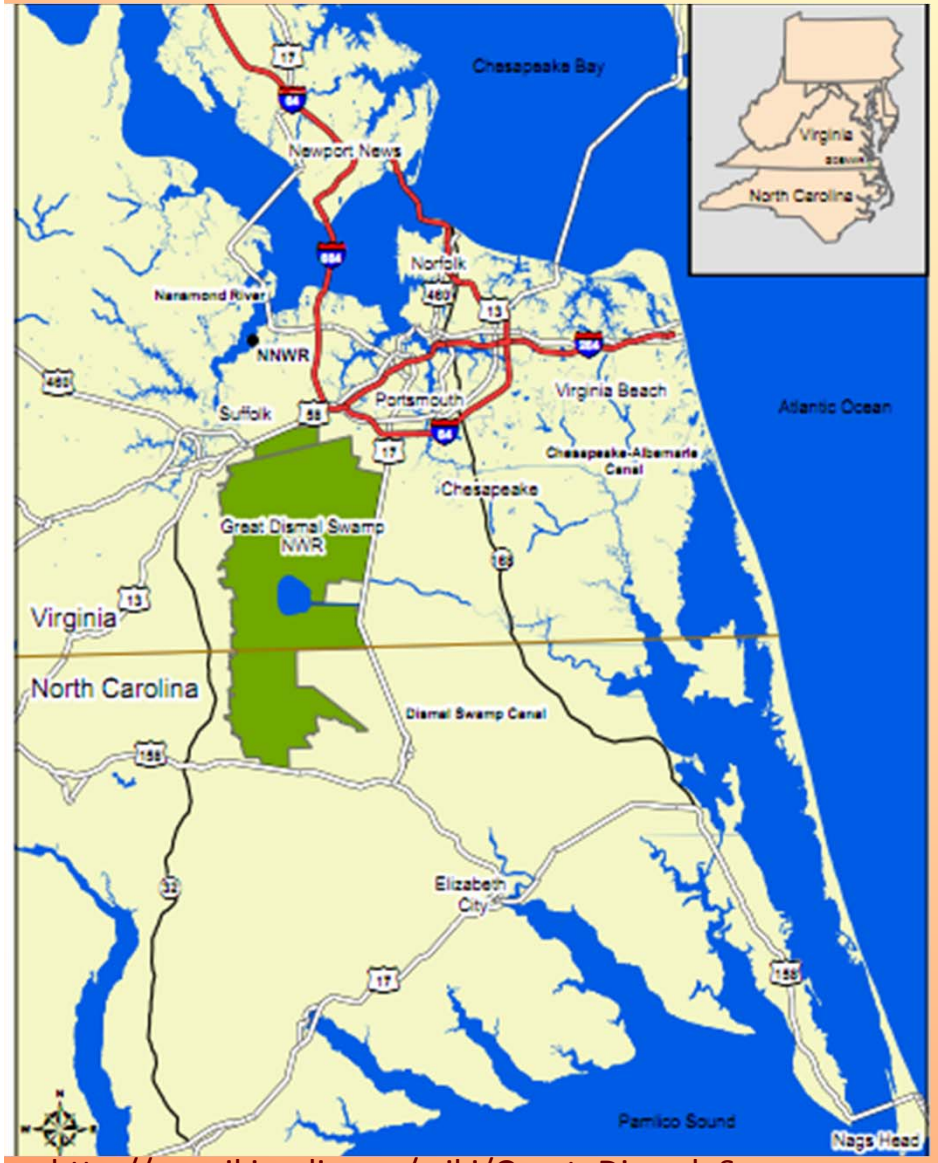
Soil properties in burned and unburned Atlantic White Cedar stands as a means to quantify impacts from recent fires in the Great Dismal Swamp National Wildlife Refuge

Kristina M. Kowalski

Jackie Roquemore

Robert B. Atkinson

Great Dismal Swamp National Wildlife Refuge (GDSNWR)



< http://en.wikipedia.org/wiki/Great_Dismal_Swamp>

- 112,000 acres of forested wetlands
- Flow into two main watersheds
  - Roanoke-Tar-Neuse-Cape Fear
  - Chesapeake Bay-Susquehanna River
- Has a deep organic layer of soil

Peat Soil

Ecological Role

- Filters sediment and excess nutrients from neighboring agriculture
- Sequesters atmospheric carbon
- Habitat for unique species

Characteristics

- Typically acidic
- Periods of inundation and anaerobic conditions
- Nutrient poor

(Brady and Weil 2008)

<http://soilsdev.waikatoregion.govt.nz/PageFiles/49/SoilPics/Large/Rukuhia%20Peat.jpg>

Atlantic White Cedar (AWC)

Originally one of the dominant species of the Great Dismal Swamp (Kearney 1901)

Shortly after the Refuge was established in 1974 AWC was classified as a target species for protection

http://www.fws.gov/nc-es/coastal/plnwrawc/awcindex.html

AWC and Fire

http://www2.wnct.com/news/2011/aug/11/12/great-dismal-swamp-fire-grows-crosses-nc-ar-1289874/

Fire dependence

- Stand clearing fire coinciding with a high water table promotes AWC regeneration
- Seeds remain dormant in moist peat layer and will germinate after fire (Laderman 1989, Motzkin *et al.* 1993)

