US$): $500,000
Country: USA, with cooperators in other countries Location within country: Syracuse, with cooperators in other locations	Duration of assignment (months): 84
Name of Client: National Science Foundation	Total No. of staff-months of the assignment: 60
Contact Person, Title/Designation, Tel. No./Address: Elizabeth Blood, Program Director 2415 Eisenhower Avenue Alexandria, VA 22314, USA 703.292.4349	
Start date (month/year): March 2013 Completion date (month/year): February 2020	No. of professional staff-months provided by your consulting firm/organization or your sub consultants: 60
Name of associated Consultants, if any: Craig See analyzed QUEST survey results Keith Olsen programmed the Stochastic Uncertainty Estimator (SUE)	Name of senior professional staff of your consulting firm/organization involved and designation and/or functions performed: Ruth Yanai, Project Coordinator John Campbell, Information Management Mark Green, Statistical Coordinator Mary Hagemann, Admin/Tech/Webmaster
Description of Project: The mission of the Research Coordination Network (RCN) is to facilitate the Quantification of Uncertainty in Ecosystem Studies (QUEST). The calculation of pools and fluxes at ecosystem scales has advanced our understanding of water, carbon, and nutrient cycling. However, uncertainty due to variability or error in observations or representations has rarely been reported. This makes it difficult to determine rates of change over time or compare results across multiple sites with quantitative confidence. Failure to address uncertainties can lead to erroneous conclusions, for example in identifying missing sources and sinks. Uncertainty analyses can also help to improve monitoring efficiency, by allowing sampling designs to optimize information gained relative to the resources required for data collection and analysis.	
Description of actual services provided by your staff within the assignment:	

Workshops on Uncertainty including the Monte Carlo Approach

- Introduction to Monte Carlo Error Propagation, International Long Term Ecological Research (ILTER) Open Science Meeting, Leipzig, Germany, September 3, 2019.
- Monte Carlo Propagation of Uncertainty Workshop, Biology Department at West Virginia University, Morgantown, WV, March 29, 2019.
- Better Monitoring through Uncertainty Analysis: Optimize allocation of effort, save time and money. Long Term Ecological Research All-Scientists' Meeting, October 3, 2018, Pacific Grove, CA.
- Quantifying Uncertainties and Merging Observations, Experiments, and Models for Improving Estimation, Mapping, and Forecasting of Terrestrial Ecosystem Dynamics. AGU Fall Meeting, December 12, 2016, San Francisco, CA.
- QUEST (Quantifying Uncertainty in Forest Ecosystem Studies). Soil Science Society of America International Annual Meeting, November 8, 2016, Phoenix, AZ.
- Monte Carlo Error Propagation workshop. ILTER Open Science Meeting, October 11, 2016, Skuzuka, South Africa.
- Sources of Uncertainty in Ecosystem Monitoring. LTER All Scientists Meeting, Sept 1, 2015, Estes Park, CO.
- IUFRO International Congress, Side Event: Practical Issues in Implementing Uncertainty Analysis. Oct 9, 2014, Salt Lake City, UT.
- Tools for Estimating Uncertainty in Ecology, Ecological Society of America meeting, Aug. 10, 2014, Sacramento, CA.
- Quantifying Uncertainty in Ecological Studies. LTER All Scientists Meeting, Sept 11, 2012, Estes Park, CO.
- Quantifying Uncertainty in Ecosystem Studies. Soil Sci. Soc. Am. Annual Meeting, August 9, 2011, Austin, TX.
- Estimating uncertainty in ecosystem budgets. Université Laval, Centre de foresterie de Laurentiedes (CFL) & Le Centre d'Étude de la Forêt (CEF), Québec, QC, Oct 13, 2010
- Uncertainty Workshop, Hubbard Brook Committee of Scientists, Jan 5, 2009.
- Monte Carlo in Excel: build your own uncertainty analysis.
    - Michigan State University, Department of Forestry, East Lansing, MI, Feb 20, 2009
    - Ecological Society of America meeting, Albuquerque, NM, Aug 2, 2009
    - Agronomy Society of America Meeting, Pittsburgh, PA, Nov 1, 2009

Selected Journal Articles

See, C.R., **M.B Green, R.D. Yanai**, A.S. Bailey, **J.L. Campbell,** and J. Hayward. 2020. Quantifying uncertainty in annual runoff due to missing data. *PeerJ*, *8*, p.e9531

Mobley, M.L., Y. Yang, **R.D. Yanai**, K A. Nelson, A.R. Bacon, and D.D. Richter. 2019. How to estimate statistically detectable trends in a time series: a study 1 of soil carbon and nutrient concentrations at the Calhoun Long-Term Soil-Ecosystem Experiment. *Soil Science Society of America Journal,* 83(Suppl1):S133-S140. DOI:10.2136/sssaj2018.09.0335

Campbell, J.L., M.B. Green, R.D. Yanai, C. Woodall, S. Fraver, M. Harmon, M. Hatfield, C. Barnett, C. R. See, and G. Domke. 2018. Estimating uncertainty in the volume and carbon storage of downed coarse woody debris. *Ecological Applications*, 29(2):e01844. DOI:10.1002/eap.1844

Yanai, R.D., C.R. See, **J. L. Campbell.** 2018. Current practices in uncertainty analysis in ecosystem ecology. *Ecosystems,* 21(5), 971-981. DOI: 10.1007/s10021-017-0197-x

Green, M.B, J.L. Campbell, R.D. Yanai, S.W. Bailey, A.S. Bailey, N. Grant, I. Halm, E.P. Kelsey, and L. E. Rustad. 2018. Downsizing a long-term precipitation network: using a quantitative approach to inform difficult decisions. *PLOS One,* 13(5): e0195966. DOI: 10.1371/journal.pone.0195966

Yang, Y., C.R. See, **R.D. Yanai** and M.A. Arthur. 2017. Sampling effort and uncertainty in litterfall mass and nutrient flux in northern hardwoods. *Ecosphere*, 8(11):e01999. DOI: 10.1002/ecs2.1999

Fahey, T.J., **R.D. Yanai,** K.E. Gonzales, and J.A. Lombardi. 2017. Sampling and processing roots from rocky forest soils. *Ecosphere*, 8(6). DOI: 10.1002/ecs2.1863

Campbell, J.L., R.D. Yanai, M.B. Green, G.E. Likens, C.R. See, A.S. Bailey, D.C. Buso, and D. Yang. 2016. Uncertainty in the net hydrologic flux of calcium in a paired-watershed harvesting study. *Ecosphere* 7(6). DOI:10.1002/ecs2.1299

Aulenbach, B.T., D.A. Burns, J.B. Shanley, **R.D. Yanai,** K. Bae, A.D. Wild, Y. Yang, and D. Li. 2016. Approaches to stream solute load estimation for solutes with varying dynamics from five diverse small watersheds. *Ecosphere* 7(6). DOI: 10.1002/ecs2.1298

Paré, D., G.Z. Gertner, P.Y. Bernier, PY and **R.D. Yanai.** 2016. Quantifying uncertainty in forest measurements and models: approaches and applications. *Can. J. For. Res.* 46(3): v. DOI:10.1139/cjfr-2016-0029

Yang, Y., **R.D. Yanai,** F.R. Fatemi, C.R. Levine, P.J. Lilly, and R.D. Briggs. 2016. Sources of variability in tissue chemistry in northern hardwood species. *Can. J. For. Res.* 46(3): 285–296. DOI: 10.1139/cjfr-2015-0302

Yanai, R.D., N. Tokuchi, **J.L. Campbell, M.B. Green**, E. Matsuzaki, S.N. Laseter, C.L. Brown, A.S. Bailey, P. Lyons, C.R. Levine, D.C. Buso, G.E. Likens, J. Knoepp, and K. Fukushima. 2015. Sources of uncertainty in estimating stream solute export from headwater catchments at three sites. *Hydrol. Processes* 29: 1793–1805. DOI: 10.1002/hyp.10265

Levine, C.R., **R.D. Yanai**, G.G. Lampman, D.A. Burns, C.T. Driscoll, G.B. Lawrence, J.A. Lynch, and N. Schoch. 2014. Evaluating the efficiency of environmental monitoring programs. *Ecol. Indic.* 39: 94–101. DOI: 10.1016/j.ecolind.2013.12.010

Yanai, R.D., C.R. Levine, **M.B. Green, and J.L. Campbell**. 2012. Quantifying uncertainty in forest nutrient budgets. *J. For*. 110(8): 448–456. DOI: 10.5849/jof.11-087

Campbell, J., R. Yanai, and M. Green. 2011. Estimating uncertainties in watershed studies. *Eos Trans. AGU*, 92(26):220. DOI: 10.1029/2011EO260004

Yanai, R.D., J.J. Battles, A.D. Richardson, E.B. Rasetter, D.M. Wood and C. Blodgett 2010. Estimating uncertainty in ecosystem budget calculations. *Ecosystems* 13(2): 239–248

Assignment name: Quantifying Uncertainty Estimates and Risk for Carbon Accounting (QUERCA)	Approx. value of the contract (in current US$): $110,000
Country: USA, with cooperators in other countries Location within country: Syracuse, with cooperators in other locations	Duration of assignment (months): 20
Name of Client: US Forest Service, International Programs	Total No. of staff-months of the assignment: 14.5
Contact Person, Title/Designation, Tel. No./Address: Rebecca Ciciretti, Latin America and Caribbean Program Specialist, Forest Service, International Programs, Office of the Chief One Thomas Circle, Suite 400 Washington, DC 20005 202-644-4611 rebecca.ciciretti@usda.gov	
Start date (month/year): January 2020 Completion date (month/year): August 2021	No. of professional staff-months provided by your consulting firm/organization or your sub consultants: 14.5
Name of associated Consultants, if any: Lalita Adhikari is a consultant and future ESF graduate student who is developing the QUERCA Survey Brett Butler, USDA Forest Service is an expert on survey design, who is guiding Lalita Adhikari.	Name of senior professional staff of your consulting firm/organization involved and designation and/or functions performed (e.g. Project Director/Coordinator, Team Leader): Craig Wayson, Vision Ruth Yanai, Project Lead Mark Green, Monte Carlo Expert John Campbell, Forest Carbon

Description of Project: QUERCA (Quantifying Uncertainty Estimates and Risk in Carbon Accounting) was founded in 2019 to address the need to improve REDD+ uncertainty calculations.
Description of actual services provided by your staff within the assignment: Currently, QUERCA is developing a survey of authors of REDD+ reports to help identify obstacles to properly estimating uncertainty.

