Learning Science Through Research
Published by Keck Geology Consortium
Short Contributions
29th Annual Symposium Volume
23rd April, 2016
ISBN: 1528-7491

HOLOCENE ENVIRONMENTAL CHANGE AND HUMAN IMPACTS IN SOUTHERN NEW ENGLAND

WILL OUIMET, University of Connecticut
MICHAEL HREN, University of Connecticut

INTRODUCTION

The processes that shape the southern New England landscape have shifted dramatically from Pleistocene glaciation to Holocene transgression to Anthropocene land management. While some processes such as glacial scour, fluvial incision or the formation of kettle ponds are readily apparent, other processes such as climatic impacts on long-term fire history or human alteration of elemental cycling may be less visible. New geospatial and geochemical techniques allow for a broader understanding of the geomorphology and dynamic history of this region and has revealed the great extent to which humans have modified the southern New England landscape (Johnson and Ouimet, 2014). A detailed understanding of past environmental change and the processes that have combined to form the landscape of southern New England is critical for evaluating the potential for future alteration due to climate and land use change as well as historical impacts on factors such as soil quality or water retention.

The legacy of glacial history and human impact in southern New England is made visible in the erosion and mobilization of sediment during large floods (Yellen et al., 2014) and in river restoration and dam removal efforts underway throughout the region as researchers are tasked with engineering rivers back to a sustainable natural condition (e.g., Burchsted et al., 2010; Gartner et al., 2015). Past geochemical alteration of the landscape or markers of change are somewhat less apparent. However, land use such as forest clearing, the development of intensive agriculture and animal husbandry, and the production of charcoal on an industrial scale can fundamentally alter soil properties (e.g. water retention, infiltration, pH, redox state, organic C content, nutrient availability), C and N cycling, the distribution of combustion-related geochemical markers (e.g. PAHs), as well as the abundance of metals associated with the weathering of recently deglaciated terrain or industrial activity. In combination, geochemical and geomorphic data can yield a comprehensive record of Anthropocene alteration of the southern New England landscape.

The primary goal of the 2015 Keck Connecticut project was to develop sedimentary and geochemical records of climate, landscape change, and human impact from the Holocene through the Anthropocene. Students and faculty utilized high resolution Digital Elevation Models from LiDAR data available throughout western and eastern Connecticut to target wetlands and mill ponds for coring, and to identify tracts of land characterized by varied historic land use for detailed soil studies. The 2015 Keck Connecticut project built on previous Keck projects (Connecticut, 2013; Connecticut, 2010; Block Island, 2008) that addressed the confluence of natural and anthropogenic processes affecting the geomorphology and geochemistry of this historic region. Similar to these past Keck projects, Keck Connecticut took advantage of the close proximity of focus areas and project faculty home institutions, allowing for a mix of field and laboratory research by student participants and active engagement with thriving research communities. In addition, Keck Connecticut integrated the geomorphic and geochemical expertise of project faculty to engage students in interdisciplinary research.