- The loss of AWC in the Refuge has been attributed to recent fires that coincided with a low water table and no pure stands remain
  - South One Fire in 2008
  - Lateral West Fire in 2011

Acute Effects of Drainage Ditches

- Increases frequency and severity of forest fires
- Reduces AWC seed bank
- Alters hydrology and microtopography
- Directly or indirectly alters soil physical and chemical properties

Fire Effects Peat Properties

(Brady and Weil 2008)

- Decrease of organic matter
- Increase bulk density
- Variable effect on nutrient content
  - Nitrogen
  - Carbon

<http://www.uci.edu/uci/features/2008/12/images/deforestation_p081208_01a_.jpg>

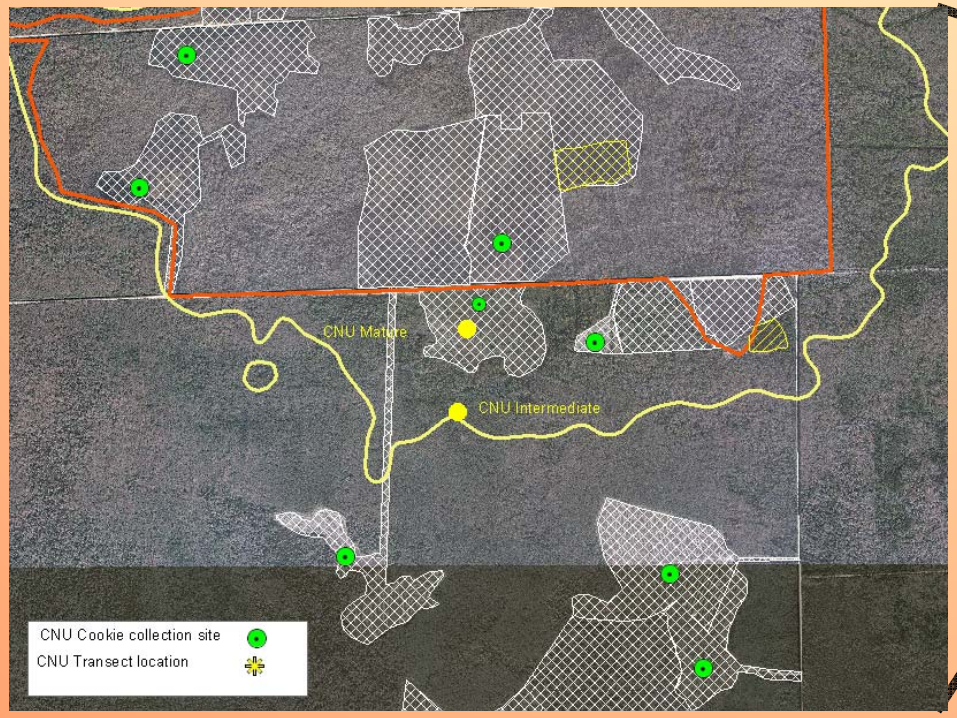
Purpose of This Study

- To evaluate soil properties after the South One Fire in 2008 in order to support AWC restoration
  - **SOIL PROPERTIES:** Quantify the effects of fire on selected soil physical (bulk density) and chemical characteristics (carbon and nitrogen content)
  - **TREE TISSUE:** Determine if nutrient content in post fire soils effects the tissue nutrient content in AWC needles

- **CARBON EMISSIONS:** Estimate the amount of carbon released from peat burned in the Lateral West Fire in 2011