Assignment name: Fellowship to Assess Long-Term Monitoring Programs for Sulfur, Nitrogen and Mercury Deposition and Impacts in New York State	Approx. value of the contract (in current US$): $79,446
Country: USA Location within country: New York State	Duration of assignment (months): 16
Name of Client: New York State Energy Research and Development Authority	Total No. of staff-months of the assignment: 10.5
Contact Person, Title/Designation, Tel. No./Address: Greg Lampman, Program Manager for Environmental Research at NYSERDA 17 Columbia Circle Albany, NY 12203-6399 518-862-1090 x3372	
Start date (month/year): July 1, 2011 Completion date (month/year): November 30, 2012	No. of professional staff-months provided by your consulting firm/organization or your sub consultants: 10.5
Name of associated Consultants, if any: Carrie Rose Levine	Name of senior professional staff of your consulting firm/organization involved and designation and/or functions performed (e.g. Project Director/Coordinator, Team Leader): Ruth Yanai, Project Lead
Description of Project:	

It is important to evaluate long-term monitoring programs periodically to ensure that these programs remain efficient and effective. A comprehensive evaluation of long-term environmental monitoring had never been undertaken in New York State. Such an analysis is necessary to identify possible improvements in sampling designs to maximize information gained relative to the resources required for data collection.
Description of actual services provided by your staff within the assignment: 1. Provide a compendium of past and current research activities and monitoring efforts in New York State relating to the study of acidic and Hg deposition. 2. Analyze monitoring efforts to characterize the efficiency of monitoring and to identify redundancies and gaps in coverage. 3. Provide guidance for data users, funders, and cooperators to use in having informed discussions around how to modify existing monitoring programs most effectively to meet the policy and science needs of tomorrow, given the resource constraints of today.

C – Comments and/or Suggestions on the Terms of Reference

We propose the use of a survey prior to working with REDD+ program staff, to better understand their initial attitude towards and state of understanding of uncertainty analyses. This will enable us to select which training modules are appropriate to which participants and to adjust our draft guidelines and tools. At the end of our work with each program we administer the survey again to assess whether our efforts have in fact improved capacity or merely helped programs with their applications. The survey tool is under development with separate funding and will be ready for testing by December.

There are differences of opinion as to whether tools for uncertainty analysis can be made sufficiently generic that any program could merely enter their data and push a button without understanding the details of the uncertainty analysis. We are not fans of this approach. We trust that you will select up to four REDD+ programs for us to work with that will represent the range of possible problems encountered in the process of uncertainty analysis. Perhaps we will be proven wrong and a black box tool will work for all of them. There is a second reason to avoid the black box approach. We hope to build capacity for understanding the fundamentals of uncertainty sources and error propagation methods. Improved understanding will reduce the chances of making mistakes in propagating uncertainties or accepting uncertainty estimates that are wildly unrealistic.

We understand that at this point the FCPF Carbon Fund is committed to propagating uncertainty using Monte Carlo methods. We will also introduce and teach the use of analytical methods, for two reasons. The first is for capacity building, specifically for developing an understanding of how to combine uncertainties. The second reason is that it can improve the results. In cases where uncertainty sources are treated as independent, summing in quadrature gives the same result as Monte Carlo simulation. Even where uncertainties are correlated, analytical error propagation can be easier to implement, and using both approaches builds confidence in the results.

D - Description of Approach, Methodology and Work Plan

a)Technical Approach and Methodology.

Our understanding of the current state of uncertainty reporting in REDD+ programs is summarized here, mostly abstracted from our paper (Yanai et al. 2020, in press in Environmental Research Letters). The paper, including the full list of authors and the references, is provided as an Appendix.

1. Background

Forests are a critical part of the solution to address the global climate crisis because of their natural ability to remove carbon dioxide from the atmosphere and the magnitude of carbon dioxide emissions from deforestation and forest degradation. One strategy for decreasing carbon emissions and enhancing forest carbon sinks is to provide developing countries with results-based financial incentives to reduce deforestation. Countries participating in these incentive programs must document the uncertainty in their estimates along with their claimed emission reductions (ERs).

Unfortunately, uncertainties in estimates of net emissions in the forest sector can be quite large, making it challenging to evaluate carbon mitigation efforts in the forest sector. Most results-based payment programs include procedures that reduce payments to account for uncertainty in emissions estimates (i.e., payments are made for a portion of estimated emission reductions). Our examination of documentation submitted to date to the United Nations Framework Convention on Climate Change (UNFCCC) and the Forest Carbon Partnership Facility (FCPF) revealed that uncertainties are commonly underestimated, both by omitting important sources of uncertainty (Section 2) and by incorrectly combining uncertainties (Section 3).

2. Omitting important sources of uncertainty

There are many sources of uncertainty in estimates of forest carbon fluxes, some more difficult to quantify than others (Houghton 2003). These uncertainty sources include sampling error (e.g., due to variability in point estimates within a land-use type), measurement error (e.g., in tree diameter, height, wood density), model error (e.g., in regressions describing tree allometry, such as the relationship of biomass to diameter and height), and inaccurate land-use classification based on remote sensing (FAO 2018, Hill et al. 2013). Omitting sources of uncertainty from consideration has the effect of underestimating the true combined uncertainty (Picard et al. 2015a).

Although countries have made efforts to discuss sources of uncertainty and account for some of them, many sources are still omitted, which effectively assigns them, incorrectly, zero uncertainty. Of the 18 countries that have submitted reference levels to the FCPF Carbon Fund, none of them reported measurement uncertainty in land-use change (AD), which, admittedly, is not straightforward to quantify. Some countries (7) quantified at least some sources of measurement uncertainty in forest carbon density (EF). The most widely quantified source of uncertainty is spatial sampling error, with all but 1 country reporting this for both AD and EF. Ten countries accounted for uncertainty in allometric models and carbon concentrations and 14 countries accounted for uncertainty in below ground biomass estimated

using root-to-shoot ratios. Finally, describing the procedures used to assure the quality of the data (QA/QC) is accepted in lieu of reporting measurement uncertainty: 14 countries took this approach for EF and 7 for AD. Unfortunately, meeting this requirement does not ensure that the QA/QC data are used to improve measurements; many countries collect the information necessary to quantify measurement uncertainty but have not analyzed the results.

Similarly, omitting specific carbon pools, as often occurs because they are difficult to quantify, makes it difficult to evaluate the importance of these pools. There are five carbon pools in REDD+; most countries report on above- and belowground tree carbon, but few provide information on dead wood, soils, or litter (FAO 2019). Ironically, the usual justification given for omitting these sources of carbon emissions is that they are poorly known and difficult to quantify, meaning that the uncertainties may be quite large. Quantifying them would be better than ignoring them, given that all the sources contribute to the climate crisis and the shared goal is to reduce emissions for the lowest cost. Attention to uncertainty sources might reveal that efforts could be better placed by attending to these pools and sources.

3. Errors in error propagation (incorrectly combining uncertainties)

Combining multiple sources of uncertainty to provide a single estimate, as is needed for country-level carbon accounting, can be challenging, in part because there are so many ways to make mistakes.

As of April 2020, our examination of 60 forest reference level submissions, including resubmissions, to the UNFCCC (figure 5) and 18 Emission Reductions Program Documents to the FCPF (which contain proposed reference levels) found that very few correctly combined the uncertainty of individual components to estimate overall uncertainty. There were 19 submissions that combined uncertainties by summing in quadrature, commonly reporting a total error smaller than the individual component errors. This result would be correct if the errors of each component were independent, but often they are not, as described below. At least 5 countries incorrectly reported the uncertainty in the mean or median of Monte Carlo estimates, rather than the dispersion of the estimates (described below), resulting in reported uncertainties as low as 0.1%.

3.1 Pitfalls of Monte Carlo Error Propagation

One way to combine the effects of uncertain inputs is to randomly sample from their assumed distributions. In this approach, called Monte Carlo simulation (for its similarity to gambling), a carbon accounting calculation is iterated hundreds or thousands of times, with the inputs varying randomly to mimic the uncertainties in their values (Metropolis 1987). The distribution of the resulting hundreds or thousands of outputs reflects the net effects of the input uncertainties.

A common mistake in interpreting this output is to report the uncertainty in the mean or median of that distribution as an indicator of the uncertainty in the output. It is not, for the simple reason that in the real world, we will not get all the Monte Carlo trials; we will only get one of them, and we don't know which one. Each trial has the same chance as all the

other trials of corresponding to reality, as far as we know. This mistake is a big one, typically underreporting uncertainty by a factor of 100, because calculating uncertainty in the central tendency (e.g., the standard error of the mean) involves dividing the standard deviation by the square root of the number of "observations," which is commonly 10,000 trials.

For the country shown below (Dominican Republic), the uncertainty reported to the FCPF should have been >1000%. Instead, the uncertainty in the median of the Monte Carlo estimates was reported, which was very small (0.11 Mt/yr, or 7%), because the number of estimates was very large (10,000). To accurately characterize the distribution, it is important to make a large number of estimates, but making more estimates does not diminish the uncertainty. The confidence in the best estimate (sometimes reported as the standard error of the mean, which is the standard deviation divided by the square root of the number of estimates, and in this case the 90% CI around the median, obtained by sampling from the estimates) could be made arbitrarily small by increasing the number of Monte Carlo iterations, but the 90% CI of the increased number of estimates would remain just as wide.

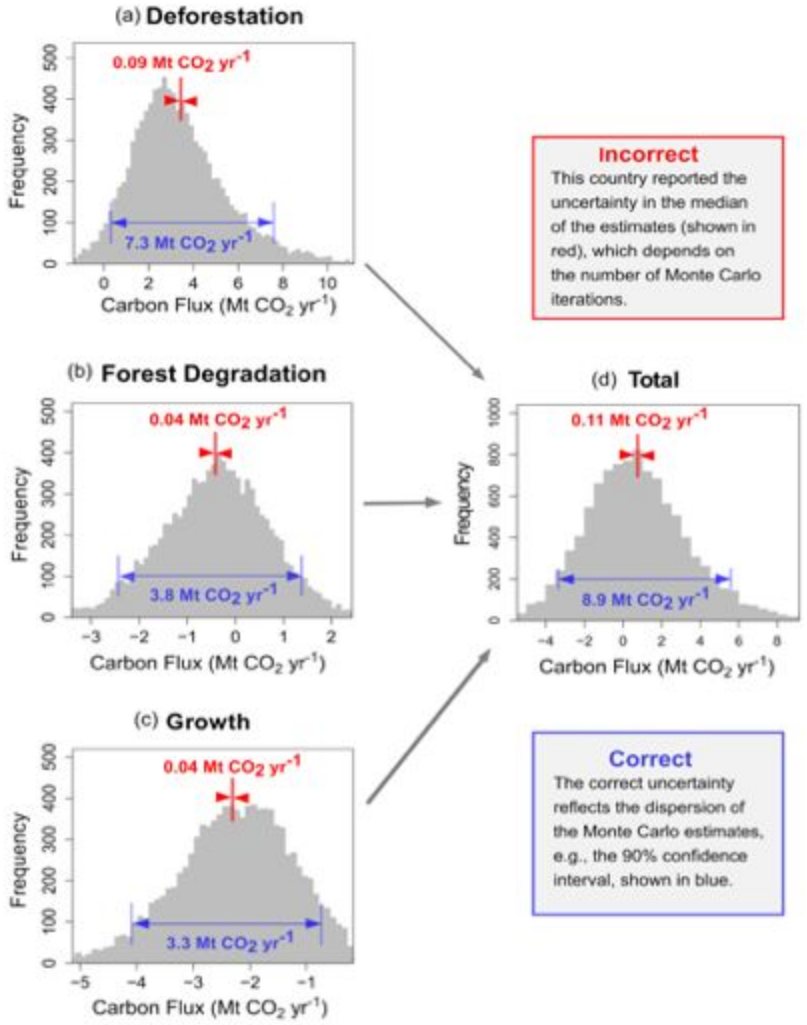


Figure 1. Confidence intervals in a Monte Carlo simulation. (a) The estimated carbon emissions from deforestation over the reference period are significantly positive, with more than 90% of the Monte Carlo estimates greater than zero. (b) For forest degradation, the 90% confidence interval (CI), shown in blue, includes zero--we are not confident whether the net effect is positive or negative. (c)

Forest growth is clearly a carbon sink. (d) The net effect of deforestation, degradation, and growth is highly uncertain, with 90% of the values falling between -3.3 and +5.6 megatonnes of CO2 per year. This uncertainty (8.9 Mt/yr) dwarfs the mean estimate of +0.8 Mt/yr.

