Soil Carbon Storage in Barrier Island Landscapes as a Function of Topography and Landform

DEPARTMENT OF ENVIRONMENTAL SCIENCE & TECHNOLOGY
College of Agriculture & Natural Resources
www.enst.umd.edu

Ann M. Rossi and Martin C. Rabenhorst

Department of Environmental Science and Technology, University of Maryland

Contact: Ann M. Rossi, arossi1@umd.edu

Introduction

Barrier islands of the Mid-Atlantic coast are estimated to be between 5000 and 7000 years in age, but many of the surfaces and landforms on the islands are far younger, on the order of tens to hundreds of years. Initial soil development in these weathering resistant parent materials is often limited to the formation of O and A horizons as organic matter accumulates. Barrier island landscapes provide a unique opportunity to study these early soil formation processes. Depth to water table and duration of saturation controls plant growth, development of anaerobic or reducing conditions in the soil, and decomposition and accumulation of organic matter. High infiltration rates, high hydraulic conductivities, and low water holding capacities result in water tables that are fairly level despite greater variation in topography. Topographic position becomes an analog to the depth of the water table and drainage.

Objective

The objective of this study is to assess the magnitude of soil organic carbon stocks in barrier island landscapes as a function of topography and landform in order to better understand soil carbon accumulation and decomposition processes in these environments.

Methods

Four topographic transects were identified across a range of landforms at Assateague Island National Seashore, located along the Mid-Atlantic coast in Maryland (Figs. 1 and 2). Topographic transects ranged from excessively or moderately well drained summit positions to poorly or very poorly drained interdunal swales and depressions in the barrier core (Figs. 3 and 4). Two meter deep wells with automatic data loggers (12 hour intervals) were installed at the high, mid, and low positions of the transect. Vegetation surveys were conducted along each of the transects.

Fig. 1

Fig. 2

Fig. 3

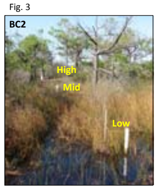


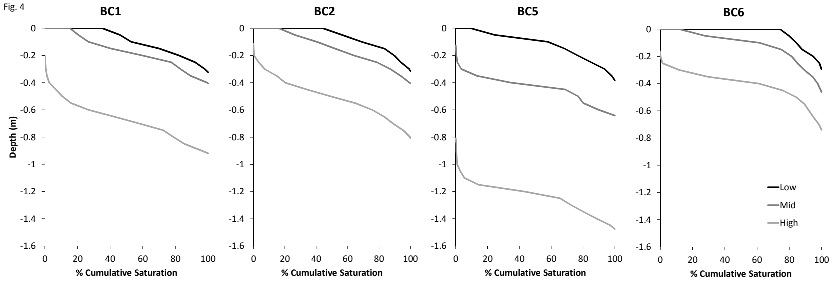
Fig. 4

At each of the high, mid, and low positions three replicate 50 cm soil cores were collected. Soil cores were divided by horizons and analyzed for organic carbon content by dry combustion at 950°C using a LECO CHN-2000 Analyzer (LECO Corporation, St. Joseph, MI) (Nelson and Sommers, 1996).

Hydrology

Topographic relief corresponds closely to differences in water table depth between low, mid, and high positions within a transect (Figs. 4 and 5). Cumulative saturation graphs (Fig. 4) are based on twice daily measurements recorded 3/1/2011 through 2/29/2012.

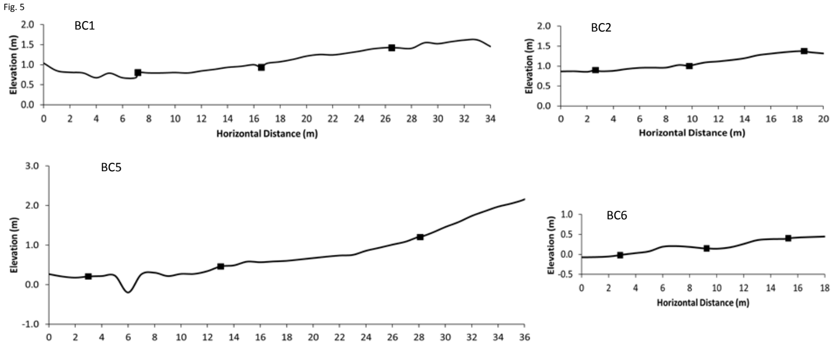
Fig. 4



Topographic Relief, Soil Morphology, and Vegetation

Topographic relief across transects (Fig. 5) was subtle (generally less than 1.0 m) however, there are notable differences in soil morphology, vegetation, and hydrology. Across all transects, thicker O and A horizons were observed at low and mid positions.

Fig. 5



BC1 and BC2

- Vegetation at low and mid sites is dominantly herbaceous with increasing shrub cover at the mid positions. Shrub species include wax myrtle (*Morella cerifera*), northern bayberry (*M. pensylvanica*), and loblolly pine (*Pinus taeda*).
- High sites are sparsely vegetated by grasses, wooly beachheather (*Hudsonia tomentosa*) dwarf-shrubs, shrubs (*M. cerifera, M. pensylvanica*) and stunted trees (*P. taeda*).
- Significant soil organic matter accumulation at low (Fig. 6) and mid (Fig. 7) positions is limited to the upper 5 cm of the soil profile in Oa and A horizons.
- CA horizons at the surface of high sites (Fig. 8) are very low in organic matter, less than 0.5%.