South One Fire of 2008

- 1960 ha (4,844 acres)
- Burned approximately 1 meter (3 feet) of peat

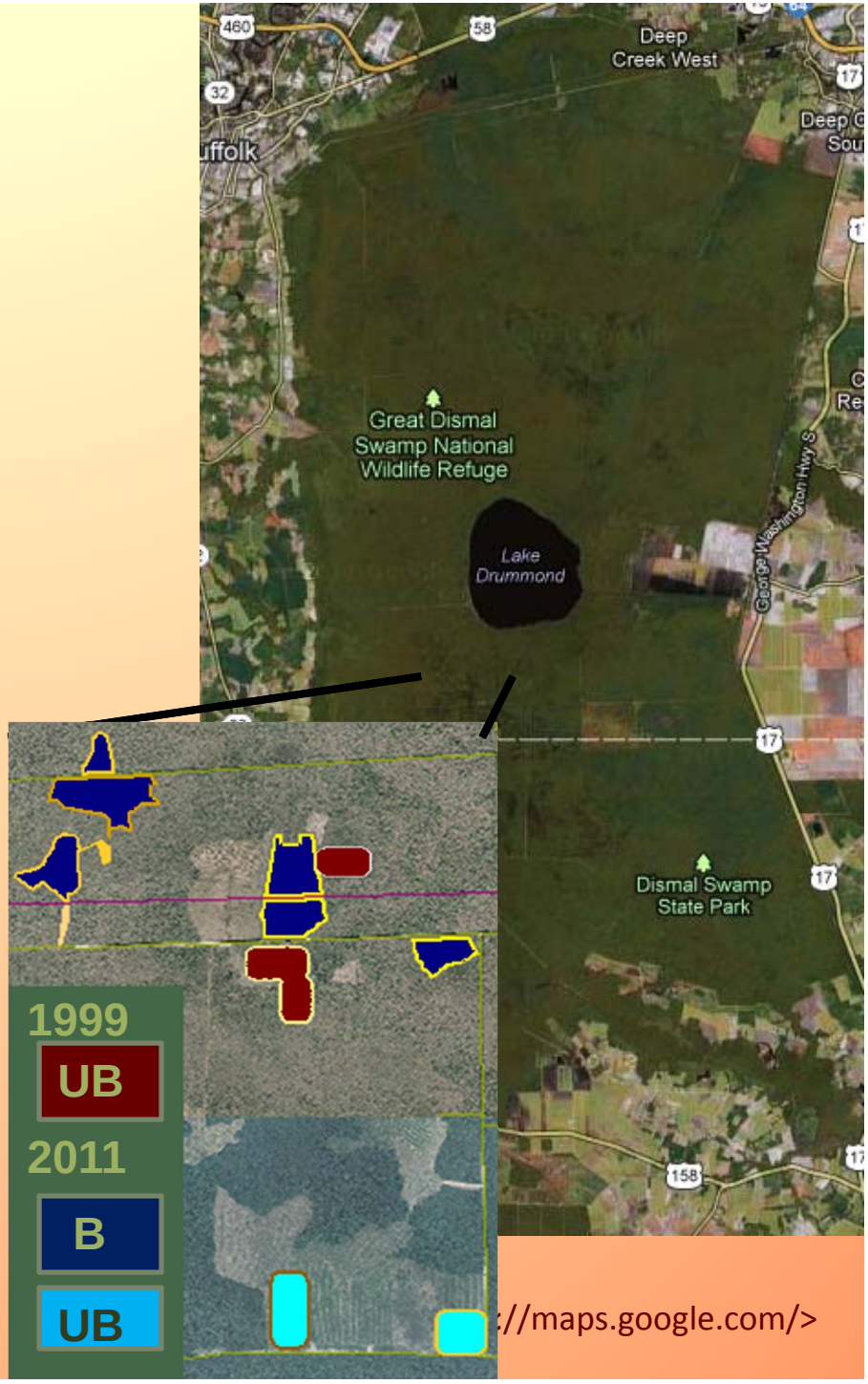


Courtesy Bryan Poovey, GDSNWR

< https://maps.google.com/>

Site Description

- In 1999, Thompson (2003) studied three stands consisting of 27 10-m x 10-m plots
  - Young (~2 yrs) stand of AWC
    - Salvage-logged in 1995
  - Intermediate (25-35 yrs)
  - Mature (60-65 yrs)
- In 2011, 7 stands consisting of 28 10-m x 10-m plots
  - Salvage logged between 2005-2007
    - 5 stands in areas that burned in the 2008 South One Fire
    - 2 stands in areas left unburned in 2008



://maps.google.com/>

Methods: Soil Properties

In the summer of

1999 and 2011

- Soil samples were collected from the upper 10 cm of each plot

- Dried around 100°C for 24 hrs
  - Bulk density

    = dry mass/ original volume

In 1999,

- Carbon and nitrogen percent dry weight was found using Carlo Erba nitrogen-carbon analyzer on a UV-VIS spectrometer after digestion with sulfuric acid

In 2011,

- Carbon and nitrogen percent dry weight were found using Thermo Scientific FLASH 2000 CHNS/O analyzer

Methods: Tree Tissue

<http://www.duke.edu/~jspippen/plants/chamaecyparis.htm>

In 2011, tree tissue clippings were collected from young, living AWC within the same plots

- 2 cm clippings from each tree were combined into one comosite sample per plot
- Dried at 75°C for 24 hrs
- Percent carbon and nitrogen by dry weight Thermo Scientific FLASH 2000 CHNS/O analyzer

- Data analysis was preformed using SigmaPlot v12
  - Significant threshold $P<0.05$