Using the Monte Carlo approach requires defining the distributions of the inputs; commonly, in the absence of information to the contrary, normal distributions are used, based on the standard deviation of the observations, which may not be realistic. An alternative to describing the distribution of the inputs is to resample the data. This approach requires no assumption of a distribution and is thus most true to the measured population. The drawback to this approach is that the representation of the population is only as good as the data, and if the data set is small, it may not accurately capture the range of potential values.

An analytical approach to combining uncertainty sources is easier to implement and avoids the mistake of reporting the wrong property of a distribution of Monte Carlo trials. For example, when adding uncertain estimates, the uncertainty in the sum can be calculated as the so-called "sum in quadrature" of the uncertainty in the inputs. The uncertainty in a sum can be estimated by squaring the uncertainties of the component quantities, adding them together, and taking the square root of the sum--as long as the uncertainty sources are independent (sometimes they are not; see below). This approach, referred to as Approach 1 in the IPCC guidelines (IPCC 2006), was commonly used in early submissions to the UNFCCC. Since 2013, the Monte Carlo approach (Approach 2 in IPCC parlance) has been required for participation in the FCPF. Using multiple approaches to combine uncertainties could be a good strategy for identifying some of these common mistakes.

3.2 Independent vs. Shared Sources of Uncertainty in Space

For both the analytical approach and the Monte Carlo approach to combining sources of uncertainty, it is easier to treat the various sources as independent than to account for the relationships among them. Misrepresenting these relationships, either by assuming that uncertainties are independent when they are shared, or assuming that they are shared when they are independent, is another common source of mistakes in uncertainty accounting.

When combining uncertainties from multiple land areas, treating all uncertainty sources as independent can result in very low combined uncertainty. For example, in 2015, one country reported a reference level for carbon emissions with an uncertainty of only 1.5%. This calculation involved 18 forest types, with uncertainties based only on sampling error, which averaged 19% (and ranged from 2 to 92%). Combining values that range from 2 to 92 to obtain a summary of 1.5 seems counterintuitive, because we are more familiar with averaging observations than uncertainties. A weighted average of the carbon emissions would lie between the highest and lowest values. But the uncertainties in carbon emissions, if independent, do not add directly--they sum in quadrature--because any estimate could be either too high or too low, and combining opposing errors can give an answer closer to the truth. However, if the uncertainties were shared, over- and under-estimates would coincide, and they would sum normally.

Another report submitted in 2019 used a national-scale sampling error of 10%, assigned this to all the forest types, and then combined them as if they were independent. If there were two evenly distributed forest types, this would give a combined uncertainty of 7% (using analytical uncertainty propagation, the square root of the sum of squared uncertainties in this case is); if there were 20 forest types, each 5% of the land area, the combined uncertainty would be 2.2% (), and so on, down to vanishingly small uncertainties with very large numbers of forest types. Thus it appears to be advantageous for uncertainty reporting to consider as many forest types as possible.

However, these reports of small uncertainties, although correct for sampling error alone, fail to account for many other sources of uncertainty. Those sources that are shared are not diminished by dividing up the landscape. For example, the belowground biomass of forests is often estimated from aboveground biomass, using a ratio (root:shoot) measured at another location. Measurements of root biomass are rare, because they are costly and destructive; thus, the same root:shoot ratio is commonly used across many forest types, because the true root:shoot ratios are unknown. Similarly, although forest inventory data are collected independently across forest types, they are usually converted to carbon stores using common allometric relationships, tissue density, and carbon fraction. These sources of uncertainty, which may amount to 5-10%, are not diminished by applying them to multiple forest types. To the degree that they are in error, they are in error in the same direction in every instance, and for this reason it is a mistake to combine them as if they were independent.

The two examples described above did not incorrectly combine uncertainties, they merely omitted sources that should have been treated as shared. Summing in quadrature is incorrect when used to combine shared uncertainties, as illustrated in a 2017 report, in which carbon emissions of 19% from the area in rainforest and 24% from the area in mesophytic forest were combined to give a country-level uncertainty of 15%. Summing in quadrature was not appropriate for the sources that were shared, which included allometry, tissue density, and carbon fraction. Rather than using addition in quadrature, they should be combined with proper attention to correlation among the sources, which can be done analytically (JCGM/WG1 2008). Monte Carlo sampling of shared errors, such as tree allometry, can be done correctly by assigning the same error to all trees at each Monte Carlo trial (Yanai et al. 2010). It is easy to make the mistake of assigning error independently for each observation, which results in unrealistically small errors at large spatial scales.

3.3 Independent vs. Shared Sources of Uncertainty in Time

While shared sources of uncertainty in assessing carbon stocks over multiple forest types in a country give higher uncertainty than if the sources were independent, they reduce uncertainties in change over time, compared to independent sources of uncertainty. If, for example, the same root:shoot ratio is used in two successive carbon inventories, an error in that ratio will lead to similar errors in both inventories and thus to relatively small uncertainty in the net change between them. Changes over time in carbon stocks and carbon emissions are what matter to mitigating climate change, not estimates at one point in time.

Similarly, revisiting the same plots over time to assess forest biomass gives a more precise estimate of change over time, by reducing the effects of plot-to-plot. Every plot on the

landscape is different; thus, if we conducted a new sample each time, this source of variation (sampling error) would be independent at each time. The value of resampling permanent forest inventory plots is illustrated with data from the US Forest Service Forest Inventory and Analysis (FIA) Program (Bechtold et al. 2005) for the state of Minnesota, USA (Figure 2). A pairwise comparison of estimates has about half the uncertainty (0.8 Mg C/ha) of an unpaired comparison (1.5 Mg C/ha).

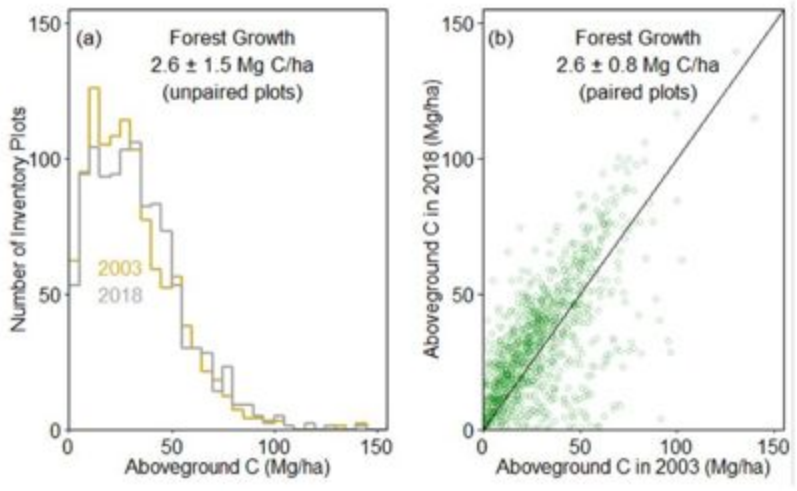


Figure 2. Uncertainties in independent vs. remeasured plots. Comparing aboveground carbon from 2003 to 2018 for 1093 forested FIA plots in Minnesota, USA, results in an uncertainty (90% CI) of 1.5 Mg C/ha if plots are treated as independent (a) but only 0.8 Mg C/ha if they are paired (b) because of the high correlation in forest biomass by plot.

Other examples of correlated error over time, besides sampling error, include allometric models. Allometric relationships are uncertain, as are conversion factors such as wood density and root-to-shoot ratio. However, although these parameters are not perfectly known, if they are incorrect at both time periods in the same way, they do not detract as much from our confidence in change over time as if they were incorrect in different ways at the two time periods. For this reason, it is important to use the same models and methods of calculation over time. There is also uncertainty in determining the land area undergoing transitions such as deforestation or degradation, and these uncertainties are less likely to be correlated over time than the factors that contribute to estimates of carbon per unit area. When maps are used to compare rates of change between two periods, there can be correlations in inaccuracies in classifying land cover change, which are commonly ignored. Again, accounting for these correlations would reduce the combined uncertainties.

4. Deliverables

Output 1: Draft guidance for applying the Monte Carlo approach for the estimation of the uncertainty of emission reductions

Draft guidance will be in the form of tutorials posted on the QUERCA web site. We will report on draft guidance in December 2020, within 6 weeks of the start of the contract. A detailed list of tutorials is provided in the Work Plan below.

Output 2: Application of the draft guidelines in training up to four ER programs to correctly report uncertainty.

We will report on our interactions with ER programs at the midpoint of our work with them. The results of our initial QUERCA survey of attitudes and knowledge of uncertainty analysis will be reported at this time. Our working notes will be available for review and comment in Google Docs or other internet-accessible form.

Output 3: Successful performance of up to four ER programs in reporting uncertainty in applying the draft guidelines and preparing the relevant sections of the required documentation.

We will summarize our interactions with ER programs at the end of our work with them, and the Montoring Reports required by the FCPF Carbon Fund will demonstrate the success of our efforts (and those of the program partners). We will also report, based on the QUERCA survey of members of the participating programs, as to improvements in attitudes and knowledge of uncertainty in REDD+ programs.

Output 4: Final Guidance posted on the QUERCA website.

The third and last output is the revised and improved guidance and tools, which will be posted on the QUERCA website.

b)Work Plan.

Task #1: Prepare draft guidance for applying the Monte Carlo approach for the estimation of the uncertainty of emission reductions

The first task is to prepare a draft of guidance and tools for quantifying uncertainty in emission reductions, consistent with the FCPF Methodological Framework, to be used and refined during Task #2.

Materials will be written in English, with the goal of being easily understood, and the test of how readily understandable these materials are will be their application in Task #2.

