Wildland Fires on Temperate Peatlands: A Look at NC, US, and Global Carbon Emissions

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Global Histosols Since the Last Glacial Maximum

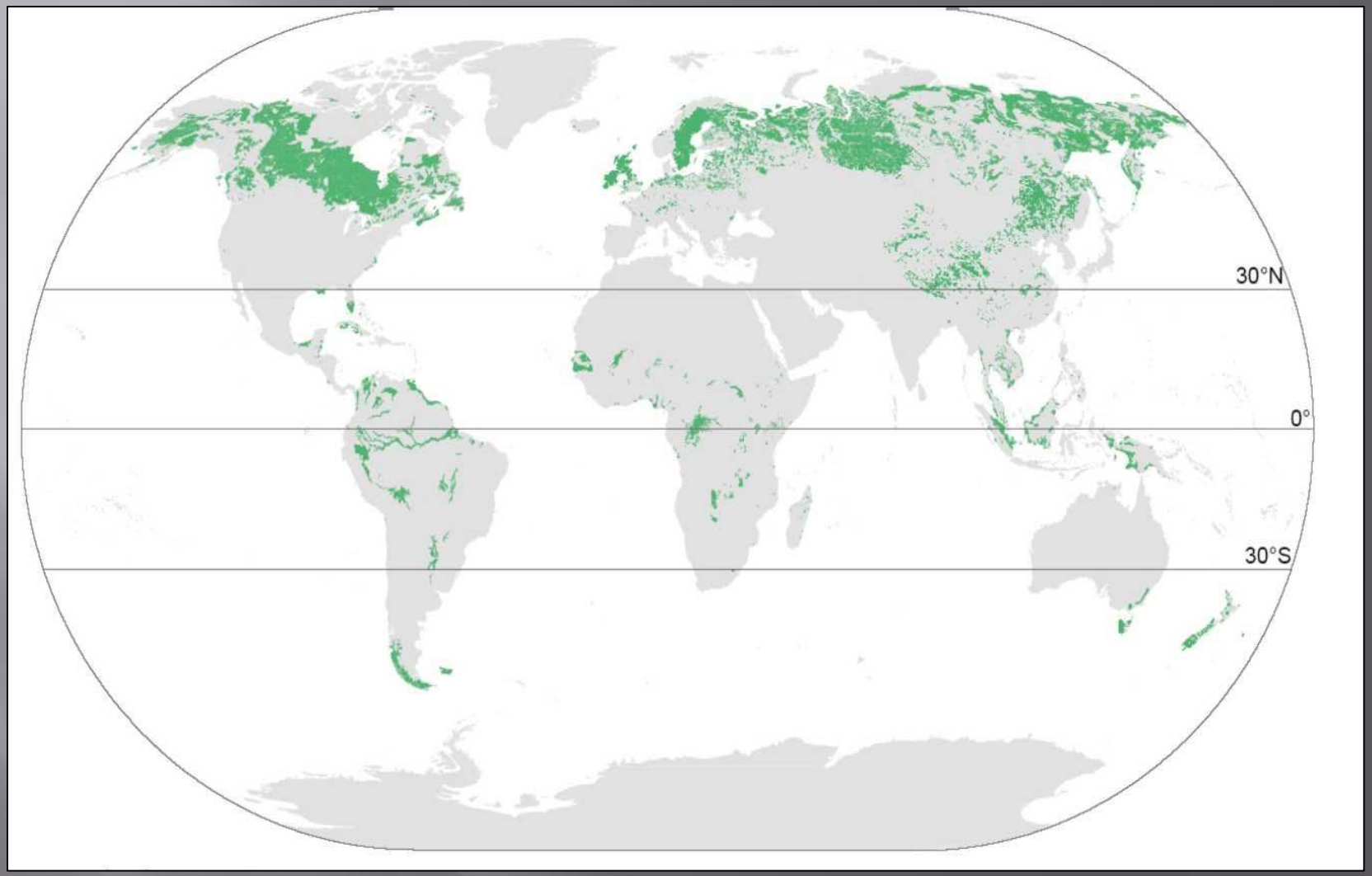


Image from Yu, Zicheng, J. Loisel, D. Brosseau, D. Beilman, S. Hunt. 2010. Geophysical Research Letters.