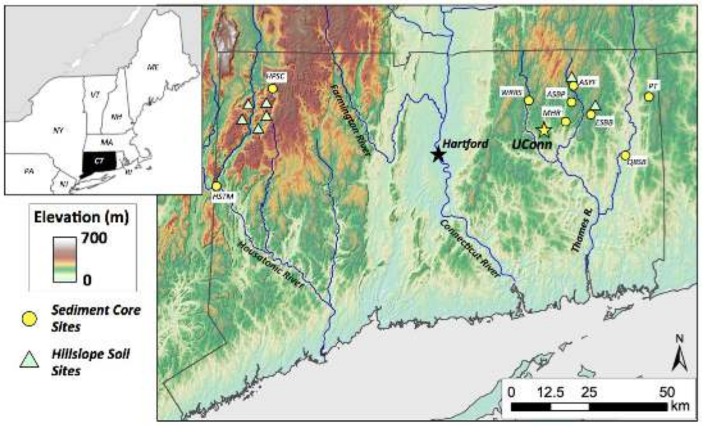

Figure 1. Overview map of the 2015 Keck Connecticut project

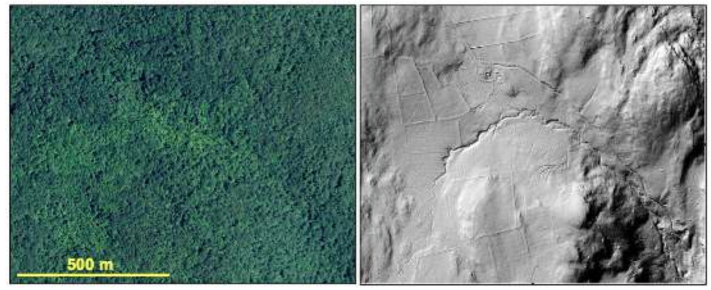

Figure 2. An aerial image shows a forested landscape while a hillshaded DEM derived from LiDAR data for the same area reveals polygons of stone wall lined fields, an old road, circular charcoal hearth platforms (lower right), an old foundation, and gully erosion. Data sources: CTECO (imagery) and USDA NRCS (LiDAR).

BACKGROUND

The landscape of southern New England preserves a diverse record of Late Pleistocene to present environmental change. The Laurentide Ice Sheet retreated from the region between 21 and 17 ka, leaving a diverse array of glacial landforms and sediments throughout the landscape and leading to complex grain size variations throughout watersheds, river fragmentation (including wetlands), and varied bedrock/alluvial rivers (Thorson et al., 1998; Stone et al., 2005).

Humans began to inhabit the region following deglaciation and produced a range of measurable ecological changes throughout the Holocene such as agriculture and the burning of large swaths of forest underbrush to maintain hunting habitat and agricultural areas (Cronon, 1983). The regional extent of early human impacts throughout the region is likely to have been relatively small and concentrated near the coast and along major river valleys. More recently, the landscape underwent an even more remarkable land-use/land-cover change when nearly 200 years of widespread deforestation and agricultural expansion from the 17th to early 20th centuries was followed by a dramatic reduction in agriculture and forest regrowth (Cronon, 1983; Merchant 1989; Foster et al., 2008) (Figure 2). In addition to landscape response associated with deglaciation and human impact, the southern New England landscape has also seen a range of climatic variability and extreme events such as hurricanes, floods and large-scale fires over the Holocene (e.g., Patton, 1988).

New geospatial data (LiDAR) has opened our eyes to a deeper level of detail for the geomorphology and dynamic history of this region. Available LiDAR datasets cover vast stretches of the forested terrain that now dominates the region and allow for a high resolution view of landforms and processes, and the region's 17th to early 20th century land use history (Johnson and Ouimet, 2014). The most prominent and widespread type of 17th to early-20th land use in southern New England was agriculture and pasture. For hundreds of years, each "crop" of stones that rose to the surface due to soil erosion and the deep frosts within rocky, glacial till-mantled fields and pasture lands were built into walls that have become an iconic feature of this landscape. Maps of stone wall distribution indicate the extent of historically cleared or plowed land. In turn, these stone wall maps can be used to study the impacts of historically cleared land on modern soils and forests in the region, such as contributing to the stoniness of the soil (Dincauze, 2004; Thorson, 2002), development of a thick A-horizon plow-zone, and forest structure and location of specific types of species (Foster, 1992).

Another prominent example of pre-20th century land use in southern New England was clearing forests for charcoal production. Though not as widespread as agriculture and pasture land use, charcoal production occurred in select regions of the northeast such as northwestern CT and adjacent MA and NY counties where iron mining and subsequent processing was dominant from the late 18th to late 19th century. Today, direct evidence of historic charcoal production is extant throughout northwestern Connecticut in the form of relict charcoal hearths (RCHs) that are observed in LiDAR (Figure 2). A single charcoal hearth required 25 to 35 cords of wood (typically from 1-2 acres of cleared forest) and produced 900-1200 bushels of charcoal (Straka, 2014). The impacts of charcoal production on soil and forest ecosystems must be considered in watershed studies, such as increased stocks of soil organic carbon (SOC) and reduced plant growth (Mikan and Abrams, 1995).