Our vision of guidance and tools includes developing the capacity of participating personnel to understand the methods of identifying uncertainty sources and propagating them, including

understanding whether uncertainty sources are shared, independent, or partially shared. Merely providing black-box tools will not prevent the types of errors that are currently common in REDD+ reporting.

This draft of the guidance will include the following parts.

- A tutorial that introduces basic error propagation by Monte Carlo methods and analytical methods, demonstrating that both give the same result, with attention to the improved precision (but not reduced uncertainty) provided by greater numbers of Monte Carlo iterations.
- A tutorial that introduces error propagation with covariance among the terms, again with reference to both Monte Carlo and analytical methods. The use of both approaches, in simple cases, provides an easy means of verifying a result.
- A flowchart showing how to identify sources of uncertainty in REDD+ calculations.
- A tutorial on propagating uncertainty in allometric models of forest biomass.
- A tutorial introducing two approaches to defining the values to be sampled in Monte Carlo simulation: bootstrapping (sampling data) and probability distributions.
- A tutorial demonstrating how to propagate uncertainty in sample-based estimation of Activity Data taking into account variability associated with sampling (e.g., confidence intervals for area of deforestation) and variability associated with visual interpretation of remotely sensed data to produce reference data (e.g., use of an agreement matrix derived from independent, duplicated interpretations of a subsample of units).
- Examples of correctly propagated uncertainties in Emission Factors and mistakes to avoid.
- Examples of correctly propagated uncertainties in Activity Data and mistakes to avoid.
- Examples of correctly propagated uncertainties in Emission Reductions, showing the effects of shared uncertainty sources between the reference level and the monitored estimates.
- A fun quiz game to test whether participants have mastered the concepts illustrated in all of the above products.

Developing the guidance may reveal opportunities to improve the FCPF Guidelines on Uncertainty Analysis of Emission Reductions. For example, based on our limited experience, it is not clear why analytical methods of error propagation should be prohibited, where they are equally correct and easier to apply than Monte Carlo methods.

Output 1, reporting the products of Task #1, will be delivered within 6 weeks of the project start date, in December 2020.

Task #2: Support maximum four ER programs in applying the draft guidelines and preparing the relevant sections of the required documentation.

The draft guidelines developed under Task #1 will be applied in up to four case studies in the FCPF Carbon Fund, using participating programs to be selected by the World Bank.

Our interactions with participants will be conducted remotely, which has several advantages in addition to avoiding the risk of transmitting Covid-19. Remote interactions allow more freedom in scheduling and this convenience in scheduling plus readiness of access can allow broader participation both by members of participating programs and also the QUERCA personnel.

- Before our first training session, we will survey participants to assess their current level of understanding of uncertainty approaches. The results will allow us to tailor our training sessions to the appropriate level and to invite specific participants to the appropriate sessions. This step will also allow us to test and improve our survey instrument. The QUERCA survey development is funded separately by SilvaCarbon and does not appear in the budget for this contract.
- We will conduct online trainings, using the tools developed under Task #1. The objectives of these trainings are to
    - Develop basic understanding and skills in error propagation, using Excel, introducing both analytical and Monte Carlo approaches.
    - Introduce the application of these skills to FCPF reporting
- We will interact closely with program staff as they proceed through the steps required to estimate uncertainties as required by the Monitoring Report.
- We will provide feedback for improvement on section 5 of the Monitoring Report as prepared by the program team both before and after review by the Validation and Verification Body (VVB).
- At the end of our interactions with each of the program teams, we will ask them to complete the QUERCA Survey a second time. Thus we will have an indication of improvement in knowledge and attitudes resulting from our efforts.

Task #2 has two reporting dates, in February and May 2021, to provide information and seek feedback. Output 2 will document our work to date and report on the initial survey results. Output 3 will demonstrate the successful completion of the Montoring Reports required by the FCPF Carbon Fund.

Task #3: Finalize the guidance and identify common tools

Application of the draft guidelines under Task #2 will reveal opportunities to improve the guidelines, both by showing where communication of ideas or techniques could be more effective, and by encountering additional types of problems or errors not anticipated in the draft guidelines. Thus the final task is to produce the best compilation of guidance and tools, including those developed by others in addition to those developed by the QUERCA team.

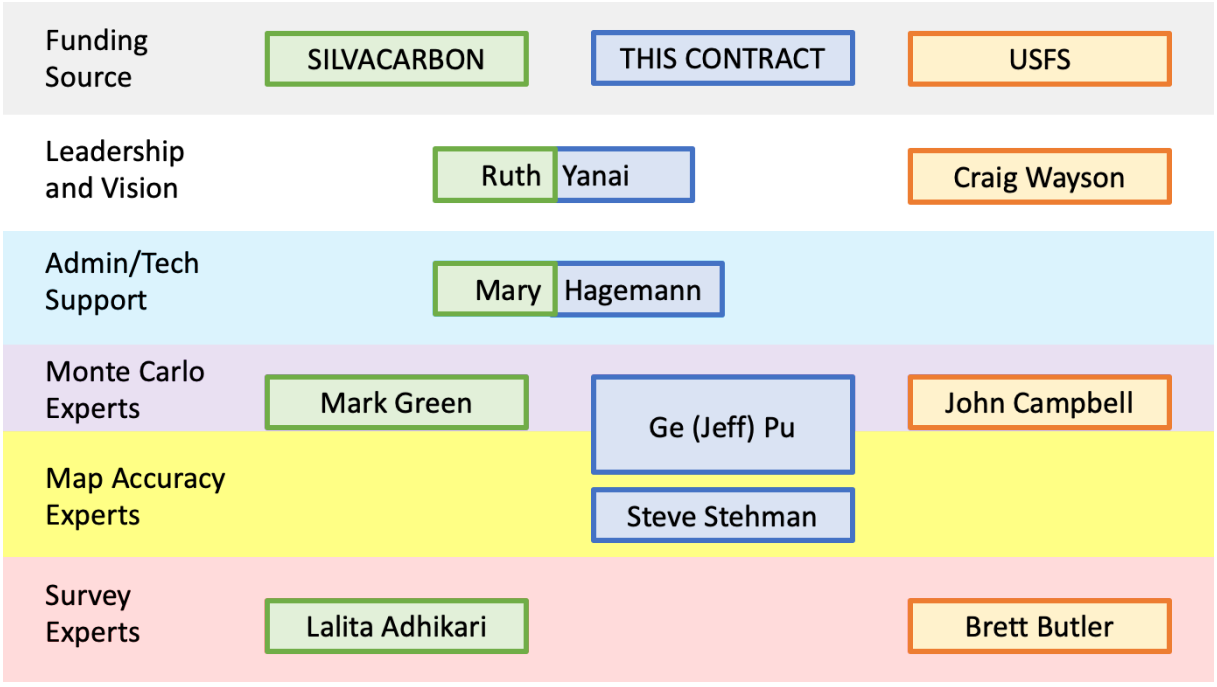
Output 4, reporting the products of Task #3, will be delivered in June, 2021.

We plan to develop a QUERCA website where resources specific to REDD+ carbon accounting will be made available. The QUEST website, which will provide a link to the QUERCA website, made tools, sample code, and relevant papers available to an audience interested in Quantifying Uncertainty in Ecosystem Studies (www.quantifyinguncertainty.org).

We will welcome additional interaction with program teams, as QUERCA's commitment to improving the appreciation and reporting of uncertainty in REDD+ carbon accounting will persist beyond the duration of this contract.

c)Organization and Staffing.

Personnel funded by this contract are shown in blue in the center of the organizational chart shown below. Ruth Yanai will lead the project. Ge (Jeff) Pu and Steve Stehman are experts in map accuracy assessment, and Ge Pu is also proficient in Monte Carlo simulation. Mary Hagemann will provide administrative and technical support, including designing and maintaining the website. The QUERCA team is also supported by SilvaCarbon, through the US Department of State and US Agency for International Development (personnel shown on the left), and by the USDA Forest Service (shown on the right). Contributions to the proposed work by QUERCA personnel funded by these other sources will add value to the outputs of this contract at no additional expense to the World Bank. Specifically, Mark Green (SilvaCarbon) and John Campbell (Forest Service) will provide Monte Carlo expertise, and the QUERCA Survey is the work of Lalita Adhikari (SilvaCarbon) and Brett Butler (Forest Service). Craig Wayson (Forest Service) is a REDD+ uncertainty expert, who together with Ruth Yanai provides leadership and vision for all QUERCA activities.



ANNEX 1: TEAM COMPOSITION, TASK ASSIGNMENTS & LEVEL OF EFFORT (LOE)

Key Personnel

Name of Staff & Firm associated with[1]	Area of Expertise Relevant to the Assignment	Designation for this Assignment[2]	Assigned Tasks or Deliverables (Tasks 1, 2, 3)	Location[3]	Number of Days
Ruth Yanai SUNY RF	Uncertainty, Forests	Project Leader	Project supervision Tasks 1, 2, 3	Local	20
Steve Stehman SUNY RF	Activity data uncertainty	Statistical expert	Develop guidance 1, 3	Local	20
Mary Hagemann SUNY RF	Admin, Technical	Support specialist	Support all Tasks 1, 2, 3	Local	20
Pu Ge SUNY RF	Map uncertainty, Monte Carlo	Tool development	Guidance and tools 1, 3	Local	125
Craig Wayson USFS	REDD+ Uncertainty	International Capacity Building	Strategic guidance 1, 2, 3	Local	0 (Funded by USFS)
Mark Green Case Western	Monte Carlo	Monte Carlo Expert	Participate in Tasks 1, 2, 3	Local	0 (Funded by Silvacarbon)
John Campbell USFS	Uncertainty, Forest C cycling	Monte Carlo Expert	Participate in Tasks 1, 2, 3	Local	0 (Funded by USFS)
Brett Butler USFS	Forests, Surveys	Survey Expert	Survey guidance Task 2	Local	0 (Funded by USFS)
Lalita Adhikara Consultant	REDD+ in Nepal	Survey Expert	Survey development, 2	International	0 (Funded by Silvacarbon)

[1] Indicate if the proposed staff is an employee or agent of your consulting firm/organization or a sub consultant.
[2] Title or position as described in the TOR or otherwise named in your proposed Organization and Staffing under Section D, sub section (c).
[3] Relative to the assignment subject of the Contract, indicate if the staff/consultant local or international.

ANNEX 2: CURRICULUM VITAE (CV) OF PROPOSED KEY PERSONNEL

1. **Name of Staff**: Ruth Diane Yanai

2. **Proposed Position**: Project Lead

3. **Employer**: State University of New York College of Environmental Science and Forestry

4. **Date of Birth**: 08/20/1958 **Nationality**: American

5. **Education**

School, college and/or University Attended	Degree/certificate or other specialized education obtained	Date Obtained
Yale Graduate School	Ph.D./M.Phil/M.S	1990/1987/1985
Yale College	B.A.	1981

6. **Professional Certification or Membership in Professional Associations**:

Ecological Society of America, Agronomy Society of America, Soil Science Society of America, and American Geophysical Union.