US Histosols Since the Last Glacial Maximum

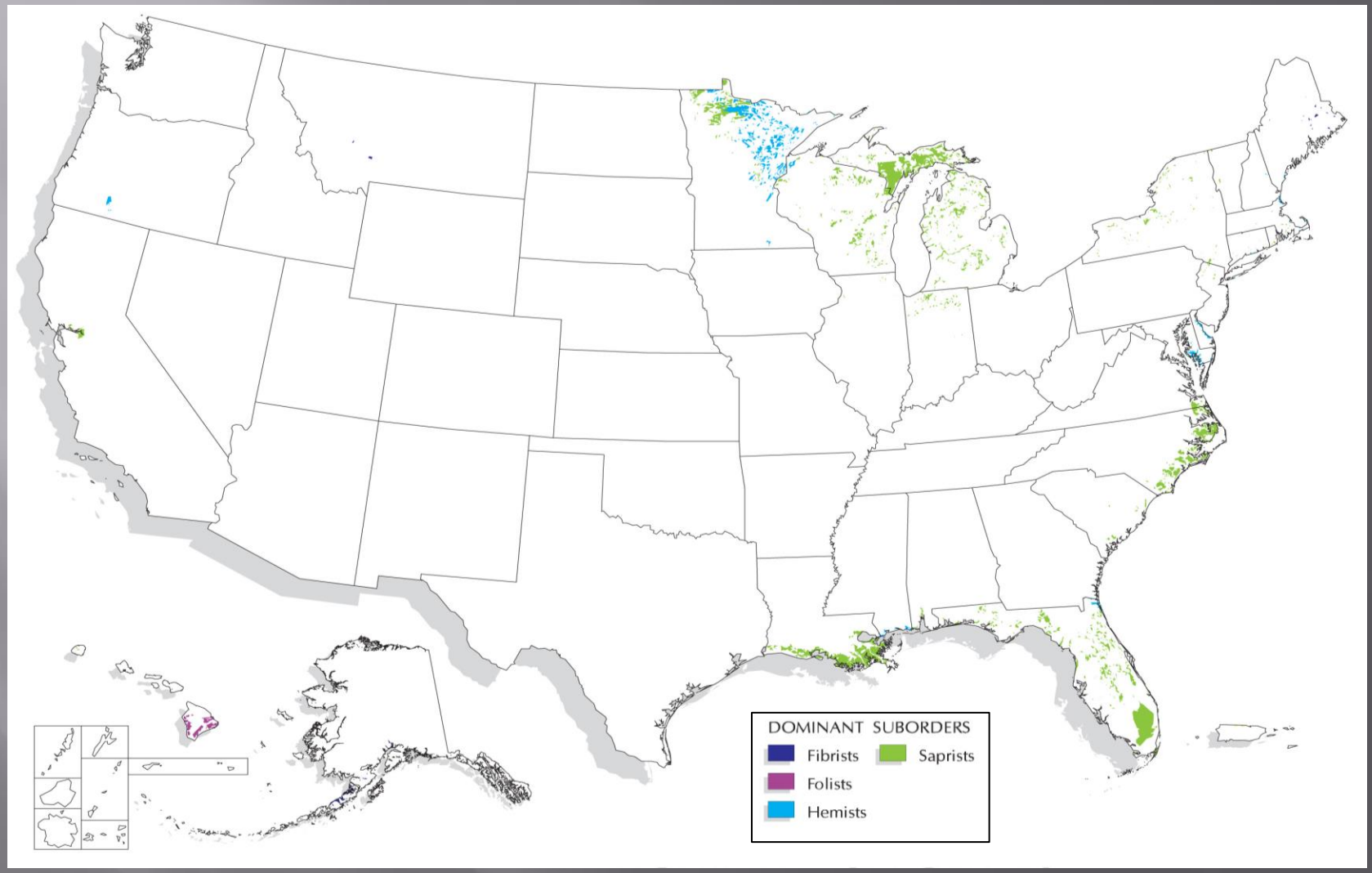
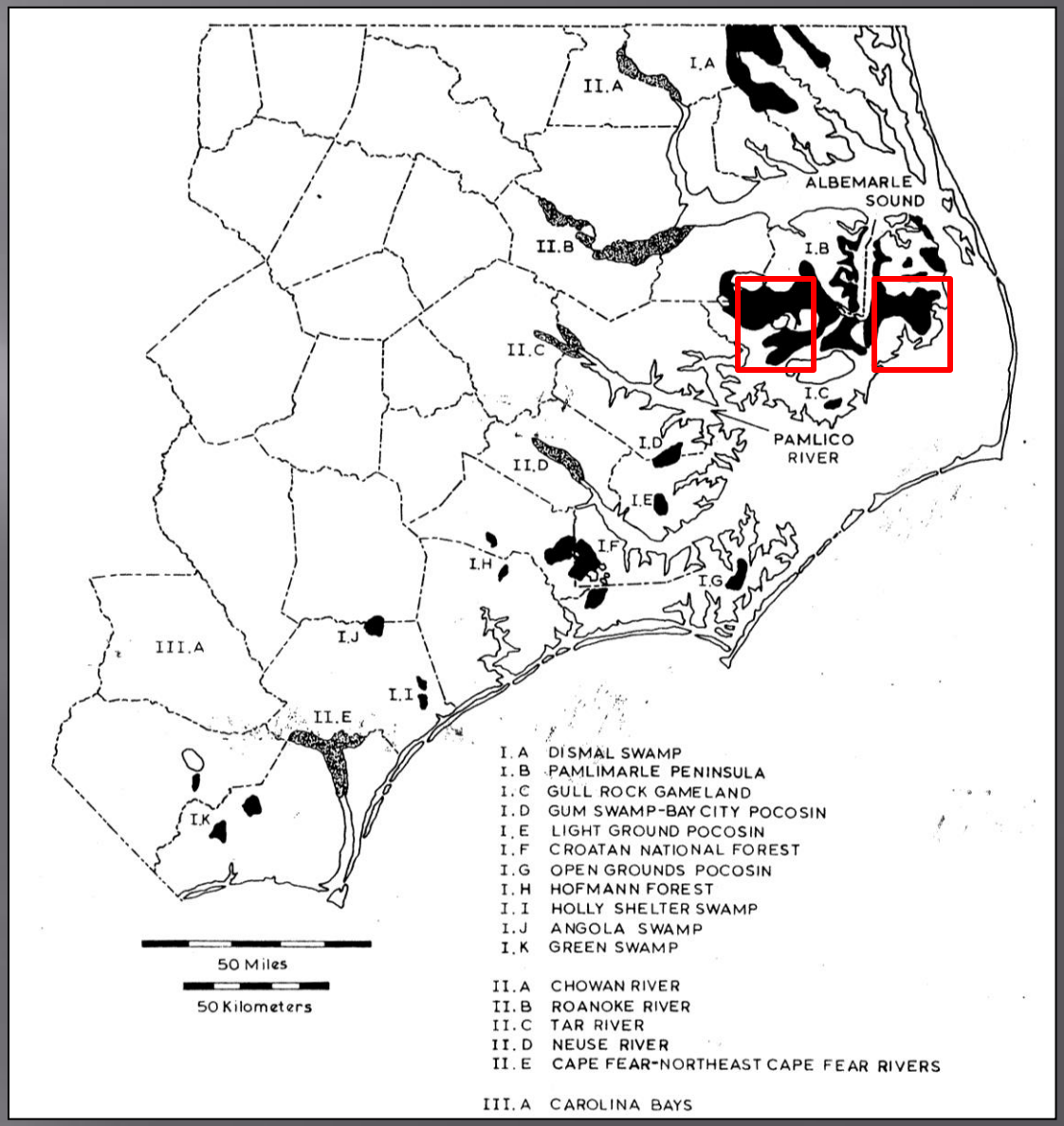