The emerging view of 17th to early 20th century southern New England is that of a patchwork of historic land use (agriculture and pasture from stone walls; charcoal production from RCHs; Figure 3), such that forested watersheds throughout southern New England today should be assumed to have been 70-100 % cleared at some point prior to the 20th century. One of the byproducts of land clearing is soil degradation, increased run-off and downstream sedimentation (e.g., Trimble, 1985). Soil erosion and sediment mobilization are well-documented in 19th century accounts, and associated legacy sediment is likely to be stored within watersheds behind historic mill dams and in wetlands (e.g., Walter and Merritts, 2008; Merritts et al., 2011; Thorson et al., 1998).

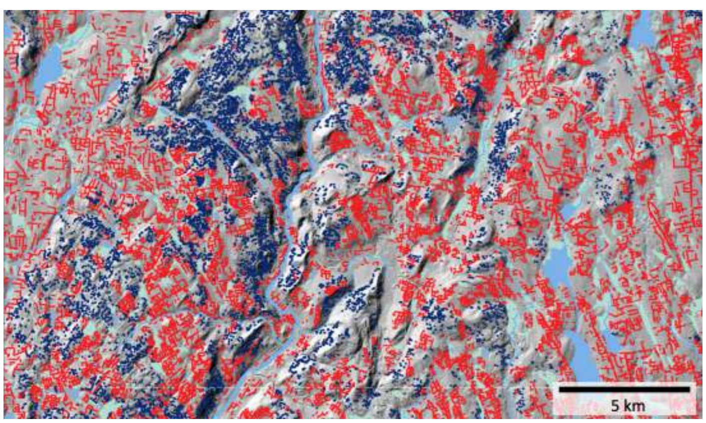

Figure 3. Historic land use in Litchfield Country Connecticut - agriculture and pasture is inferred from the extent of stone walls (RED); timber harvesting and charcoal production is inferred from the extent of relict charcoal hearths (DARK BLUE). Forested watersheds throughout the region today should be assumed to have been 70-100 % cleared at some point prior to the 20th century.

APPROACH

Students and faculty of the 2015 Keck Connecticut project conducted field measurements and sampling throughout Connecticut to characterize the impact of historic land use (including agriculture, pasture and charcoal production), Holocene fire frequency, climate change and vegetation shifts, and effects of the historic mill dams. Students supported by the Keck Geology Consortium learned sediment coring, soil sampling techniques, core description, LOI and grain size measurement, data reduction, processing and GIS visualization methods (including LiDAR) and methods in stable isotope and organic molecular geochemistry. Students chose from a variety of potential projects in western and eastern Connecticut. The 2015 topical areas included:

Characterizing the effects of historic land use on soil geochemistry and hillslope sediment transport

Evaluating the integrated record of climate, ecosystems and forest fire in northeastern forests over the Holocene

Analyzing the geochemistry of wetlands as archives of Holocene and Anthropocene landscape change

Characterizing sedimentation and legacy sediments behind 19th century mill-dams (see Figure 4)

Figure 4. Top: Dam and sediment filled reservoir at the Buena Vista/Hunts Lyman Iron Company Furnace site on the Hollenbeck River in Canaan, Connecticut. Bottom: (left) Historical photo of the iron furnace, c. 1870 (courtesy of David M. Hunt Library) - note bridge over dam site in the foreground; (right) Keck Connecticut students vibracoring the reservoir sediment behind the dam in July 2015

In addition to these projects, students helped with an ongoing project within UConn Geosciences to study Holocene floods inferred from sediment cores taken within kettle holes adjacent to major watersheds in the region (Housatonic and Thames). Establishing a record of past fluvial processes is crucial for developing a long-term context for evaluating modern floods and future climate change. Detailed records of past storms exist for some small watersheds in northern New England (e.g, Bierman et al. 1997), but are lacking for larger rivers and watersheds throughout southern New England in general. LiDAR analysis reveals many sites for coring and detailed analysis within the Housatonic and Thames River watersheds, including sites along the Mount Hope River, Fenton River and Willimantic River, which were cored in July 2015 with the help of Keck Connecticut students. There is no local sediment input at these kettle pond sites and only floods large enough to overtop the topography surrounding the kettle pond can deposit sediment at the sites.