7. **Other Relevant Training**:

Data Handling and Exploratory Analysis in R, Oct-Nov 2012, Tokyo University, led by Mark Green

8. **Countries of Work Experience**:

Japan, New Zealand, USA

9. **Languages**

English: excellent in speaking, reading, and especially writing
French: good in speaking and reading, fair in writing
Japanese: poor in speaking, reading, and writing

10. **Employment Record**

2007 - present Professor, SUNY College of Environmental Science and Forestry.
2016 Visiting Academic, School of Forestry at the University of Canterbury, New Zealand.
2011 - 2015 Director, Graduate Program in Environmental Science, SUNY College of Environmental Science and Forestry.

2012 – 2013 Visiting Professor, University of Tokyo, Graduate School of Agricultural and Life Sciences (5 months).
2008 Sabbatical Fellow, Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA.
1999 - 2007 Associate Professor, SUNY College of Environmental Science and Forestry.
2007 Instructor, Forestry and Forest Products Research Institute, Tsukuba, Japan (1 month).
2006 Visiting Professor, University of Tokyo, Graduate School of Agricultural and Life Sciences (4 months).
1994 – 1999 Assistant Professor, SUNY College of Environmental Science and Forestry.
1994 Senior Research Associate, Boyce Thompson Institute for Plant Research.
1993 Visiting Assistant Professor, SUNY College of Environmental Science and Forestry.
1992 -1993 Research Associate, Boyce Thompson Institute for Plant Research.
1991 Postdoctoral Associate, Boyce Thompson Institute for Plant Research.
1989-1990 Research Support Specialist, Center for Environmental Research, Cornell University.
1987-1988 Fulbright Fellow, Edinburgh University and Institute of Terrestrial Ecology, UK.
1982-1983 Secondary School Teacher, The Putney School, Putney Vermont.

11. Detailed Tasks Assigned	**12. Work Undertaken that Best Illustrates Capability to Handle the Tasks Assigned**
Project Supervision, (Tasks 1, 2, 3) Guidance and tools (Tasks 1, 3) Support ER programs (Task 2)	Name of assignment or project: QUEST RCN Year: 2010-2020 Location: Syracuse, NY Client: National Science Foundation Main project features: Quantifying Uncertainty in Ecosystem Studies Activities performed: Coordinate the overall project, report outcomes to the client. Engage participants in organizing trainings, workshops, symposia, and journal publications. Identify challenges in uncertainty analysis.

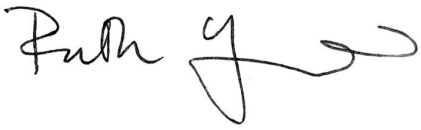
12. Do you currently or have you ever worked for the World Bank Group including any of the following types of appointments: Regular, term, ETC, ETT, STC, STT, JPA, or JPO? If yes, please provide details, including start/end dates of appointment.

No.

Certification

I certify that (1) to the best of my knowledge and belief, this CV correctly describes me, my qualifications, and my experience; (2) that I am available for the assignment for which I am proposed; and (3) that I am proposed only by one Offeror and under one proposal.

I understand that any wilful misstatement or misrepresentation herein may lead to my disqualification or removal from the selected team undertaking the assignment.



Date: 10/12/20

1. **Name of Staff**: Steve Stehman

2. **Proposed Position**: Statistician

3. **Employer**: State University of New York College of Environmental Science and Forestry

4. **Date of Birth**:09/25/57 **Nationality**: American

5. **Education**

School, college and/or University Attended	Degree/certificate or other specialized education obtained	Date Obtained
Cornell University	PhD Biometry	1990
Oregon State University	MS Statistics	1982
Penn State University	BS Biology	1979

6. **Professional Certification or Membership in Professional Associations**:
   Membership American Statistical Association

7. **Other Relevant Training**:
   None

8. **Countries of Work Experience**:
   USA

9. **Languages**:
   English: excellent in speaking, reading, and writing

10. **Employment Record**:

2015-present, Distinguished Teaching Professor, SUNY College of Environmental Science and Forestry

2003-2015, Professor, SUNY College of Environmental Science and Forestry

1995-2003, Associate Professor, SUNY College of Environmental Science and Forestry

1989-1995, Assistant Professor, SUNY College of Environmental Science and Forestry

1996-1997, Visiting Assistant Professor, Department of Statistics, Oregon State University

1987, Visiting Instructor, Department of Statistics, University of Washington

1981-1982, Instructor, Department of Mathematics, Oregon State University

11. Detailed Tasks Assigned	**12. Work Undertaken that Best Illustrates Capability to Handle the Tasks Assigned**
Develop guidance (Tasks 1, 3), especially for Activity Data	Name of assignment or project: National Land Cover Datasets (NLCD) and the Land Cover Monitoring, Assessment and Projection (LCMAP). Year: 2000 (starting with early NLCD products) to the present (both NLCD and LCMAP are currently active projects) Location: Syracuse, NY and Sioux Falls, SD Client: US Geological Survey Main project features: Long-term, land-cover monitoring, for NLCD 5-year intervals starting with 2001 through 2016, LCMAP annual monitoring from 1985-present. Sample-based estimates of area are produced from the reference land-cover data, and the map products are used for stratified sampling design and/or model-assisted estimators, and for spatially allocating the area of land cover and land-cover change. Positions held: University collaborator funded by USGS. Activities performed: Developed the sampling designs used for NLCD and LCMAP and the strategies for estimating area and accuracy of the map products.

12. Do you currently or have you ever worked for the World Bank Group including any of the following types of appointments: Regular, term, ETC, ETT, STC, STT, JPA, or JPO? If yes, please provide details, including start/end dates of appointment.

I have held several STC appointments. Most recently, I provided a review of the methods and results used to produce activity data in Mozambique and Ghana (date of appointment approximately March 15, 2020 to June 30, 2020). In a separate appointment (November 10, 2019 through February 15, 2020), I helped develop a sampling method and analysis plan procedure for estimating area of fallow land and abandoned agriculture in Nepal.

Certification

I certify that (1) to the best of my knowledge and belief, this CV correctly describes me, my qualifications, and my experience; (2) that I am available for the assignment for which I am proposed; and (3) that I am proposed only by one Offeror and under one proposal.

I understand that any wilful misstatement or misrepresentation herein may lead to my disqualification or removal from the selected team undertaking the assignment.

Date: 10/12/20

1. **Name of Staff**: Pu Ge

2. **Proposed Position**: Post-doctoral researcher

3. **Employer**: State University of New York College of Environmental Science and Forestry

4. **Date of Birth**: June 6, 1990 **Nationality**: China

5. **Education**

School, college and/or University Attended	Degree/certificate or other specialized education obtained	Date Obtained
SUNY-ESF	Doctor of Philosophy in Water Resource Engineering	expected Dec 2020
Drexel University	Master of Science in Environmental Engineering	June 2015
Drexel University	Bachelor of Science in Environmental Engineering	June 2013

6. **Professional Certification or Membership in Professional Associations**:

US. Green Building Council
LEED Green Associate Certification, Certified April 2017

The National Council of Examiners for Engineering and Surveying
Engineer in Training (EIT) Certification, Certified April 2014

American Water Resource Association (AWRA)
American Society of Civil Engineers (ASCE)
American Society of Photogrammetry and Remote Sensing (ASPRS)

7. **Other Relevant Training**:

None

8. **Countries of Work Experience**:

USA

9. **Languages**:

English (good), Chinese (good)

10. **Employment Record**

2015-present

Graduate Research Assistant, SUNY College of Environmental Science and Forestry.

2012-2015
Undergraduate and Graduate Research Assistant, Drexel University.

2011-2011
Operations Intern, Philadelphia Water Department.

2010-2010
Survey Crop Intern, Philadelphia Streets Department.

2009-2010
Student Assistant, Drexel University.

11. Detailed Tasks Assigned	**12. Work Undertaken that Best Illustrates Capability to Handle the Tasks Assigned**
Develop guidance and tools (Tasks 1, 3) Support ER programs (Task 2)	Name of assignment or project: QUEST RCN Year: 2010-2020 Location: Syracuse, NY Client: National Science Foundation Main project features: Quantifying Uncertainty in Ecosystem Studies Positions held: Graduate Research Assistant Activities performed: Monte Carlo uncertainty analysis of runoff and stream solute loads at Hubbard Brook

12. Do you currently or have you ever worked for the World Bank Group including any of the following types of appointments: Regular, term, ETC, ETT, STC, STT, JPA, or JPO? If yes, please provide details, including start/end dates of appointment.
No

Certification

I certify that (1) to the best of my knowledge and belief, this CV correctly describes me, my qualifications, and my experience; (2) that I am available for the assignment for which I am proposed; and (3) that I am proposed only by one Offeror and under one proposal.

I understand that any wilful misstatement or misrepresentation herein may lead to my disqualification or removal from the selected team undertaking the assignment.

Date: 10/12/20

1. **Name of Staff**: Mary Hagemann

2. **Proposed Position**: Research Support Specialist

3. **Employer**: State University of New York College of Environmental Science and Forestry

4. **Date of Birth**: 6/8/1966 **Nationality**: American

5. **Education**:

School, college and/or University Attended	Degree/certificate or other specialized education obtained	Date Obtained
San Francisco State University	BA	May 1997
Herkimer County Community College	AAS	May 1986

6. **Professional Certification or Membership in Professional Associations**:

Yoga Instructor and YogaKids® Facilitator

7. **Other Relevant Training**:
   None

8. **Countries of Work Experience**: [*List countries where staff has worked in the last ten years*]:

United States

9. **Languages**

English: good in speaking, reading, and writing

10. **Employment Record** [*Starting with present position, list in reverse order every employment held*]:

2016 - present
Research Support Specialist, SUNY College of Environmental Science and Forestry

2015 - present
Westcott Street Cultural Fair Coordinator, independent contractor

2004 - present
Yoga instructor, independent contractor

1998 - 2001

Cartographer, Lonely Planet Publications

1997 - 1998
Recycling Representative, Alameda County Waste Management Authority

1994 - 1999
Assistant Manager/Bartender, Triple Rock Brewery

1990 - 1995 (summers)
Customer Representative, Alaska Sightseeing Cruise West

11. Detailed Tasks Assigned	**12. Work Undertaken that Best Illustrates Capability to Handle the Tasks Assigned**
Provide administrative and technical support for all Tasks (1, 2, 3). Develop and maintain the QUERCA website.	Name of assignment or project: QUEST RCN Year: 2010-2020 Location: Syracuse, NY Client: National Science Foundation Main project features: Quantifying Uncertainty in Ecosystem Studies Positions held: Research Support Specialist Activities performed: Maintained the QUEST website and provided administrative and technical support for the project.