Image from Natural Resources Conservation Service, 2016

Histosols of Eastern North Carolina

Image from Ingram, R.L. and L.J. Otte. 1981. Peat in North Carolina Wetlands. Pages 125-134. In: Richardson, C.J. (ed.), Pocosin Wetlands: An Integrated Analysis of Coastal Plain Freshwater Bogs in North Carolina. Hutchinson Ross Publishing Co. Stroudsburg, PA. 364 p.



Why are Histosols or Peatlands Important?

Peatlands comprise less than 3% of Earth's land area (400 Mha) and store an estimated 15-30% of the global soil carbon stocks.

Global Boreal and Subarctic	**346 Mha**	**273-621 Pg C**
Tropical and Subtropical Asia	**27 Mha**	**42-55 Pg C**
South America	**4.5 Mha**	**13-18 PgC**
Global Temperate	**35 Mha**	**455 Pg C**
Temperate United States	**6 Mha**	**7.6 PgC**
Temperate North Carolina	**0.27 Mha**	**0.3 Pg C**

The Math:
1 hectare equals 2.47 acres
1 PG (petagram) equals 10^{15} grams
1 metric ton equals 10^{6} grams
455 Pg equal 455,000,000,000 metric tons

How much carbon is 455 Pg?

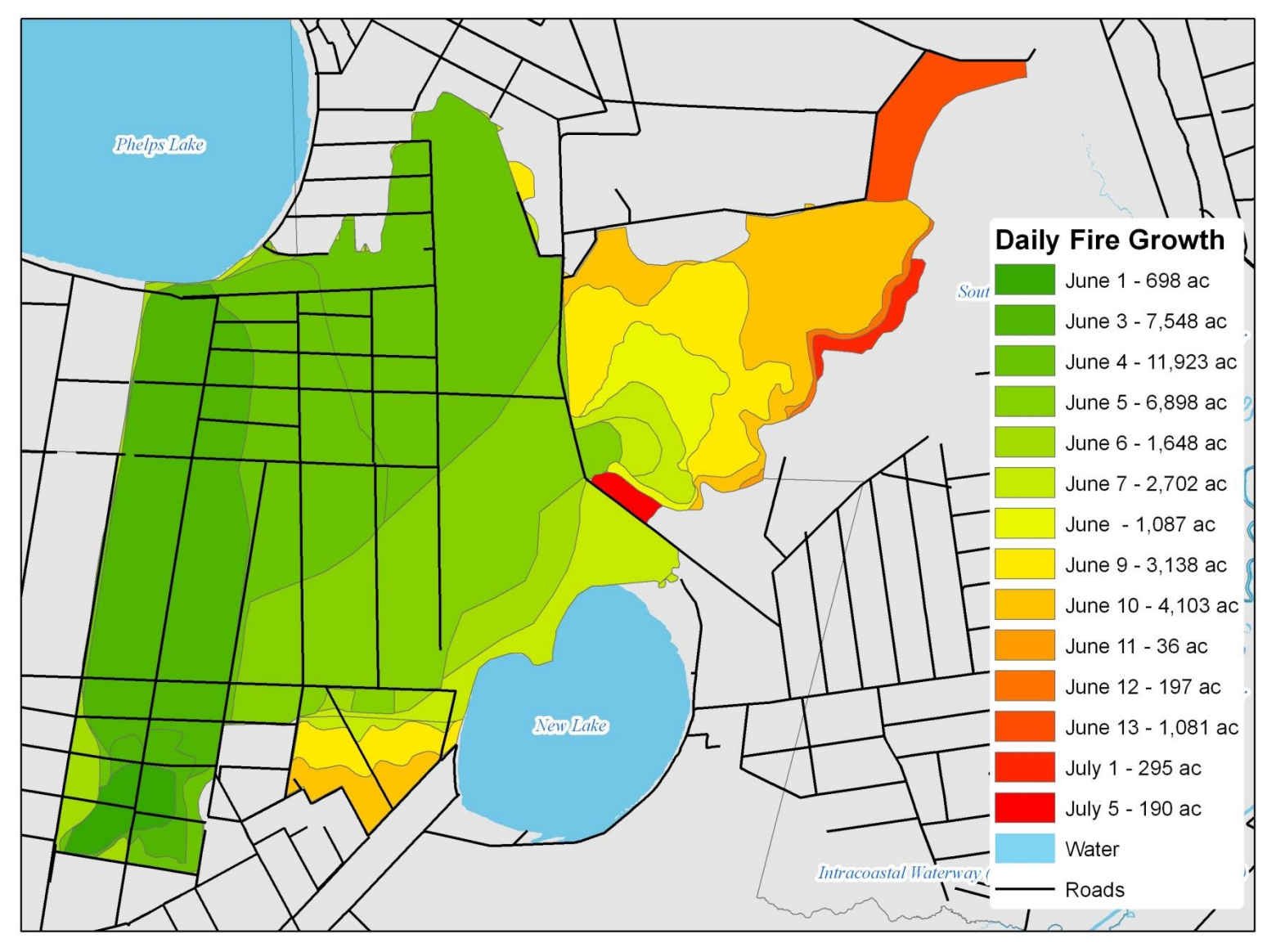
The equivalent of the carbon stored in all living things on the surface of the planet.

