

**Modeling fine-scale above ground carbon storage using LiDAR: A comparison across two watersheds**  
**Kristen Brubaker: Assistant Professor of Environmental Studies, Hobart and William Smith Colleges**

**Statement of Proposed Work:**

LiDAR has the potential to be a transformative technology in the study of the Critical Zone. Understanding the carbon balance across watersheds can shed light on the role of abiotic factors in carbon sequestration in forested ecosystems. LiDAR has already been used extensively to model ecological metrics across landscape scales, including Leaf Area Index (LAI), forest biomass, and carbon. LiDAR is also useful for studying geomorphic and hydrologic processes in the Critical Zone. Due to the intensive ground truthing and field instrumentation at the Susquehanna/Shale Hills CZO, as well as the fine scale leaf-on and leaf-off LiDAR available, this study site provides researchers with an excellent opportunity to link these robust ecological metrics with our current understandings of geologic and hydrological processes occurring within the Shale Hill and Garner Run watersheds. Commonly used allometric equations for modeling above ground biomass from trees (e.g. Jenkins et al., 2004) are intended for landscape scale use, and commonly do not incorporate tree height. This may limit their effectiveness in small watersheds such as Shale Hills and Garner Run, where tree height, an important predictor of biomass, is known to vary significantly across different topographic positions, as well as across sites. In order to fully understand the role that abiotic factors including dominant bedrock, topographic position, and terrain may play on carbon storage at the watershed scale, a different approach is needed.

**The proposed seed grant will provide funds to measure and calculate fine-scale above ground carbon pools on both the Shale Hill and Garner Run watersheds, and link those calculations to spatially explicit LiDAR-based models of the individual components of carbon, including living trees, coarse woody debris (CWD), and shrub/understory.** These models should facilitate the exploration of several research questions, including how carbon storage changes throughout a watershed—particularly with regard to landform—and how carbon storage may differ between shale and sandstone dominated watersheds. In the field, tree height is difficult to determine; with the leaf-on and leaf-off LiDAR available for the region, tree height can be easily determined across both an individual tree scale and a landscape scale. By combining these fine-scale LiDAR data with robust field data and allometric equations that consider height, we should be able to model the spatial patterns of carbon storage across sites, and link those patterns to abiotic conditions.

**Field Data Collection**

Current field protocols for vegetation at Shale Hills and Garner Run have included georeferencing all trees greater than 10 cm diameter at breast height (DBH) along permanent transects at both Shale Hills and Garner Run. Permanent transects were positioned at ridge top, mid-slope, and toe-slope topographic positions. Trees were also identified by species, and their DBH was measured. Coarse woody debris (CWD) data has been collected along each transect. Although some shrub metrics were collected during the summer of 2014, detailed measures of shrubs and understory (<10 cm DBH) trees were not collected. **In order to create a fine-scale, spatially explicit carbon storage model across both watersheds, I will work with two undergraduate students to collect shrub data at both watersheds and across all transects. My proposed budget includes one month of salary for myself, as well as six**

**weeks of salary and housing for two summer students at Shale Hills so that we can collect field data at the site. We will also collect tree, shrub, and CWD data from additional plots across the Shaver's Creek watershed to use in a model validation process.**

#### Products of Research

- Field data on shrub and understory trees along transects in Shale Hills and Garner Run, with calculated biomass and carbon pool estimates
- Carbon pool estimates for the shrub, tree, and coarse woody debris component from Shale Hills and Garner Run
- Spatially explicit LiDAR-based models of carbon pools from trees, understory, and coarse woody debris for Shale Hills and Garner Run watersheds

#### PI Background and Qualifications

I am currently an assistant professor at Hobart and William Smith Colleges, a primary undergraduate institution in Geneva, NY. I received my Ph.D. from Penn State in 2012 in Forestry, with a focus on LiDAR and remote sensing. In May of 2014, I attended the Community Workshop: The Next Generation of LiDAR Analysis for Critical Zone Research in Boulder, CO, as a funded participant. Through that workshop, I am a co-author on a publication with attendees, currently in review, that argues for the transformative value of LiDAR as a tool to conduct Critical Zone research. I also have significant experience working with LiDAR, both as part of my dissertation, and with a more recent study that utilized landscape scale LiDAR to model canopy height across the entire Bureau of Forestry State Forest lands in Pennsylvania, much of which is included within the Shaver's Creek watershed. I have worked tangentially with the Critical Zone community since 2012, and would like to continue strengthening my collaborations, particularly with the Susquehanna/Shale Hills CZO.