12. Do you currently or have you ever worked for the World Bank Group including any of the following types of appointments: Regular, term, ETC, ETT, STC, STT, JPA, or JPO? If yes, please provide details, including start/end dates of appointment.
No**.**

Certification

I certify that (1) to the best of my knowledge and belief, this CV correctly describes me, my qualifications, and my experience; (2) that I am available for the assignment for which I am proposed; and (3) that I am proposed only by one Offeror and under one proposal.

I understand that any wilful misstatement or misrepresentation herein may lead to my disqualification or removal from the selected team undertaking the assignment.

Date: October 12, 2020

ANNEX 3: WORK SCHEDULE

No	Activity[1]	Months[2]												
		1	2	3	4	5	6	7	8	9	10	11	12	n
1	Activity 1: Prepare draft guidance (Task 1)	Nov	Dec											
2	Activity 2: Report draft guidance (Output 1)		Dec											
3	Activity 3: Support ER programs (Task 2)		Dec	Jan	Feb	Mar	April	May						
4	Activity 4: Continue development of guidance			Jan	Feb	Mar	April	May	June					
5	Activity 5: Report on Support of ER Programs (Output 2)				Feb									
6	Activity 6: Report on Completed Monitoring Reports (Output 3)							May						
7	Activity 4: Finalize guidance and tools								June					
8	Activity: Submission of Final Report (Output 4)								June					
n														

ANNEX 4: CVS OF EXPERTS NOT PAID ON THIS PROJECT

Craig A. Wayson

Biological Scientist, International Programs, Forest Service, United States Department of Agriculture
1 Thomas Circle, NW
Suite 400
Washington D.C., 20005
U.S.A.
Tel: 1(202) 763-2937
cwayson@fs.fed.us

a. Professional Preparation

Iowa State University, Ames Animal Ecology, Environmental Studies	B.S. 1992
Indiana University, Bloomington Environmental Science	M.S.E.S. 2002
Indiana University, Bloomington Public Affairs	M.P.A. 2002
Indiana University, Bloomington Environmental Science	Ph.D. 2005
Indiana University, Bloomington Geography	2005-2007

b. Appointments

2008- Visiting Assistant Professor and Research Fellow, Center for Research in Energy and the Environment (CREE), School of Public and Environmental Affairs, Indiana University

c. Publications most relevant to proposed project

- Olguín M., C.A. Wayson, M. Fellows, R. Birdsey, C.E. Smyth, M. Magnan, A.J. Dugan, V.S. Mascorro, A. Alanís, E. Serrano and W.A. Kurz. 2018. Towards a systems approach for assessing carbon emission reductions from climate change mitigation in Mexico's forest sector. Environmental Research Letters 13:3
- Hribljan J.A., Suarez E., L. Bourgeau-Chavez, S. Endres, E.A. Lilleskov, S. Chimbolema, C.A. Wayson, E. Serocki, R.A. Chimner. 2017. Multidate, multisensor remote sensing reveals high density of carbon-rich mountain peatlands in the páramo of Ecuador. Global Change Biology 00:1–14. https://doi.org/10.1111/gcb.13807
- Phillips, J, Á. Duque, C. Scott, C. Wayson, G. Galindo, E. Cabrera, J. Chave, M. Peña, E. Álvarez, D. Cárdenas, J. Duivenvoorden, P. Hildebrand, P. Stevenson, S. Ramírez, A. Yepes. 2016. Live aboveground carbon stocks in natural forests of Colombia. Forest Ecology and Management 374:119-128.
- Johnson, K.D., R. Birdsey, A.O. Finley, A. Swantaran, R. Dubayah, C. Wayson, and R. Riemann. 2014. Integrating forest inventory and analysis data into a LIDAR-based carbon monitoring system. Carbon Balance and Management 9:3.

d. Other significant publications

- Wayson, C.A., J.C. Randolph, P.J. Hanson, H.P. Schmid and C.S.B. Grimmond. 2006. Comparison of soil respiration methods in a mid-latitude deciduous forest. Biogeochemistry 80:173-189.

- Oliphant A.J, S.B Grimmond; H.P. Schmid, C.A. Wayson. 2006. Local-scale heterogeneity of photosynthetically active radiation (PAR), absorbed PAR and net radiation as a function of topography, sky conditions and leaf area index. Remote Sensing of the Environment 103:324-337.
- Ehman, J.L., H.P. Schmid, C.S.B. Grimmond, J.C. Randolph, P.J. Hanson, C.A. Wayson and F.D. Cropley. 2002. An initial intercomparison of micrometeorological and ecological inventory estimates of carbon exchange in a mid-latitude deciduous forest. Global Change Biology, 8:575-589.

e. Collaborators & Other Affiliations

(i) Collaborators – R. Birdsey, Woods Hole Research Center, W. Kurz, Canadian Forest Service, D. Dragoni, Indiana University; J.L. Ehman, Image Matters, LLC; C.S.B. Grimmond, King's College London, London, UK; J.C. Randolph, Indiana University; Hans Peter Schmid, Research Center Karlsruhe (FZK/IMK-IFU) -82467 Garmisch-Partenkirchen, Germany

Mark B. Green

Department of Earth, Environmental, and Planetary Science - Case Western Reserve University

Northern Research Station - U.S. Forest Service

E-mail: mark.b.green@case.edu

Professional Preparation

Bachelor of Science (2000) - Minnesota State Univ. - Mankato (Biology)

Master of Science (2002) - Univ. of Nevada (Hydrologic Science)

Doctor of Philosophy (2007) - Univ. of Minnesota (Water Resources Science)

Postdoctoral Preparation (2007-2009) - Univ. of New Hampshire and City Univ. of New York

Appointments

Senior Research Associate

Case Western Reserve University, Cleveland, OH
Department of Earth, Environmental, and Planetary Sciences
2/2019 to present

Assistant and Associate Professor of Hydrology

Plymouth State University, Plymouth, NH
Center for the Environment
8/2009 to 5/2019

Research Hydrologist

U.S. Forest Service, Durham, NH
Northern Research Station
8/2009 to present

Selected Publications

Vadeboncoeur, M.A., **M.B. Green**, H. Asbjornsen, J.L. Campbell, M.B. Adams, E.W. Boyer, D.A. Burns, I.J. Fernandez, M.J. Mitchell, and J.B. Shanley. 2018. Systematic variation in evapotranspiration trends and drivers across the Northeastern United States. *Hydrological Processes*, 32(23): 3547-3560.

Oda, T., **M.B. Green**, R. Urakawa, T.M. Scanlon, S.D. Sebestyen, K.J. McGuire, M. Katsuyama, K. Fukuzawa, M.B. Adams, and N. Ohte. 2018. Stream runoff and nitrate

recovery times after forest disturbance in the USA and Japan. *Water Resources Research*, 54(9): 6042-6054.

Contosta, A.R., A. Adolph, D. Burchsted, E. Burakowski, **M.B. Green**, D. Guerra, M. Albert, J. Dibb, M. Martin, W.H. McDowell and M. Routhier. 2017. A longer vernal window: the role of winter coldness and snowpack in driving spring transitions and lags. *Global Change Biology*, 23 (4):1610-1625.

Creed, I.F., D.M. McKnight, B.A. Pellerin, **M.B. Green**, B.A. Bergamaschi, G.R. Aiken, D.A. Burns, S.E. Findlay, J.B. Shanley, R.G. Striegl and B.T. Aulenbach. 2015. The river as a chemostat: fresh perspectives on dissolved organic matter flowing down the river continuum. *Canadian Journal of Fisheries and Aquatic Sciences*, 72(8): 1272-1285.

Inserillo, E.A., **M.B. Green**, J.B. Shanley, and J.N. Boyer. 2017. Comparing catchment hydrologic response to a regional storm using specific conductivity sensors. *Hydrological Processes*, 31(5): 1074-1085.

Benettin, P., S. W. Bailey, J. L. Campbell, **M. B. Green**, A. Rinaldo, G. E. Likens, K. J. McGuire, and G. Botter. 2015. Linking water age and solute dynamics in streamflow at the Hubbard Brook Experimental Forest, NH, USA. *Water Resources Research*, doi: 10.1002/2015WR017552.

Yanai, R.D., N. Tokuchi, J.L. Campbell, **M.B. Green**, E. Matsuzaki, S.N. Laseter, C.L. Brown, A.S. Bailey, P. Lyons, C.R. Levine, and D.C. Buso. 2015. Sources of uncertainty in estimating stream solute export from headwater catchments at three sites. *Hydrological Processes*, 29(7): 1793-1805.

Green, M.B., A.S. Bailey, S. Bailey, J.J. Battles, J.L. Campbell, C.T. Driscoll, T.J. Fahey, L.C. Lepine, G.E. Likens, S.V. Ollinger, and P. Schaberg. 2013. Decreased water flowing from a forest amended with calcium silicate. *Proceedings of the National Academy of Sciences*, 110 (15): 5999-6003, doi: 10.1073/pnas.1302445110.

Green, M. B., B. K. Laursen, J. L. Campbell, K. J. McGuire, and E. P. Kelsey. 2015. Stable water isotopes suggest sub-canopy water recycling in a northern forested catchment. *Hydrological Processes*, doi: 10.1002/hyp.10706.

Groffman, P.M., L.E. Rustad, P.H. Templer, J.L. Campbell, L.M. Christenson, N.K. Lany, A.M. Socci, M.A. Vadeboncoeur, P.G. Schaberg, G.F. Wilson, C.T. Driscoll, T.J. Fahey, M.C. Fisk, C.L. Goodale, **M.B. Green**, S.P. Hamburg, C.E. Johnson, M.J. Mitchell, J.L. Morse, L.H. Pardo, and N.L. Rodenhouse. 2012. Climate change effects are manifest in complex and surprising ways in the northern hardwood forest. *BioScience* 62 (12): 1056-1066.

Outreach Activities

Member, Scientific Coordinating Committee, Hubbard Brook Ecosystem Study, 2018-2020

Fellow, Fulbright Scholar Program, University of Tokyo, Japan, 2012-2013.

Member, Education and Outreach committee, Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI), 2009-2013.

Member, Water quality technical committee, American Geophysical Union, Hydrology Section, 2009-2011.

Technical Advisory Committee Member, Browns Creek Biological Stressor Identification Study, Washington Conservation District, Minnesota, 2007

John L. Campbell
U.S. Forest Service, Northern Research Station
271 Mast Road, Durham, NH 03824
Tel.: (603) 868-7643
Email: jlcampbell@fs.fed.us

Education

University of New Hampshire	Environmental Conservation	B.S. 1989
University of New Hampshire	Forestry	M.S. 1996
SUNY-ESF	Environmental and Forest Biology	Ph.D. 2006

Work Experience

2001- Research Ecologist, U.S. Forest Service
1997-2001 Ecological Science Data Manager, U.S. Forest Service
1996-1997 Forester, U.S. Forest Service
1994-1996 Research Assistant, University of New Hampshire
1993-1994 Teaching Assistant, University of New Hampshire
1992-1993 Forestry Technician, U.S. Forest Service
1991 Park Naturalist, National Park Service, Denali National Park
1989-1991 Environmental Consultant, Enviro-Sciences, Inc.