Methods:
Carbon Emissions in the 2011 Fire

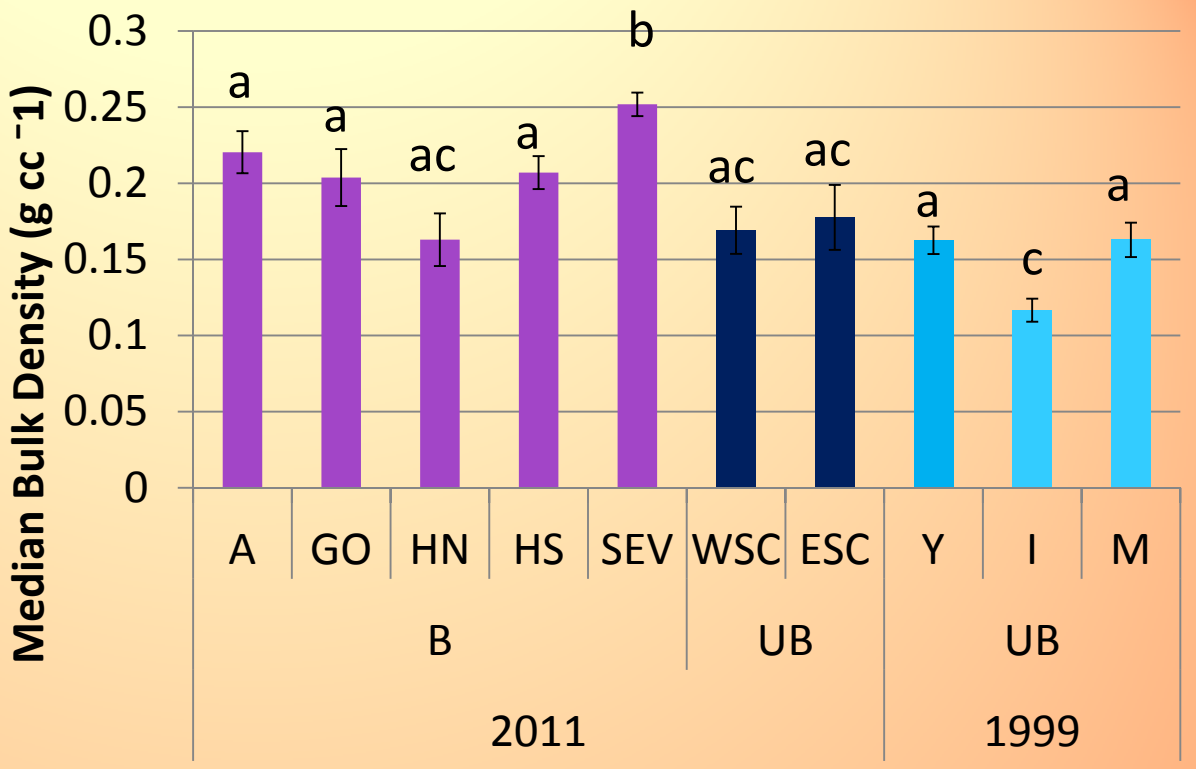
Parameters:	Data Sources:
Area of Burn(hectares)	GDSNWR
Depth of Burn (meter)	Hypothetical
Bulk Density (g/cm^3)	Current Study
x Carbon Content of Peat (% dry weight)	Current Study

(Lindsay 2010)


Results
and
Discussion

Results: Soil Properties

Bulk Density



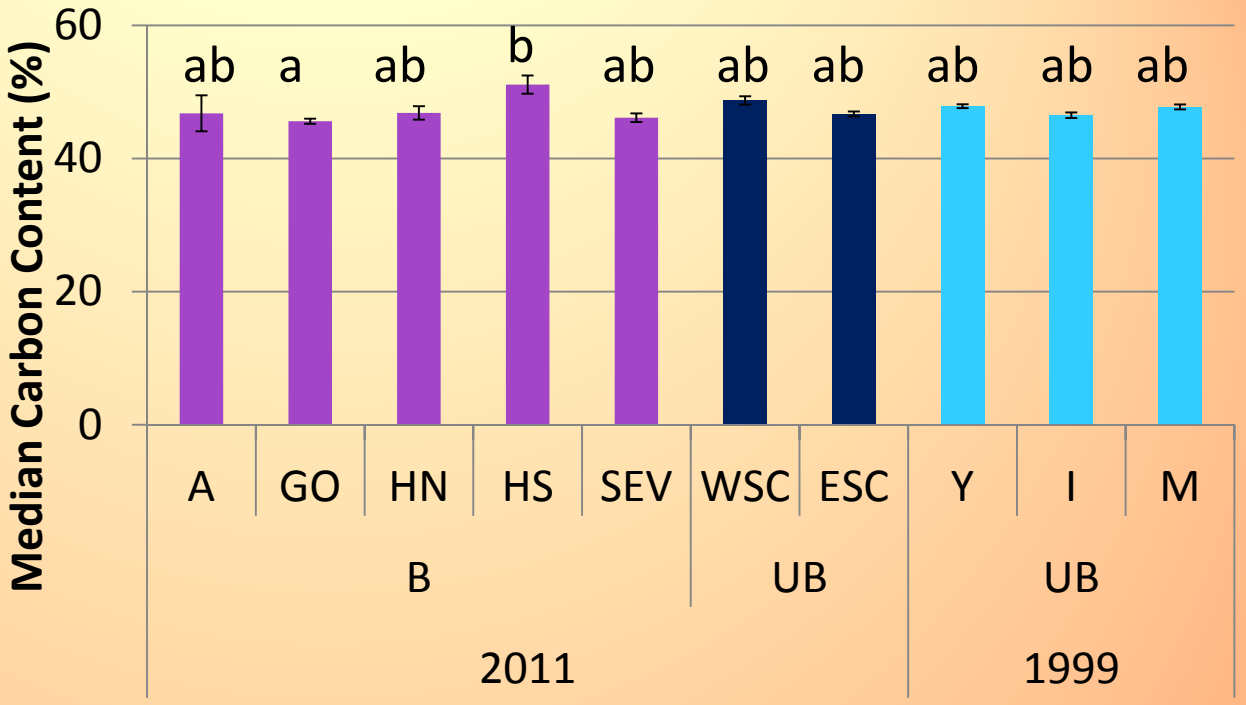
Unburned soils from 2011 not significantly different from 1999

Burned sites tended to have a higher bulk density than unburned 1999 and 2011

- Smith *et al.* (2001) found that 1 year after a peat fire bulk density was significantly higher at depths of 2-10 cm