Figure 5. Keck Connecticut students and Will Ouimet in Natchaug State Forest, Eastford, Connecticut.

STUDENT PROJECTS

Six Keck students joined project faculty Will Ouimet and Michael Hren, and UConn graduate students Tom Schenck (UConn Geosciences MS) and Abigail Oakes (UConn Chemistry PhD) for field work in western and eastern Connecticut and laboratory work at the University of Connecticut. Keck Connecticut students worked in pairs on a daily basis and often as a group on field trips (Figure 5) to extract 3-5 m sediment cores, dig soil pits, or work as a team in the lab for core splitting, description, photographing, and sampling. Short papers elsewhere in this volume report results of the field and laboratory studies in some detail. We summarize and provide brief notes on this research here.

Land use can directly impact the physical and geochemistry of soils that are preserved on the landscape. **Sally Donovan (Carleton College)** sampled soils from areas with distinct historic land use histories (e.g. pasture, agriculture, charcoal production, and minimally-altered old growth forest) to measure the effects of land use on physical and chemical soil properties such as O/A thickness, organic content, grain size, pH, available phosphorous, and extractable base cations (Mg, Ca, Na, and K). Differences in these variables may fundamentally impact soil nutrient availability, water retention, and ecosystem resilience to external perturbations. A primary goal of her study was to evaluate the impact of the ubiquitous charcoal production in NW Connecticut forests on associated soil chemistry. Sample sites focused on quantifying geochemistry of relict charcoal hearths and adjacent soils in comparison with soils formed on pastoral, agricultural and old-growth forest lands with similar glacial till cover. Her work demonstrated significant and lasting changes in soil density, organic content, and major cation and P availability over a broad areal extent associated with this major regional land use.

Charcoal production in northwestern CT and associated land clearing has led to region-wide stores of buried organic carbon and changes in the physical morphology of hillslopes throughout the region. **Mary Ignatiadis (Williams College)** mapped and sampled over 60 relict charcoal hearths preserved on forested hillslopes in Litchfield County, Connecticut. The sites, active between late 18th and late 19th century, record a period of intense charcoal production and are representative of the over 21,000 relict charcoal hearths mapped to date in northwest Connecticut (Johnson et al., 2015). Each site consists of a soil platform that was constructed to facilitate a charcoal mound, as well as the layers of soil and charcoal rich material that accumulated during repeated use at the site. Mary quantified the average thickness of organic, charcoal-rich material and the volume of redistributed soil and hillslope material at RCH sites. Her results provide new quantification of the impact of charcoal production on region-wide buried carbon as well as the process of charcoaling as an agent of geomorphic change, hillslope sediment transport and soil diffusion.

Figure 6. Sally Donovan (left) and Mary Ignatiadis (right) sampling soils and studying relict charcoal hearths in western Connecticut

Colonial-era land clearing and industrialization may have fundamentally altered "natural" patterns of fire and disturbance. While there is considerable evidence of "recent" land use change, there is still significant uncertainty over the long-timescale coupling of New England ecosystems, climate and fire. **Chad Fagan (UConn)** analyzed the abundance and distribution of polycyclic aromatic hydrocarbons (PAHs) and plant wax C isotopes in a 5.5 m, 12 ka sediment core in western Connecticut to produce an integrated record of the postglacial ecosystem, climate and fire. Chad's site, located in an abandoned paleo-channel at the confluence of the Housatonic and Ten Mile Rivers, preserves a record of Holocene climate and vegetation changes, as well as forest fire intensity. Data from his work show a clear transition in the local and regional ecosystem from a small lake system that was likely characterized by overall frequent regional fires ~12,000 years BP, to a mid-Holocene peatland environment with regional forests characterized by low PAH abundance and likely low fire frequency. The late Holocene/Anthropocene shows a return to enriched carbon isotopes that are consistent with rapid regrowth of vegetation and an increase in PAH abundance due to regional wood-burning or industrially-produced PAHs.