Selected Publications (out of 90 peer-reviewed articles)

Yanai, R.D., Wayson, C., Lee, D., Espejo, A.B., Campbell, J.L., Green, M.B., Zukswert, J.M., Yoffe, S.B., Aukema, J.E., Lister, A.J., Kirchner, J.W., Garmarra, J.G.P. Improving uncertainty in forest carbon accounting for REDD+ mitigation efforts. *Environmental Research Letters*. doi.org/10.1088/1748-9326/abb96f

See, C.R., Green, M.B., Yanai, R.D., Bailey, A.S., Campbell, J.L., Hayward, J. 2020. Quantifying uncertainty in annual runoff due to missing data. *PeerJ* 8: e9531. doi.org/10.7717/peerj.9531

Campbell, J.L., Laudon, H. 2019. Carbon response to changing winter conditions in northern regions: Current understanding and emerging research needs. *Environmental Reviews* 27(4):545-566. doi:10.1139/er-2018-0097

Asbjornsen, H., Campbell, J.L., D'Amato, A.W., Garnas, J., Gunn, J.S., Iverson, L.R., Ontl, T.A., Pederson, N., Peters, M.P., Shannon, P.D. 2019. Managing Effects of Drought in the Midwest and Northeast United States. In: Vose, J.M.; Peterson, D.L. Luce, C.H., Patel-Weynand, T. (eds). Effects of drought on forests and rangelands in the United States: translating science into management responses. Gen. Tech. Rep. WO-98. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office.

Campbell, J.L., Green, M.B., Yanai, R.D., Woodall, C.W., Fraver, S., Harmon, M.E., Hatfield, M.A., Barnett, C.J., See, C.R., Domke, G.M. 2019. Estimating uncertainty in the volume and carbon storage of downed coarse woody debris. *Ecological Applications* 29(2):e01844. doi: 10.1002/eap.1844.

Fahey, R.T., Atkins, J., Campbell, J.L., Rustad, L.E., Duffy, M., Driscoll, C.T., Fahey, T.J., Schaberg, P.G. 2020. Effects of an experimental ice storm on forest canopy structure. Canadian Journal of Forest Research 50(2):136-145. doi:10.1139/cjfr-2019-0276

Campbell, J.L., Green, M.B., Yanai, R.D., Woodall, C.W., Fraver, S., Harmon, M.E., Hatfield, M.A., Barnett, C.J., See, C.R., Domke, G.M. 2019. Estimating uncertainty in the volume and carbon storage of downed coarse woody debris. *Ecological Applications* 29(2):e01844. doi: 10.1002/eap.1844.

Yanai, R.D., Craig R. See, C.R., Campbell, J.L. 2018. Current practices in uncertainty analysis in ecosystem ecology. *Ecosystems* 21(5):971-981.

Campbell, J.L., Yanai, R.D., Green, M.B., Likens, G.E., See, C.R., Bailey, A.S., Buso, D.C., Yang, D. 2016. Uncertainty in the net hydrologic flux of calcium in a paired-watershed study. *Ecosphere* 7(6) e01299

Yanai, R.D., Tokuchi, N., Campbell, J.L., Green, M.B., Matsuzaki, E., Laseter, S.N., Brown, C.L., Bailey, A.S., Lyons, P., Levine, C.R., Buso, D.C., Likens, G.E., Knoepp, J., Fukushima, K. 2015. Sources of uncertainty in stream solute export from headwater catchments. *Hydrological Processes* 29(7): 1793-1805

Campbell, J.L., Rustad, L.E., Porter, J.H., Taylor, J.R., Dereszynski, E.W., Shanley, J.B., Gries, C., Henshaw, D.L., Martin, M.E., Sheldon, W.M., Boose, E.R. 2013. Quantity is nothing without quality: Automated QA/QC for streaming sensor networks. *BioScience* 63(7): 574-585

Yanai, R., Levine, C., Green, M. Campbell, J. 2012. Quantifying uncertainty in forest nutrient budgets. *Journal of Forestry* 110(8): 448-456

Fahey, T.J., Siccama, T.G., Driscoll, C.T., Likens, G.E., Campbell, J.L., Johnson, C.E., Battles, J.J., Aber, J.D., Cole, J.J., Fisk, M.C., Groffman, P.M., Hamburg, S.P., Holmes, R.T., Schwarz, P.A., Yanai, R.D. 2005. The biogeochemistry of carbon at Hubbard Brook. *Biogeochemistry* 75: 109-176

Activities

1. Vernal Window Citizen Science Network: Participating in the development of a citizen science high school program in New Hampshire and Maine that trains students to collect data to assess how climatic conditions during winter and spring affect forest ecosystems.
2. Smart Forests Network: Serve on the steering committee that provides the vision and expertise in establishing the Smart Forests Network, which consists of US Forest Service Experimental Forests and Ranges, as well as cooperating research sites, equipped with sensors that collect and distribute environmental data in real-time.
3. Forest Science Dialogues: Serve as a Core Science Team member for this program that is developing and piloting a model to foster engagement and learning among diverse stakeholders related to timely ecosystem, social, economic, and policy issues in rural regions of the Northern Forest.

4. Hubbard Brook Scientific Coordinating Committee: Serve as the U.S. Forest Service representative on this committee, which provides vision and scientific leadership to the research program at Hubbard Brook, fostering integration and synthesis across diverse projects, and promoting interactions and communication among scientists.

Brett J. Butler

Curriculum Vitae

Contact Information

Mailing Address: USDA Forest Service
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Amherst, MA 01003 USA
Telephone: 413-545-1387 (office); 413-459-1145 (cell)
E-mail: brett.butler2@usda.gov; bbutler@eco.umass.edu

Education

Ph.D., Oregon State University, 2005, Forest Science
B.S., University of Connecticut, 1995, Renewable Natural Resources

Employment

2006 – present	Research forester. USDA Forest Service, Northeastern Research Station, Forest Inventory and Analysis program, Amherst, MA.
2000 – 2006	Research forester. USDA Forest Service, Northeastern Research Station, Forest Inventory and Analysis program, Newtown Square, PA.
1998 – 2000	Forester. USDA Forest Service, Pacific Northwest Research Station, Land Use and Land Cover Dynamics program, Corvallis, OR.
1997 – 2000	Graduate research assistant. Oregon State University, Department of Forest Science, Corvallis, OR.
1995 – 1997	Research ecologist, on-site science coordinator, and land management liaison. Wildlife Conservation Research Center, University of Connecticut stationed at Robins Island Preserve, New Suffolk, NY.
1994	Research assistant. Connecticut Agricultural Experiment Station, Forestry Department, New Haven, CT.
1993	Undergraduate research assistant. La Selva Biological Research Station, Costa Rica.
1992	Research assistant. Connecticut Agricultural Experiment Station, Plant Pathology department, New Haven, CT.

Academic Affiliations

2016 – present	Adjunct professor, University of the Sunshine Coast (Australia)
2005 – present	Adjunct professor, University of Massachusetts-Amherst
2003 – present	Affiliate associate professor, Auburn University

Major Awards

2015 National Woodland Owners Association/National Association of University Forest Resource Programs Family Forests Education Award
2014 IUFRO 3.08 Small-scale Forestry Brandl Award

Professional Activities

2019 – present Coordinator, U.S. Forest Service, Timber Products Output, Northeastern and Midwestern U.S.

2015 – present Editor-in-Chief, Small-scale Forestry Journal
2015 – present Chair, Society of American Foresters, Private Forestry Working Group
2012 – 2014 Member, Society of American Foresters, Forest Science & Technology Board
2010 – present Deputy Coordinator, International Union of Forest Research Organizations, Small-scale Forestry Working Group
2010 – 2016 Associate Editor, Journal of Forestry
2010 – 2015 Associate Editor, Small-scale Forestry Journal
2010 – 2012 Chair, Society of American Foresters, Private Forestry Working Group
2005 – present Co-director, Family Forest Research Center
2005 – present Co-director, Sustaining Family Forests Initiative
2000 – present Coordinator, U.S. Forest Service, National Woodland Owner Survey\

Selected Externally Funded Projects

Assessing the Potential for Climate Change and Forest Insects to Drive Land-use Regime Shifts (National Science Foundation)
Economic Valuation of the U.S. Forest Service, Forest Legacy Program (U.S. Forest Service, State & Private Forestry)
Evaluation of the U.S. Forest Service, Forest Stewardship Program (U.S. Forest Service, State & Private Forestry)
Impacts of Taxes of Family Forest Owners (American Forest Foundation)
Tools for Engaging Landowner Effectively (Multiple funding sources including federal, non-governmental, and private corporations)
Understanding and Informing Family Forest Owner Decisions of Intergenerational Land Transfer (USDA National Institute of Agriculture)

Selected Publications

Aguilar, F.X.; Cai, Z.; Butler, B. 2017. *Proximal association of land management preferences: evidence from family forest owners*. PLOS ONE 12(1): e0169667.

Andrejczyk, K.; Butler, B.J.; Dickinson, B.J.; Hewes, J.H.; Markowski-Lindsay, M.; Kittredge, D.B.; Kilgore, M.A.; Snyder, S.A.; Catanzaro, P.F. 2016. *Family forest owners' perceptions of landowner assistance programs in the USA: A qualitative exploration of program impacts on behaviour.* Small-scale Forestry 15: 17–28.

Andrejczyk, K.; Butler, B.J.; Tyrell, M., L.; Langer, J. 2016. *Hansel and Gretel walk in the forest, landowners walk in the woods: A qualitative examination of the language used by family forest owners.* Journal of Forestry 114(1): 52–57.

Bengston, D.N.; Asah, S.T.; Butler, B.J. 2011. *The diverse values and motivations of family forest owners in the United States: An analysis of an open-ended question in the National Woodland Owner Survey.* Small-scale Forestry. 10: 339-355.

Bengston, D.N.; Hujala, T.; Butler, B.J. 2020. *The "Coming Age of Wood" and family forest owners: An Implications Wheel® exploration*. Small-scale Forestry 19: 145–157.

Butler, B.J. 2008. *Family forest owners of the United States, 2006.* Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. Gen. Tech. Rep. NRS-27. 73 p.

Butler, B.J. 2009. *The timber harvesting behavior of family forest owners: theoretical and empirical individual-choice models for the southeastern United States.* Saarbrücken, Germany: VDM Verlag. 156 p.

Butler, B.J.; Butler, S.M.; Caputo, J.; Dias, J.; Robillard, A.; Sass, E.M. 2020. *Family forest ownerships of the United States, 2018: Results from the USDA Forest Service, National Woodland Owner Survey*. Gen. Tech. Rep. NRS-199. Madison, WI: USDA Forest Service, Northern Research Station.

Butler, B.J.; Butler, S.M.; Dennings, K.; Gorby Knoot, T. 2018. *What influences whether family forest owners participate in outreach campaigns?* Journal of Extension 56(7): 7RIB3.