Additionally, I currently have a collaboration with Dr. Margot Kaye through my honors student, Quincey Johanson. I encouraged Quincey to apply for a summer REU position at the CZO, and she was awarded and completed the position with Dr. Kaye in the summer of 2014. I assisted for several days in the field and helped Quincey with her data analysis and GIS work for her final conference poster. I am currently advising Quincey on an honors project at HWS for which she will quantify tree biomass across both watersheds.

#### Proposed Timeline

If I receive this grant, I will collect field data during July and early August of 2015. I am on sabbatical leave from teaching during the fall semester of 2015, and plan to utilize that time to analyze LiDAR data and develop the LiDAR models for carbon pools at each site and draft a manuscript based on these data. I plan to submit a manuscript for publication by December of 2015. Students and I will co-present this work at a conference in 2015.

#### References

Jenkins J, Chojnacky D, Heath L, Birdsey R. 2004. Comprehensive Database of Diameter-based Biomass Regressions for North American Tree Species. USDA Forest Service. General Technical Report NE 319: 1-48.

**Proposed SSHO interactions:**

This work will enhance other research taking place at SSHO because researchers at this site are interested in measures of above ground carbon and, to my knowledge, are currently not utilizing the LiDAR data for vegetation analysis on a broad scale. I am aware of the work of Dr. David Eissenstat and Katie Gaines at the site, and this should be complementary to their projects. This research will also build off of Margot Kaye's and Jason Kaye's research to quantify the watershed scale carbon budget of Shale Hills watershed. I plan to leverage the data already collected from the site, including tree, CWD, leaf litter, and soil carbon data, along with the LiDAR, to investigate new questions of interest to many in the CZO community. In particular, this research will utilize the framework that the SSHO CZO has set up to measure "everything" at Shale Hills, and targeted samples at Garner Run. I have corresponded with Jacob Flanagan at UC Merced, who has expressed interest in analyzing CWD from LiDAR from the site. Since I am not currently working at the site, I realize that I may be missing some potential interactions and that this work may intersect with other interested researchers. I look forward to learning more about what is currently taking place at this site.

I am interested in pursuing additional collaborations and am willing to co-author with any member of the Critical Zone community that is interested in collaborating in this proposed work. I will follow the CZO precepts for collaboration framework. I will work with the data manager at the Susquehanna/Shale Hills CZO to ensure that all NSF mandates are satisfied with regards to data availability, and that all data is uploaded to the website.

**Results of prior support to work on SSHO:**

I have not previously received support to work on the SSHO CZO.

# HWS Sponsored Programs Budget Template

## Proposal Budget Template

Project Title: **Modeling fine-scale above ground carbon storage using LiDAR: A compari**

Sponsor: Susquehanna Shale Hills Critical Zone Observatory

PI: Kristen Brubaker

Overseeing Department: Environmental Studies

Period of Performance for project: July, 2015-July 2016

Submission Deadline: 31-Mar-15

(add columns for additional years as needed)

<b>BUDGET</b>	<b>Year 1</b>	<b>Year 2</b>	<b>Year 3</b>	<b>Cumulative</b>
Salaries (academic year)				-
Salaries (summer)	7,183	-	-	7,183
Fringe on salaries	2,650	-	-	2,650
Student wages (academic year)				-
Student wages (summer)	5,400			5,400
Fringe on summer student	467	-	-	467
<b>Total Salaries, Wages + Fringe</b>	<b>15,700</b>	<b>-</b>	<b>-</b>	<b>15,700</b>
Travel - Domestic/Regional	1,585			1,585
Travel - Foreign				-
Equipment *	-	-	-	-
Participant Costs **				-
Materials & Supplies				-
Consultants				-
Outside Computer Services	-	-	-	-
Other Direct Costs (explain in justification)				-
Subcontract (recipient name)	-			-
<b>Total Direct Cost</b>	<b>17,285</b>	<b>-</b>	<b>-</b>	<b>17,285</b>
Indirect Costs @ 21% of salary & wages	2,642	-	-	2,642
<b>Total Request to Sponsor</b>	<b>19,927</b>	<b>-</b>	<b>-</b>	<b>19,927</b>
MANDATORY (sponsor-required) Cost Share	-	-	-	-
VOLUNTARY Committed Cost Share**	-			-
<b>Total Project Cost</b>	<b>19,927</b>	<b>-</b>	<b>-</b>	<b>19,927</b>
		(check)		19,927

\* Equipment: "an article of non-expendable, tangible personal property, having a useful life of more than one year and an acquisition cost of \$5,000 or more per unit."

\*\* Check with Sponsored Programs and confirm with Provost prior to utilizing this category.