ANOVA on ranks and error bars represent standard error

Soil Total Carbon



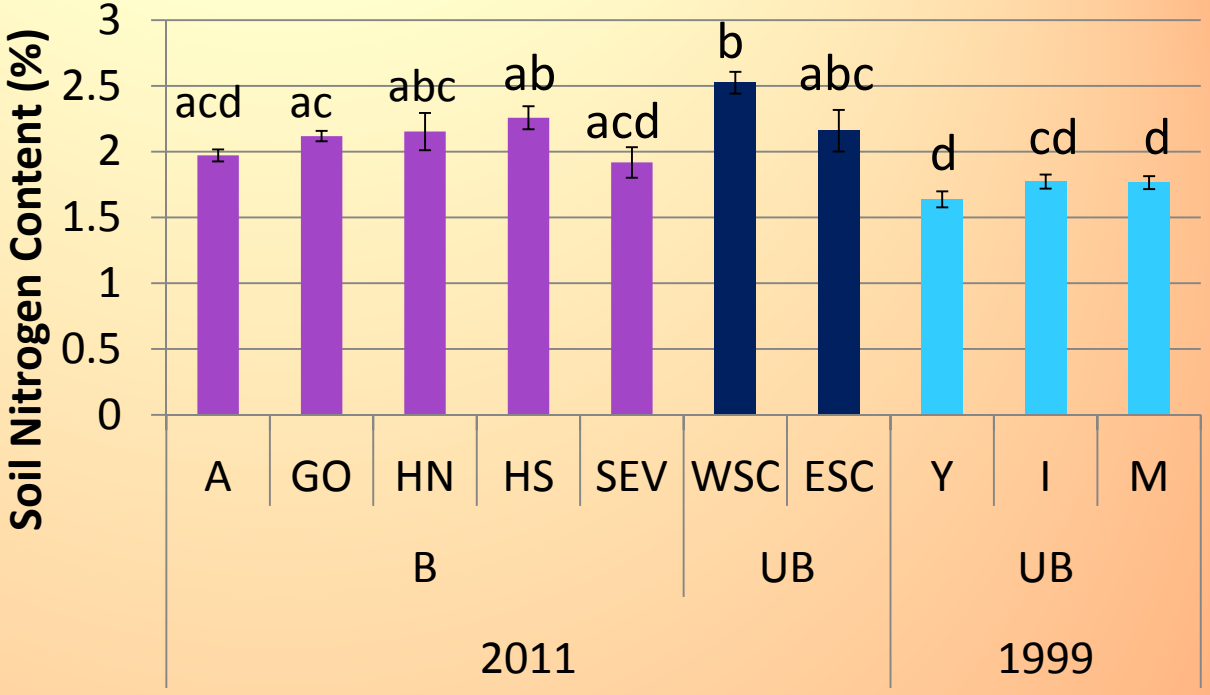
Consistent with

- 49.8% (young stand) in Pocosin Lakes National Wildlife Refuge, NC
- 47.0 % (intermediate , and 46.3% (mature) in Alligator River National Wildlife Refuge, NC

ANOVA based on ranks and error bars represent standard error

Soil Total Nitrogen

- Pocosin Lakes NWR
  - 1.39% (young)
- Alligator River NWR
  - 1.44 (intermediate)
  - 1.40 (mature)