Land use patterns impact soil and ecosystem nitrogen cycling and carbon dynamics as well as the availability of heavy metals. In particular, establishment of intensive agriculture or animal husbandry can

Figure 7. Left to right: Tom Schenck, Mike Hren, Chad Fagan and Caitlin McManimon after a successful wetland core in Ashford, Connecticut

dramatically shift C or more significantly, N availability, and local or regional industrialization can introduce significant atmospherically-deposited metal pollution. **Caitlin McManimon (Union College)** analyzed stable isotopes ($\delta^{13}C$ and $\delta^{15}N$) and heavy metal concentrations within four sediment cores from eastern Connecticut to evaluate the potential of these parameters as a clear marker of Anthropocene landscape alteration. Sediment core locations were targeted on wetland sites that hold the potential to record Holocene through Anthropocene sediment. Three of Caitlin's sites preserve records of Holocene and Anthropocene environmental change; one preserves 1 m of sediment behind a Colonial earthen dam. Results from this work show a remarkably consistent pattern of landscape change across the region, with a fundamental shift in the nitrogen isotope dynamics in the upper 0.5 m of wetland sediments coincident with a dramatic increase in heavy metals. These data show that Anthropocene agriculture, forest clearing and industrialization produces a distinct geochemical signature. Perhaps most interesting however, is that changes in Nitrogen isotope systematics precede peak shifts in metals, highlighting a two-stage record of human impact due to land use change in and around Connecticut wetlands.

Anthropocene forest clearing for charcoal production, agriculture and pasture provided significant potential to alter sediment transport budgets throughout southern New England. **Jia Kelleher (Mt. Holyoke)** mapped sediment thickness and collected sediment cores to study the record of 19th and 20th century sedimentation behind the Hollenbeck Dam, built in 1850 along the Hollenbeck River in Canaan, CT for the Buena Vista iron furnace at the site (Figure 4). Her goal was to characterize timescales of sediment deposition and associated sediment geochemistry. Historical archives show that the Hollenbeck Dam was built during a period of intense land use and coincided with peak charcoal production in NW Connecticut. Early 20th century air photos reveal a landscape in the process of revegetation, but a fluvial system that had rapidly aggraded in response to presumably high sediment fluxes during the period of peak industrial activity.