Budget Justification:

- Salary: 1 month of summer salary is requested for the PI
- Summer Research Student: 6 weeks of summer stipend for two students, at \$450.00/week
- The Colleges' current fringe rates are 36.9% of PI's salary, and 8.65% of summer student salary.
- Travel includes 5 weeks of housing for the summer student at Stone Valley Recreation Area
- Indirect costs are calculated at the Colleges' federally negotiated off-campus rate of 21% on the base of salary and wages, minus fringe. Rate agreement is attached.

## Kristen M. Brubaker

Assistant Professor of Environmental Studies  
Hobart and William Smith Colleges  
112A Rees Hall, Geneva, NY 14456  
315-781-3445  
[brubaker@hws.edu](mailto:brubaker@hws.edu)

### Professional Preparation

The Pennsylvania State University B.S. in Secondary Education, Earth and Space Science, 1999-2003  
Mississippi State University M.S. in Geosciences 2005-2007  
The Pennsylvania State University, Ph.D. in Forest Science, watershed stewardship option 2007-2011

### Appointments

2012-present Assistant Professor of Environmental Studies. Hobart and William Smith Colleges.  
2011-2012 Visiting Postdoctoral Fellow in Spatial and Sustainability Science with the Center for Sustainability Education. Dickinson College  
2007-2011 Instructor, Graduate Assistant. Penn State University.

### Five Related Publications

#### In Review

- A Harpold, J.A. Marshall, S.W. Lyon, T.B. Barnhart, B. Wenell, M. Donovan, K.M.Brubaker, C.J. Crosby, N.F.Glenn, C.L.Glennie, P.B. Kirchner, N. Lam, K.D.Mankoff, J.L. McCreight, N.P.Molotch, K.N. Musselman, T. Russo, H. Sangireddy, YSjoberg, T Swetnam, N West. Laser Vision: LiDAR as a Transformative Tool to Advance Critical Zone Science. In review, Hydrology and Earth Systems Science.

#### Published

- Grant, C. J., A. B. Weimer, N. K. Marks, E. S. Perow, J. M. Oster, K. M. Brubaker, R.V. Trexler, C. M. Solomon, and R. Lamendella. 2015. Marcellus and mercury: Assessing potential impacts of unconventional natural gas extraction on aquatic ecosystems in northwestern Pennsylvania. *Journal of Environmental Science and Health, Part A* 50, no. 5 (2015): 482-500
- Brubaker, K. M., S. E. Johnson, J. Brinks, L. Leites. 2014. Estimating canopy height of deciduous forests at a regional scale with leaf off, low density LiDAR. *Canadian Journal of Remote Sensing.* 40(2), 123-134.
- Brubaker, K. M., Myers, W. L., Drohan, P. J., Miller, D. A., & Boyer, E. W. 2013. The Use of LiDAR Terrain Data in Characterizing Surface Roughness and Microtopography. *Applied and Environmental Soil Science.*

### **Synergistic Activities**

- Nov. 2014 ForestSAT2014: a bridge between forest sciences, remote sensing and geo-spatial applications, Riva Del Garda, Italy. (participant)
- Aug. 2014 CUAHSI 2014 Biennial Colloquium, Shepardstown, WV. *Comparing Vegetation Across Topographic Positions in Two Watersheds at the Susquehanna Shale Hills Critical Zone Observatory* Quincey Johnson (undergraduate student) Kristen Brubaker Margot Kaye (poster)
- May 2014 Community Workshop: The Next Generation of LiDAR Analysis for Critical Zone Research, Boulder Colorado. (NSF funded fellow)
- Oct. 2013 Utica College Biology Seminar Series, Utica, NY. *Estimating canopy height and site productivity of deciduous forests at a regional scale with leaf off, low density LiDAR* (invited talk)
- May 2011 CZO All Hands Meeting, Tuscon, AZ. *LiDAR imagery improves classification of forested landforms in the Shale Hills/Susquehanna Critical Zone Observatory of Pennsylvania.* (poster)

### **Ph.D. Thesis Advisors**

Wayne L. Myers, Emeritus Professor of Forest Biometrics, and Dr. Elizabeth W. Boyer, Associate Professor of Water Resources (The Pennsylvania State University).