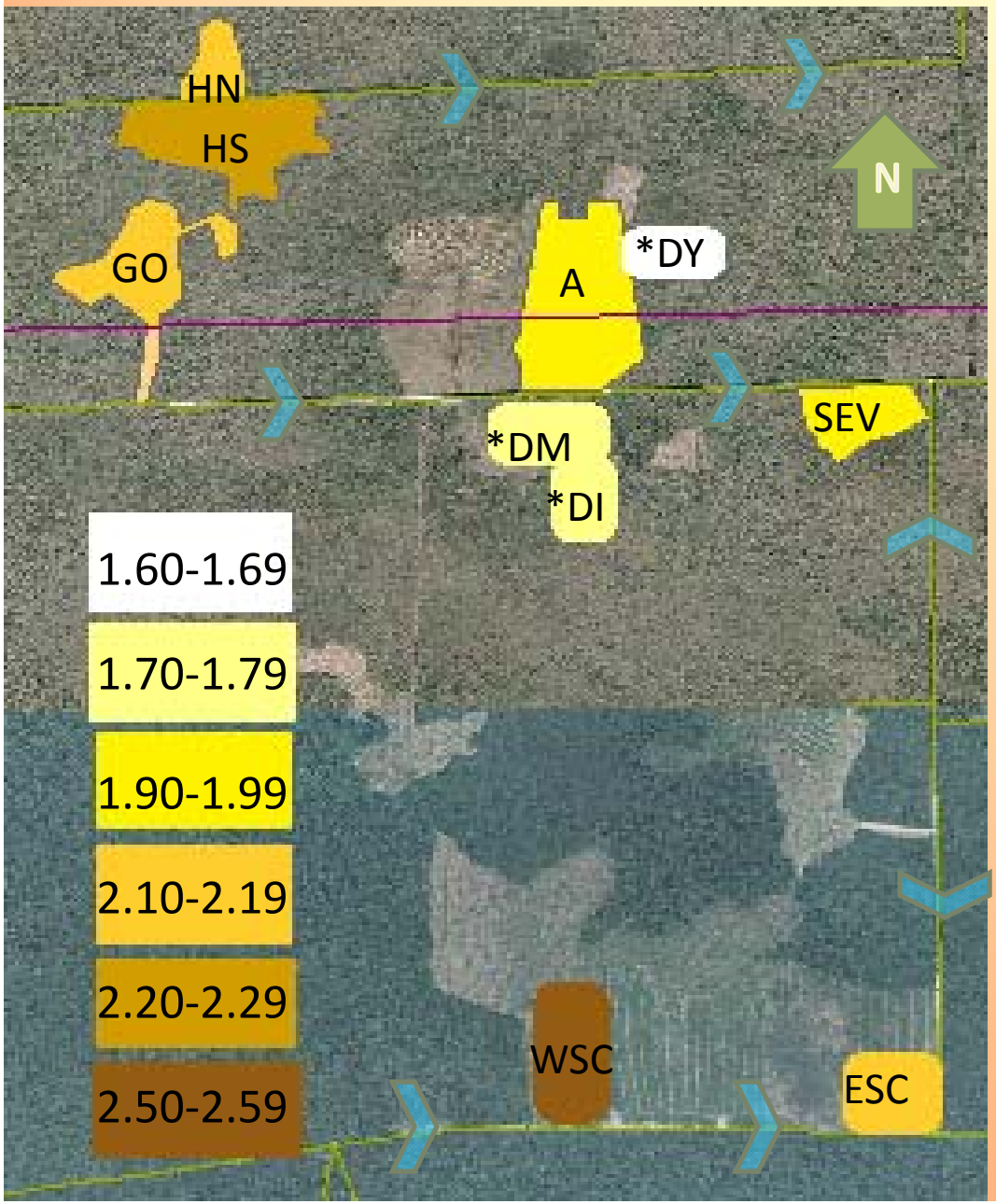


In 2011, burned stands tended to have lower nitrogen content than unburned stands

- Smith *et al.* (2001) found that
  - 1 year after peat fire soil nitrogen content significantly decreased at 2-10 cm depth increment, also found that surface fire increased soil nitrogen

Unburned stands in 1999 lower than unburned stands in 2011

Soil Total Nitrogen



Not clearly due to fire treatments

- 2011 Unit A was closest in location to three 1999 plots
  - –But not significantly different soil total nitrogen

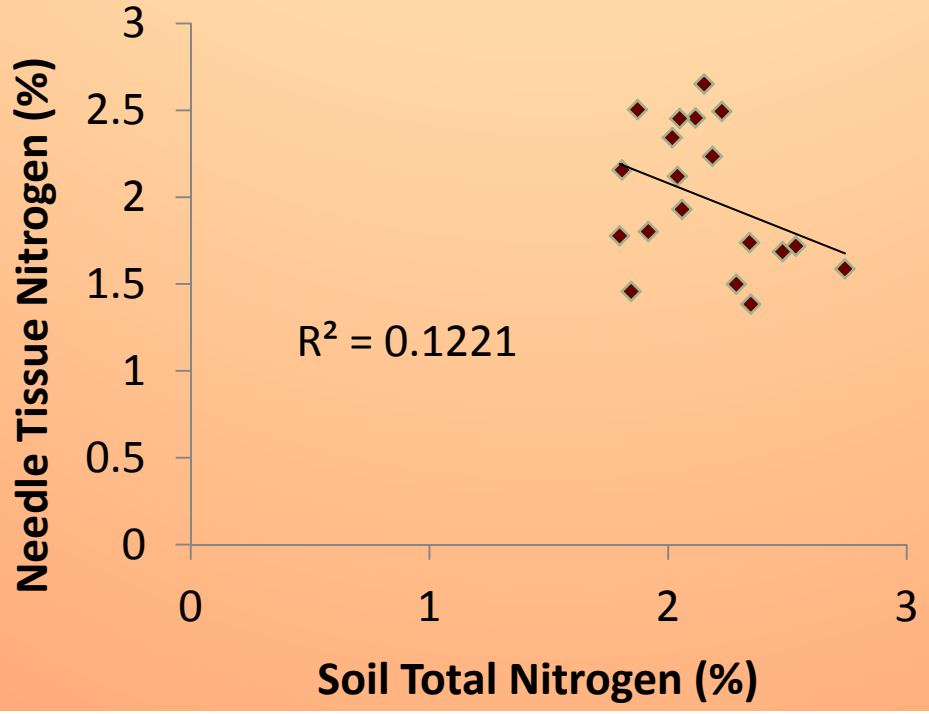
- Differences in upstream suburban or agricultural land use (Zhu and Ehrenfeld 1999)

Results: Tree Tissue

Soil vs. Tree Tissue Total Nitrogen

In 2011, average AWC needle tissue nitrogen was 2.02% ±0.38 in burned plots and 1.58% ± 0.25 in unburned plots