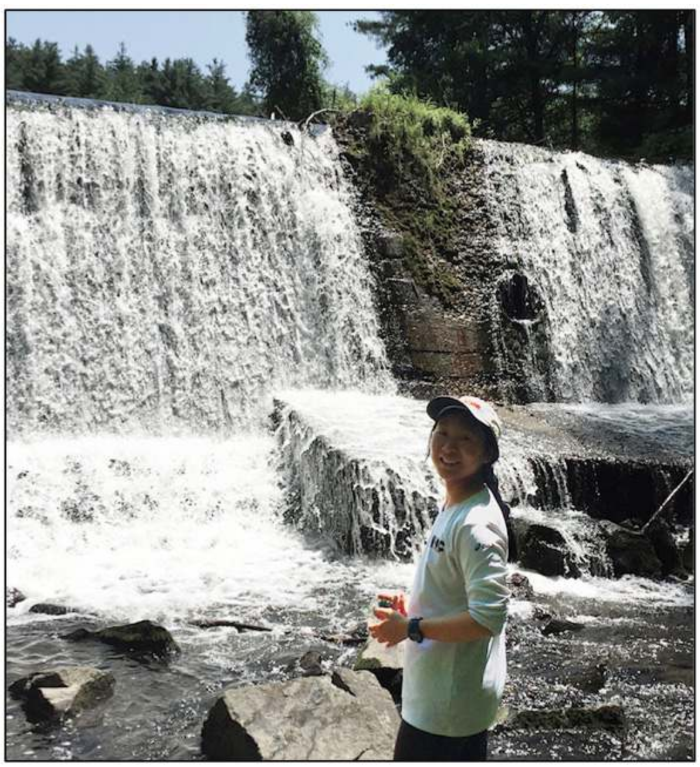

Figure 8. Jia Kelleher at the base the Hollenbeck dam, Canaan CT

CONCLUSIONS

The landscape of Southern New England provides a natural laboratory to study the integrated interactions between climate, ecosystems, and human impact on the landscape. Over the last 20,000 years, the landscape of New England has fundamentally transformed from a stark glacial terrain to a dynamic, highly vegetated ecosystem with dense networks of human habitation and land use. In just the past 500 hundred years, human modification of the landscape has imparted a signal that in some cases, may rival the physicochemical signatures associated with the dramatic retreat of glaciers from the New England landscape. The 2015 Keck Connecticut project was specifically focused on recording and quantifying geochemical and sedimentary signatures of ecosystem and land use change. In particular, our goal was to examine records of Anthropocene change in southern New England soil and wetland archives.

Designing projects that targeted ecosystem and land-use change in southern New England enabled Keck undergraduates to integrate their research projects into the ongoing research of graduate students and PIs at the University of Connecticut as well as other U.S. and international researchers. In addition, Keck students benefitted from the ability to conduct their research in both the “natural” laboratory of Southern New England and the geochemical and sedimentary laboratories on UConn’s campus. Research projects spanned a range of disciplines, but all focused on a singular goal of understanding archives of land use change. Finally, the field and laboratory research of Keck Connecticut students has directly contributed to ongoing research efforts of both UConn PIs and will provide seed data for new and emerging research ideas.

ACKNOWLEDGMENTS

Field studies, lab work and analysis in Connecticut during Summer 2015 were performed in cooperation with the University of Connecticut Center for Integrative Geosciences, Department of Chemistry and Department of Geography. We thank the following individuals for their valuable contribution: Jaclyn White and Greg Harris (University of Connecticut – Geosciences) helped with field logistics; Robert Thorson (University of Connecticut – Geosciences) taught us about quaternary stratigraphy in New England and core description; Brian Jones (Connecticut State Archaeologist) shared perspectives on Native American landscape change prior to the

17th century; Peter Leach (University of Connecticut - Anthropology) shared sediment-coring expertise and demonstrated the use of GPR for near surface geophysical studies; Jon Woodruff and Brian Yellen (University of Massachusetts) and Drew Hyatt (Eastern Connecticut State) shared expertise on sediment coring; Katharine Johnson (University of Connecticut – Geography) helped with archival research, shared GIS and LIDAR expertise and maps of historical features; David Dethier (Williams College) provided assistance in the field; Nick Boyden (Hollenbeck Gun Club land-manager) provided essential assistance with access, background information, a kayak, and extra bolts at the Hollenbeck dam site. We gratefully acknowledge the following organizations for access to field sites: Hollenbeck Gun Club; the June Norcross Scout Reservation in Ashford; Yale Forest; Sharon Audubon Center and Emily Winthrop Miles Wildlife Sanctuary; Connecticut Department of Energy and Environmental Protection (who manages Housatonic State Forest, Natchaug State Forest, Cathedral Pines and Wyantenock State Forest); and Eversource Energy. We also thank Lisa Park-Boush, director of the University of Connecticut Center for Integrative Geosciences, for funding a small portion of summer activities.

REFERENCES

Bierman, P., Lini, A., Zehfuss, P., Church, A., Davis, P.T., Southon, J. and Baldwin, L., 1997. Postglacial ponds and alluvial fans: Recorders of Holocene landscape history. *GSA TODAY*, *7*(10).

Burchsted, D., Daniels, M., Thorson, R., and Vokoun, J., 2010, The River Discontinuum: Applying Beaver Modifications to Baseline Conditions for Restoration of Forested Headwaters. *Bioscience*, 60(11), 908-922.

Cronon, W., 1983. *Changes in the Land*. Hill and Wang: New York.