Fig. 6

Fig. 7

Fig. 8

BC5 (Figs. 9-11) and BC6

- Sites are forested with a nearly closed canopy across the entire transect. Dominant species include loblolly pine (*P. taeda*), red maple (*Acer rubrum*), highbush blueberry (*Vaccinium corymbosum*), and American holly (*Ilex opaca*).
- Organic matter accumulation in surface horizons is thicker than observed at BC1 and BC2 sites. Organic horizons are predominantly Oi and Oe horizons composed of decaying leaf litter and pine needles.

Fig. 9

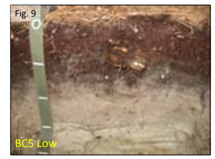


Fig. 10

Fig. 11

Organic Carbon Stocks

Lower topographic positions were more frequently saturated in the upper part of the soil profile (Fig. 4). Across all transects, organic carbon stocks increased with frequency of saturation (p=0.052) (Fig. 12), resulting in larger carbon stocks in the lower topographic positions within a transect. Sandy soils (such as those on Assateague Island) have high infiltration and rapid drainage rates. Increased moisture in the lower sites may lead to greater primary productivity, and thereby greater carbon inputs to the soil. Additionally, frequently or continuously saturated soils have slower organic decomposition rates, resulting in increased organic carbon accumulation. Comparisons of vegetative communities and soil morphology at topographic positions within transects suggest that both organic carbon input and decomposition rates influence the carbon stocks measured.

Fig. 12

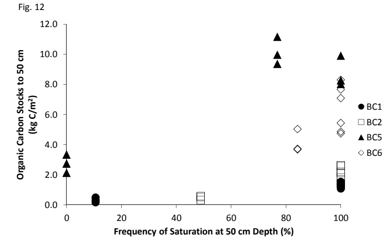
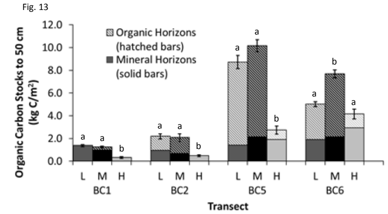


Fig. 13



Letters represent significant differences within each transect

Within each transect, organic carbon stocks at low and mid positions are not significantly different (α level = 0.05), with the exception of the BC6 transect (Fig. 13). At BC6, the mid position has greater carbon stocks than the low (p=0.0017) and high (p=0.0004) positions. At BC1, BC2, and BC5 organic carbon stocks are lowest at high positions.

BC5 and BC6 have larger carbon pools than soils at BC1 and BC2. Figure 19 shows the proportion of organic carbon contained in organic and mineral horizons (hatched and solid filled bars, respectively). A large proportion of the organic carbon in BC5 and BC6 soils is in organic horizons, particularly at the low and mid positions.

Initial Conclusions

Increased carbon stocks at low and mid sites (relative to high sites) may be related to greater carbon inputs and slower decomposition rates associated with shallower water tables. BC6 Low is ponded for the majority of the year, which may limit primary productivity and organic carbon inputs. Corresponding carbon stocks at low and mid sites within transects may reflect similar hydrology and resulting accumulation and decomposition rates.

Variability between sites and larger carbon stocks at BC5 and BC6 sites indicates a site effect. Possible influences might include:

- Differences in vegetation
  - Carbon inputs may vary with species, both due to relative above and belowground inputs and varying decomposition rates associated with different plant materials.
  - Differences in vegetative communities (species diversity and density) may affect soil temperature, pH, and nutrient availability, thereby influencing decomposition rates.
- Effect of landform stability and soil age
  - Older, more stable landforms would have increased time for organic matter accumulation, potentially leading to larger carbon stocks.
  - Ecological succession and establishment of different vegetative communities may lead to variation in carbon inputs (as mentioned above).

Future Work

In order to identify sources of variability between sites and better define the role of hydrology, vegetation, and landform on carbon accumulation, further work will include:

- Estimation and comparison of carbon inputs across and between transects through leaf litter collections and biomass harvests.
- Use of Optically Stimulated Luminescence (OSL) and radiocarbon dating techniques to estimate soil age and organic carbon accumulation and decomposition rates.
- Data from an additional six sites will be analyzed to better assess variability between sites and the effect of landform.

References:
Nelson, D.W., and L.E. Sommers. 1996. Total carbon, organic carbon, and organic matter. *In* D. L. Sparks, et al., (eds.) Methods of Soil Analysis: Part 3 Chemical Methods. SSSA, Madison, WI. p. 961-1010.

Acknowledgements
This work is supported by the Maryland Agricultural Experiment Station and the USDA-NRCS.
Thanks to Mark Matovich, Ashley Robey, Heather Hall, Ryan Adams, Chris Palardy, Phil Clements, and Dan Fenstermacher for assistance with field and laboratory work. Also, thanks to Gary Seibel and the ENST Project Development Center for assistance with instrumentation.