Butler, B.J.; Caputo, J.; Robillard, A.L.; Sass, E.M.; Sutherland, C. 2020. *One size does not fit all: Relationships between size of family forest holdings and landowner attitudes and behaviors.* Journal of Forestry.

Butler, B.J.; Catanzaro, P.F.; Greene, J.L.; Hewes, J.H.; Kilgore, M.A.; Kittredge, D.B.; Ma, Z.; Tyrrell, M.L. 2012. *Taxing family forest owners: effects of federal and state policies in the United States.* Journal of Forestry 110(7): 371–380.

Butler, B.J.; Hewes, J.H.; Dickinson, B.J.; Andrejczyk, K.; Butler, S.M.; Markowski-Lindsay, M. 2016. *Family forest ownerships of the United States, 2013: Findings from the USDA Forest Service's National Woodland Owner Survey*. Journal of Forestry 114(6): 638–647.

Butler, B.J.; Hewes, J.H.; Liknes, G.C.; Nelson, M.D.; Snyder, S.A. 2014. *A comparison of techniques for generating forest ownership spatial products.* Applied Geography 46:21–34.

Butler, B.J.; Hewes, J.H.; Tyrrell, M.L.; Butler, S.M. 2017. *Methods for increasing cooperation rates for surveys of family forest owners*. Small-scale Forestry 16(2): 169–177.

Butler, B.J.; Leatherberry, E.C. 2004. *America's family forest owners.* Journal of Forestry 102(7): 4-9.

Butler, B.J.; Ma, Z.; Kittredge, D.B.; Catanzaro, P. 2010. *Social versus biological availability of woody biomass in the northern United States*. Northern Journal of Applied Forestry. 27(4): 151-159.

Butler, B.J.; Markowski-Lindsay, M.; Snyder, S.; Catanzaro, P.; Kittredge, D.B.; Andrejczyk, K.; Dickinson, B.J.; et al. 2014. *Effectiveness of landowner assistance activities: An examination of the USDA Forest Service's Forest Stewardship Program.* Journal of Forestry 112(2): 187–197.

Butler, B.J.; Tyrrell, M.; Feinberg, G.; Vanmanen, S.; Wiseman. L.; Wallinger, S. 2007. *Understanding and reaching family forest owners: Lessons from social marketing research.* Journal of Forestry 105 (7): 348-357.

Butler, S.M.; Butler, B.J.; Markowski-Lindsay, M. 2017. *Family forest owner characteristics shaped by life cycle, cohort, and period effects.* Small-scale Forestry 16(1): 1–18.

Butler, S.M.; Huff, E.S.; Snyder, S.A.; Butler, B.J.; Tyrrell, M. 2017. *The role of gender in management behaviors on family forest lands in the United States*. Journal of Forestry.

Caputo, J.; Butler, B. 2017. *Ecosystem service supply and capacity on U.S. family forestlands*. Forests 8(10): 395.

Huff, E.S.; Butler, B.J.; Markowski-Lindsay, M.; Hewes, J.H. 2019. *Longitudinal data on family forest owners: The US Forest Service's National Woodland Owner Survey*. Landscape and Urban Planning. 188: 93–96.

Hujala, T.; Toppinen, A.; Butler, B.J., eds. 2019. *Services in family forestry*. Springer International Publishing.

Kilgore, M.A.; Snyder, S.A.; Eryilmaz, D.; Markowski-Lindsay, M.A.; Butler, B.J.; Kittredge, D.B.; Catanzaro, P.F.; Hewes, J.H.; Andrejczyk, K. 2015. *Assessing the relationship between different forms of landowner assistance and family forest owner behaviors and intentions.* Journal of Forestry 113(1): 12–19.

Ma, Z.; Butler, B.J.; Catanzaro, P.F.; Greene, J.L.; Hewes, J.H.; Kilgore, M.A.; Kittredge, D.B.; Tyrrell, M. 2014. *The effectiveness of state preferential property tax programs in conserving forests: Comparisons, measurements, and challenges.* Land Use Policy 36:492–499.

Ma, Z.; Butler, B.J.; Kittredge, D.B.; Catanzaro, P. 2012. *Factors associated with landowner involvement in forest conservation programs in the U.S.: Implications for policy design and outreach.* Land Use Policy 29(1): 53–61.

Majumdar, I.; Teeter, L.; Butler, B.J. 2008. *Characterizing family forest owners: a cluster analysis approach.* Forest Science 54(2): 176-184.

Markowski-Lindsay, M.; Butler, B.J.; Kittredge, D.B. 2017. *The future of family forests in the USA: Near-term intentions to sell or transfer*. Land Use Policy 69:577–585.

Mondal, P.; Butler, B.J.; Kittredge, D.B.; Moser, W.K. 2013. *How are America's private forests changing? An integrated assessment of forest management, housing pressure, and urban development in alternate emissions scenarios.* Land Use Policy 32: 230–238.

Shifley, S.R.; Moser, W.K.; Nowak, D.; Miles, P.; Butler, B.J.; Aguilar, F.X.; DeSantis, R.; Greenfield, E. 2014. *Five anthropogenic factors that will radically alter forest conditions and management needs in the northern United States.* Forest Science 60(5): 914–925.

Simoes, J.; Markowski-Lindsay, M.; Butler, B.J.; Kittredge, D.B.; Thompson, J.; Orwig, D. 2019. *Assessing New England family forest owners' invasive insect awareness*. Journal of Extension. 57(3): v57-3rb2.

Snyder, S.A.; Butler, B.J. 2012. *A national assessment of public recreational access on family forest lands in the United States.* Journal of Forestry 110(6): 318–327.

Snyder, S.A.; Butler, B.J.; Markowski-Lindsay, M. 2019. *Small-area family forest ownerships in the USA*. Small-scale Forestry. 18(1): 127–147.

Song, N.; Aguilar, F.X.; Butler, B.J. 2014. *Conservation easements and management by family forest owners: A propensity score matching approach with multi-imputation of survey data.* Forest Science 60(2): 298–307.

Van Fleet, T.E.; Kittredge, D.B.; Butler, B.J.; Catanzaro, P.F. 2012. *Reimagining family forest conservation: Estimating landowner awareness and their preparedness to act with the Conservation Awareness Index.* Journal of Forestry. 110(4): 207-215.

Zhang, D.; Butler, B.J.; Nagubadi, R.V. 2012. *Institutional timberland ownership in the U.S. South: Magnitude, location, dynamics, and management.* Journal of Forestry 110(7): 355–361.

LALITA ADHIKARI

Independent Contractor

Government Scholar, BS Forestry, Nepal

Worked for: Nepal Government,
Ministry of Forest and Environment

Contact Address: Lalitpur 44600, Nepal

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lalitadhikariii28@gmail.com

Academic Qualifications

Accepted for Masters of Science, SUNY ESF.
Deferred start date: January 2021 (due to COVID)

Agriculture and Forest University, Bachelor of Science in Forestry (2019) – Distinction
Advisor: Asst. Prof. Lilu Kumari Magar

Research Interests
Forest Carbon Accounting, Uncertainty, Climate Change and Finance, Agroforestry.

Research and Publication

2019 Bachelor Dissertation: "Assessing Agroforestry Practices Contributing Chure Conservation" Amlekhgunj, Bara.

Adhikari, L., Poudel, D. & Magar, L. K. (2019). Study of Agroforestry Practices adopted in Amlekhgunj, Bara Under *Chure* Conservation. South Asian Agroforestry Conference, Kathmandu, Nepal.

Conference Presentation

Agroforestry Practices in *Chure* Conservation. South Asian Agroforestry Conference, Kathmandu, Nepal.

Training Completed

2019 "Earth Observation for **Disaster Risk Assessment and Resilience**" by NASA's Applied Remote Sensing Training Program (ARSET) (webinar).

2019 "Empowering Women in **Geospatial Information Technology**" organized by ICIMOD within the framework of SERVIR-HKH supported by USAID and NASA. (4 days)

2019 "One-Day Training on Project Management" organized by Team NEPO. (1day)

2018: One-week academic Tour on **Scientific Forest Management** at Kapilvastu District, Nepal.

2018 "**Report and Proposal writing**"; Faculty of Forestry, Hetauda, Makawanpur. (3 days)

2018 "**Bird Watching and Identification Training**" Organized by Agriculture and Forestry University with the support of Bird Conservation Nepal (BCN). (2 days)

2017 "**Arc GIS**"; Faculty of Forestry, Hetauda, Makawanpur. (7 days)

2017 "**Forest Inventory and Data Analysis**"; Faculty of Forestry, Hetauda, Makawanpur. (7 days)

2016 "**Advance Anchoring and Leadership Development Training**" organized by We Can Nepal. (1 month)
2015: Three Days **Field Observation to Botanical/Zoological** aspects in Godawari, Lalitpur on February.

Seminars and Workshops

2018 **Nepal Climate Convergence** certified as a Climate Justice Advocate by Digo Bikash Institute.
2017 **Hetauda Climate Convergence** organized by Digo Bikash Institute.
2017 **Paper Writing and Presentation Competition** organized by Rotaract Club of Hetauda.

Professional Experiences

2020, National Workshop Secretariat, Gender Integration in Forestry 2020 - Reducing emissions from deforestation and forest degradation (REDD) Implementation Center of Nepal Government - Ministry of Forest and Environment, Kathmandu, Nepal.

2019, Research Intern on Assessing Agroforestry Practices Contributing Chure Conservation, Amlekhgunj, Bara under Mrs. Lilu Kumari Magar, Assistant Professor, Agriculture and Forestry University, Hetauda, Makwanpur.

2019, Former Field Data Enumerator, Practical Solution funded by UNDP and Ministry of Agriculture

2016, Editor of Himalayan Headlines at Resource Himalaya Foundation for the month of May.

Other Experiences

2019 Fieldwork: Scientific Forest Management at Jana Community forestry users' group, Doti, Nepal.

2019 Field work: Value Chain Development Project by UNDP: Field data collection

2019 Volunteer at Team NEPO

2019 Volunteer at Digo Bikash Institute

2018 Field Assistant at "Inventory and status of water sources in Samdi micro watershed of Dhandkhola sub watershed, Tanahun.

Technical Capabilities

Workshop and Conference Management
SAS, SPSS, Excel
Arc map (10.3), Google earth pro, GPS utility, Map source
Proficiency in Q-GIS, Qualtrics survey tools
Report writing, Scientific proposal and article writing
Word, Power Point – MS Packages

Awards and Scholarships

2015-2019, Government Merit Scholarship for completing B.Sc. Forestry by Agriculture and Forestry University, Faculty of Forestry, Hetauda, Makawanpur, Nepal

Leadership Experience

Member of Youth Red Cross Society.
Member of Bird Conservation Nepal (BCN).
Executive Member of CliMates Nepal.

Languages

Nepali: Mother Tongue
English: excellent in speaking, reading and writing
Hindi: excellent in speaking and reading, and fair in writing