Dincauze, D.F., 2004. Yankee Walls. Rev. *Archaeology*. 25, 10–13.

Foster, D. R., 1992. Land-use history (1730-1990) and vegetation dynamics in Central New England, USA. *Journal of Ecology* 80 (4), 753–771.

Foster, D. R., Donahue, B., Kittredge, D., Motzkin, G., Hall, B., Turner, B., and Chilton, E., 2008. New England's forest landscape: ecological legacies and conservation patterns shaped by agrarian history. In *Agrarian Landscapes in Transition: Comparisons of Long-Term Ecological & Cultural Change*, eds. C. R. Redman and D. R. Foster, 44–88. New York: Oxford University Press.

Gartner, J.D., Magilligan, F.J. and Renshaw, C.E., 2015. Predicting the type, location and magnitude of geomorphic responses to dam removal: Role of hydrologic and geomorphic constraints. *Geomorphology*, 251, pp.20-30.

Johnson, K. M., and Ouimet, W.B., 2014. Rediscovering the lost archaeological landscape of southern New England using airborne Light Detection and Ranging (LiDAR). *Journal of Archaeological Science* 43, 9–20.

Johnson, K., Ouimet, W. and Raslan, Z., 2015, Geospatial and LidarBased Analysis of 18th to Early 20th Century Timber Harvesting and Charcoal Production in Southern New England. Geological Society of America Northeastern Section Meeting. Breton Woods, NH.

Merchant, C., 1989. *Ecological Revolutions: Nature, Gender, and Science in New England*. Chapel Hill: University of North Carolina Press.

Merritts, D., Walter, R., Rahnis, M., Hartranft, J., Cox, S., Gellis, A., Potter, N., Hilgartner, W., Langland, M., Manion, L., Lippincott, C., Siddiqui, S., Rehman, Z., Scheid, C., Kratz, L., Shilling, A., Jenschke, M., Datin, K., Cranmer, E., Reed, A., Matuszewski, D., Voli, M., Ohlson, E., Neugebauer, A., Ahamed, A., Neal, C., Winter, A., and Becker, S., 2011. Anthropocene streams and base-level controls from historic dams in the unglaciated mid-Atlantic region, USA. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 369(1938), 976–1009.

Mikan, C. J., and Abrams, M. D., 1995. Altered forest composition and soil properties of historic charcoal hearths in southeastern Pennsylvania. *Canadian Journal of Forest Research* 25 (5), 687–696.

Patton, P. C., Geomorphic response of streams to floods in the glaciated terrain of southern New England, Flood Geomorphology, V. R. Baker, R. C. Kochel, P. C. Patton, 261–278, John Wiley, New York, 1988.

Straka, T. (2014). Historic Charcoal Production in the US and Forest Depletion: Development of Production Parameters. *Advances in Historical Studies*, 3, 104-114.

Stone, J. R., Schafer, J. P., London, E. H., DiGiacomo-Cohen, M. L., Lewis, R. S., & Thompson, W. B., 2005, Quaternary Geologic Map of Connecticut and Long Island Sound Basin, US Department of the Interior, US Geological Survey, p. 1–78

Thorson, R. M., Harris, A. G., Harris, S. L., Gradie, R., and Lefor, M. W., 1998. Colonial impacts to wetlands in Lebanon, Connecticut. *Reviews in Engineering Geology 12*, 23-42.

Thorson, R., 2002. *Stone by stone: the magnificent history in New England's stone walls*. New York: Walker & Company.

Trimble, S.W., 1985. Perspectives on the History of Soil Erosion Control in the Eastern United States. *Agricultural History* 59(2), 162-180.

Walter, R.C., and Merritts, D.J., 2008. Natural Streams and the Legacy of Water-Powered Mills. *Science* 319(5861), 299–304.

Yellen, B., Woodruff, J.D., Kratz, L.N., Mabee, S.B., Morrison, J. and Martini, A.M., 2014. Source, conveyance and fate of suspended sediments following Hurricane Irene. New England, USA. *Geomorphology*, 226, pp.124-134.