### **Collaborators**

Bradley Cosentino (Hobart & William Smith Colleges)  
Chris Grant (Juniata College)  
Adrian Harpold (UNLV)  
Sarah Johnson (Pennsylvania Nature Conservancy)  
Margot Kaye (Penn State University)  
Laura Leites (Penn State University)  
Susan Stout (USDA Forest Service)  
Aaron Weiskittel (University of Maine)

## Letter of support CZO seed grant

Margot Kaye [mwk12@psu.edu]

Sent: Monday, March 30, 2015 4:58 PM

To: Brubaker, Kristen

Dear Kristen,

I fully support your CZO seed grant proposal to quantifying forest structure and C dynamics at the Shale Hills and Garner Run watersheds by combining LiDAR with on-the-ground vegetation measurements. This work builds on vegetation data that have been collected in the CZO since 2008 and will fill several knowledge gaps. For example, existing tree survey and coarse woody debris data from both watersheds can be joined with LiDAR data to improve C pool estimates. Your plans to sample understory vegetation will fill a gap in C pool estimates for vegetation. The work you propose fits very well in to a concept under development at the CZO of transitions from sampling “everything” at Shale Hills to “targeted” sampling at the larger Garner Run and Shaver’s Creek watersheds, because calibrating LiDAR data with targeted vegetation measurements will facilitate modelling vegetation across the larger watershed. Finally, the research you propose will have impacts beyond the CZO through calibration of field and LiDAR data to remotely measure forest structure and function across eastern deciduous forests. I look forward to continued collaboration at the CZO. Thank you for submitting this proposal.

Margot

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Margot W. Kaye  
Associate Professor of Forest Ecology, Department of Ecosystem Science and Management  
303 Forest Resources Building  
Penn State University, University Park, PA 16802  
phone: 814-865-4841, fax: 814-865-3725  
mwk12@psu.edu, <http://ecosystems.psu.edu/directory/mwk12>  
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HOBART  
AND  
WILLIAM SMITH  
COLLEGES

Office of Sponsored Programs

March 30, 2015

Bradley King  
Susquehanna Shale Hills Critical Zone Observatory  
Seed Grant Proposal Program  
EESI  
Pennsylvania State University

Re: *Using Leaf-on and Leaf-off LiDAR to model fine scale carbon storage from trees, understory, and coarse woody debris: A comparison across two watersheds*

PI: Kristen Brubaker/Hobart & William Smith Colleges

Dear Mr. King:

Hobart and William Smith Colleges are pleased to enthusiastically support Dr. Kristen Brubaker's proposal entitled *Using Leaf-on and Leaf-off LiDAR to model fine scale carbon storage from trees, understory, and coarse woody debris: A comparison across two watersheds*, being submitted to the Susquehanna Shale Hills Critical Zone Observatory Seed Grant Program

Should this proposal be awarded, the PI requests \$19,927 in support of her program, as detailed in the attached budget and justification. The period of performance will be 7/1/2015 through 6/30/2016.

If you have any questions or concerns, or need further information, please feel free to contact me.

Best regards,



Roberta Truscello  
Director of Sponsored Programs

**COLLEGES AND UNIVERSITIES RATE AGREEMENT**

EIN: 16-0743040

DATE: 03/04/2014

ORGANIZATION:

FILING REF.: The preceding agreement was dated 01/28/2011

Hobart and William Smith Colleges

337 Pulteney Street

Geneva, NY 14456

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.

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**SECTION I: Facilities And Administrative Cost Rates**

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

EFFECTIVE PERIOD

<u>TYPE</u>	<u>FROM</u>	<u>TO</u>	<u>RATE (%)</u>	<u>LOCATION</u>	<u>APPLICABLE TO</u>
PRED.	06/01/2014	05/31/2017	70.00	On-Campus	All Programs
PRED.	06/01/2014	05/31/2017	21.00	Off-Campus	All Programs
PROV.	06/01/2017	Until Amended	70.00	On-Campus	All Programs
PROV.	06/01/2017	Until Amended	21.00	Off-Campus	All Programs

\*BASE

Direct salaries and wages excluding all fringe benefits.

ORGANIZATION: Hobart and William Smith Colleges

AGREEMENT DATE: 3/4/2014

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**SECTION II: SPECIAL REMARKS**

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TREATMENT OF FRINGE BENEFITS:

Fringe benefits applicable to direct salaries and wages are treated as direct costs.

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 are not made for the cost of these paid absences.

OFF-CAMPUS DEFINITION: For all activities performed in facilities not owned by the institution and 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.

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.

ORGANIZATION: Hobart and William Smith Colleges

AGREEMENT DATE: 3/4/2014

**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:

Hobart and William Smith Colleges

(INSTITUTION)

*Peter Polinak*

(SIGNATURE)

*Peter Polinak*

(NAME)

*Vice President for Finance*

(TITLE)

*3/5/2014*

(DATE)

ON BEHALF OF THE FEDERAL GOVERNMENT:

DEPARTMENT OF HEALTH AND HUMAN SERVICES

(AGENCY)

*Darryl W. Mayes*

(SIGNATURE)

*Darryl W. Mayes*

(NAME)

*Deputy Director, Division of Cost Allocation*

(TITLE)

*3/4/2014*

(DATE) 1207

HHS REPRESENTATIVE:

*Ryan McCarthy*

Telephone:

*(212) 264-2069*