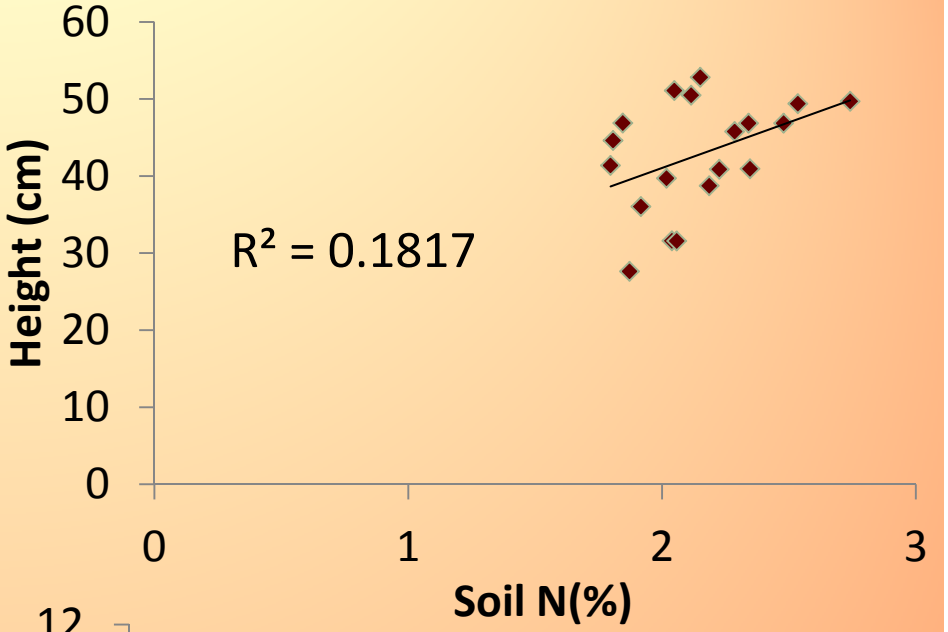
- 1.03% in Maryland (Gomez and Day 1982)
- 1.20% in Virginia (Whigham and Richardson 1988)

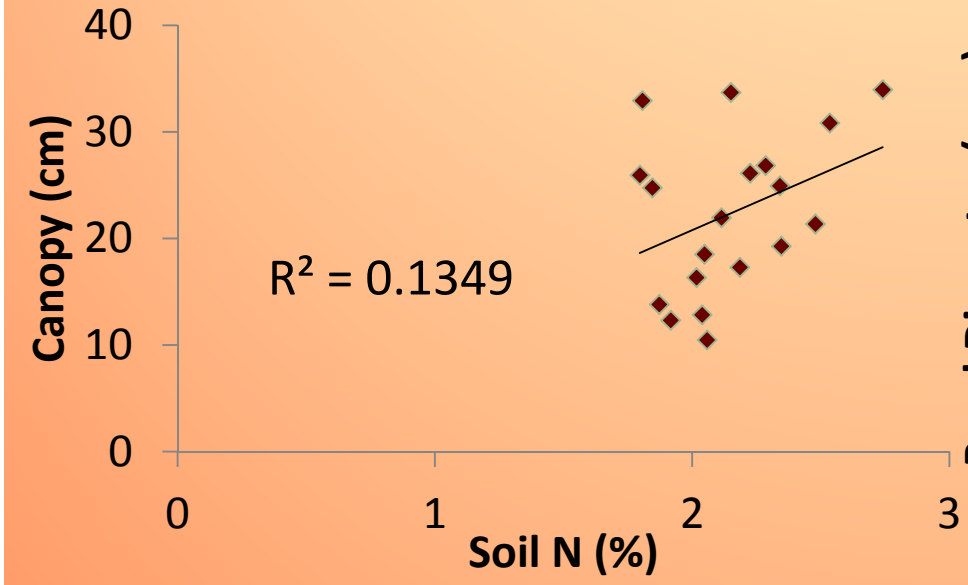


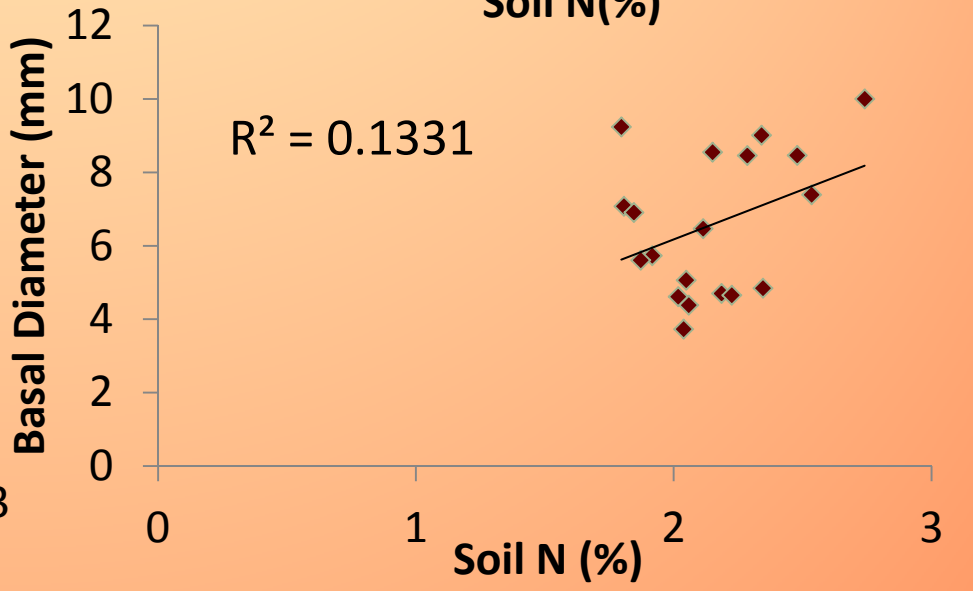
AWC Growth vs. Soil Total Nitrogen

Weak correlation

- Height growth
- Canopy growth
- Basal diameter growth







Results: Carbon Emissions

Carbon Emissions

Bulk Density x Area of Burn x Depth of burn x Carbon Content of Peat
(0.207 g/cm³) x (2770 ha) x (1 ft) x (47.45%C)

Assumptions: Bulk density and carbon content do not vary with depth

Amount of Carbon:

In one cubic centimeter = 0.0983 g/cm³

- (0.207) g/cm³ x 0.4745

In one cubic meter = 98.3 kg/m³

- (g/cm³) x (g/kg) x (cm³/m³)

In total area of burn with one meter of peat =2,720,735,550 kg

(2700h) x (m³/h) x (kg/m³)

In total area with 2-5 ft of peat = **1,659,964,869 – 4,081,103,325 kg C lost**

(kg/ha*m) x (0.61:1.5m)

Impact of 2011 Fire

- Van der Wurf (2010) estimates ~3% global C emissions are derived from peat fire
  - Averages 1.5-2.8 PgC annually
    - Our estimate for 1 m of peat loss = 0.13% of average annual global C emissions from peat fires

Lateral West Fire released as much carbon as burning ~ 1 billion (1,181,069,958) gallons of gasoline (USEPA 2011)

Conclusions

- Soil Properties : Peat fire had a variable effects on
  - Bulk density
  - Total nitrogen in soil
    - Carbon content remained around 47.45% in both soil and AWC tissue

- Tree Tissue:
  - Soil total nitrogen was not positively related to tissue nitrogen contenet
  - Hydrology my have indirectly influence results

- Carbon Emissions:
  - ~ 2.7 billion kg of carbon may have been emitted from peat fire

Acknowledgements

- Students and Faculty of the
  Center for Wetland Conservation at
  Christopher Newport University
  - Emily Foster provided growth data
  - Gregory Thompson, provided 1999 soil data
- Dr. Geoffrey Klein assisted chemical analysis
- US Fish and Wildlife Services
- Great Dismal Swamp National Wildlife Refuge Rehabilitation fund for Restoration and Management of AWC and the USEPA
- National Center for Environmental Research's STAR Program

Center for
Wetland Conservation
at Christopher Newport University

Literature cited

Brady, N.C. and R.R. Weil. 2008. The Nature and Properties of Soils, 14th ed. Pretence Hall, Upper Saddle River, New Jersey, USA.

Gomez, M.M., and F. P. Day. 1982. Litter nutrient content and production in the Great Dismal Swamp. *American Journal of Botany* 69: 1314-1321.

Kearney. T.H. 1901.Report on a botanical survey of the Dismal Swamp region. *Contributions from the U.S. National Herbarium* 5: 321-550.

Laderman, A.D. 1989. The ecology of Atlantic white cedar wetlands: a community profile. United States Fish and Wildlife Service Biological Report 85 (7-21), Washington, DC.

Lindsay, R. 2010.Peat bogs: A critical synthesis to inform policy development in oceanic peat bog conservation and restoration in the context of climate change . RSPB Scottland.E154LZ.. Environmental Research Group, University of London, Stradfford Campus, Water Lane, London, England

Motzkin, G., W.A. Patterson III, and N. E.R. Drake. 1993. Fire history and vegetation dynamics of a Chamaecyparis thyoides wetland on Cape Cod, Massachusetts. *Journal of Ecology* 81: 391-402.

Smith, S.M., S, . Newman, P.B. Garrett, and J.A. Leeds. 2001. Differential effects of surface and peat fire on soil constituents in a degraded wetland of the northern Florida Everglades. *Journal of Environmental Quality* 30: 1998-2005

Literature cited

Thompson, G.S., R.T Belcher, and R.B. Atkinson. 2003. Soil biochemistry in Virginia and North Carolina Atlantic white cedar swamps. *In* R.B. Atkinson, R.T. Belcher, D.A. Brown, and J.E. Perry [ed] Atlantic white Cedar Restoration Ecology and Management , Proceedings of a Symposium , May 31-June 2, 2000, Christopher Newport University, Newport News, Virginia, USA.

United States Environmental Protection Agency Office of Transportation and Air Quality. 2011. Questions and answers: greenhouse gas emissions from a typical passenger vehicle. EPA-420-F-11-041

van der Werf, G.R., J.T. Randerson, L. Giglio, G.J. Collatz, M. Mu, P.S. Kasibhatla, D.C. Morton, R.S. DeFries, Y. Jin, and T.T. Leeuwen. 2010. Global fire emissions and the contribution of deforestation, savanna , forest, agriculture, and peat fire (1997-2009). *Atmospheric Chemistry and Physics* 10: 11707-11735.

Whigham, D.F., and C.J. Richardson. 1988. Soil and plant chemistry in an Atlantic white cedar on the Inner Coastal Plain in Maryland. *Canadian Journal of Botany* 66: 568-576.

Zhu , W.X., and J.G. Ehrenfeld .1999. Nitrogen mineralization and nitrification in suburban and undeveloped Atlantic white cedar wetlands. *Journal of Environmental Quality* 28: 523-529.