Evans Road Fire

Evans Road Fire Chronology

- June 1, 2008 – Fire starts from lightning strike
- June 2, 2008 1700 – NC IMT dispatched to 238 ha fire
- June 3, 2008 1500 – Team arrives to 505 ha fire
- June 4, 2008 0100 – Team goes to bed managing 3,237 ha fire.
- By June 14, 2008, the fire had reached 16,592 ha in size
- Between June 3rd and August 8th, Six Type 2 Incident Management Teams managed the Evans Road fire.
- Over the course of the fire, priorities changed from evacuation, protection, and containment, to pumping, and rehab.
- January 9, 2009 – Evans Road Fire declared out at a cost of $20 Million

Daily Fire Growth

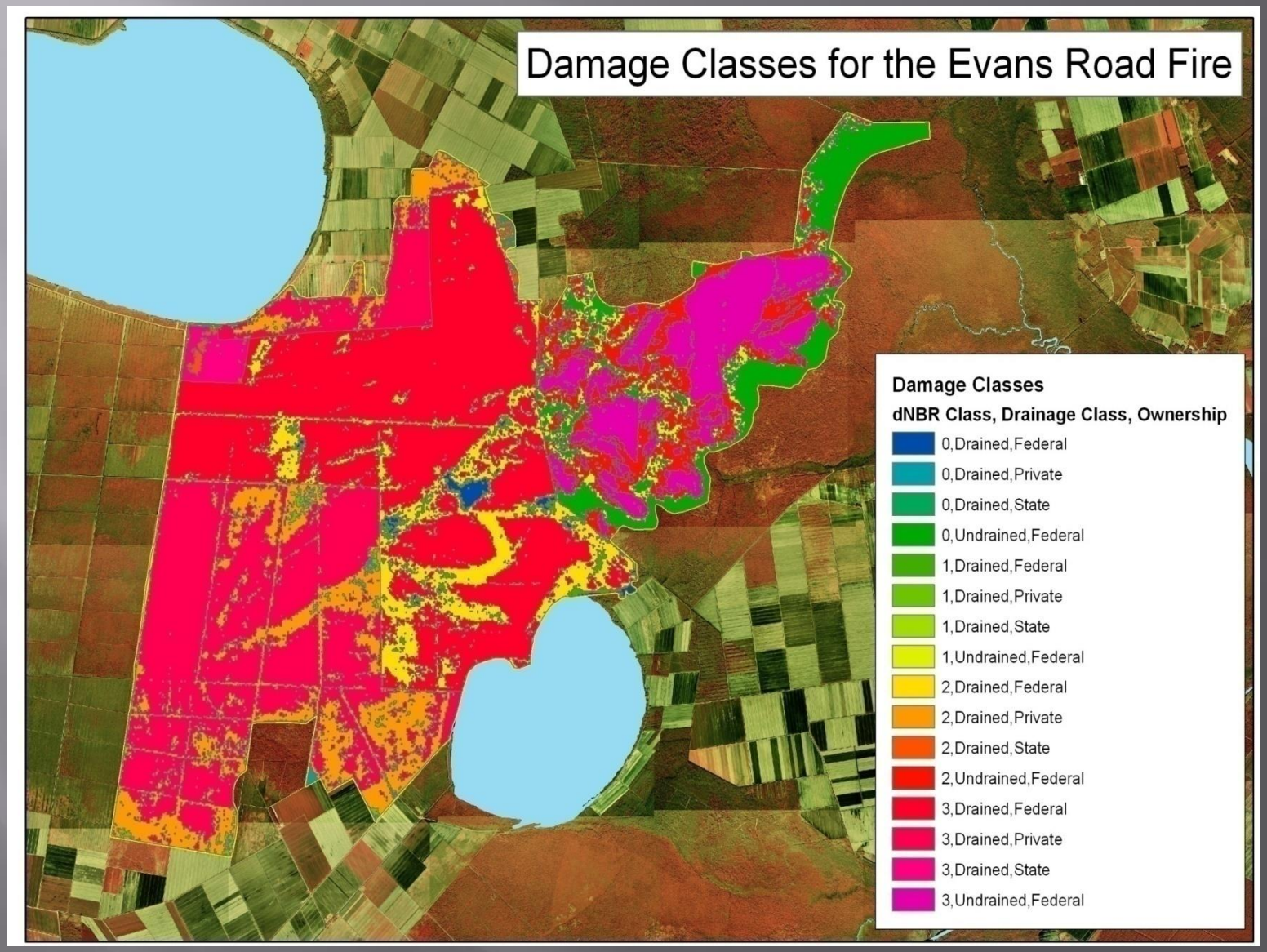


Organic Soil Fire Consumption

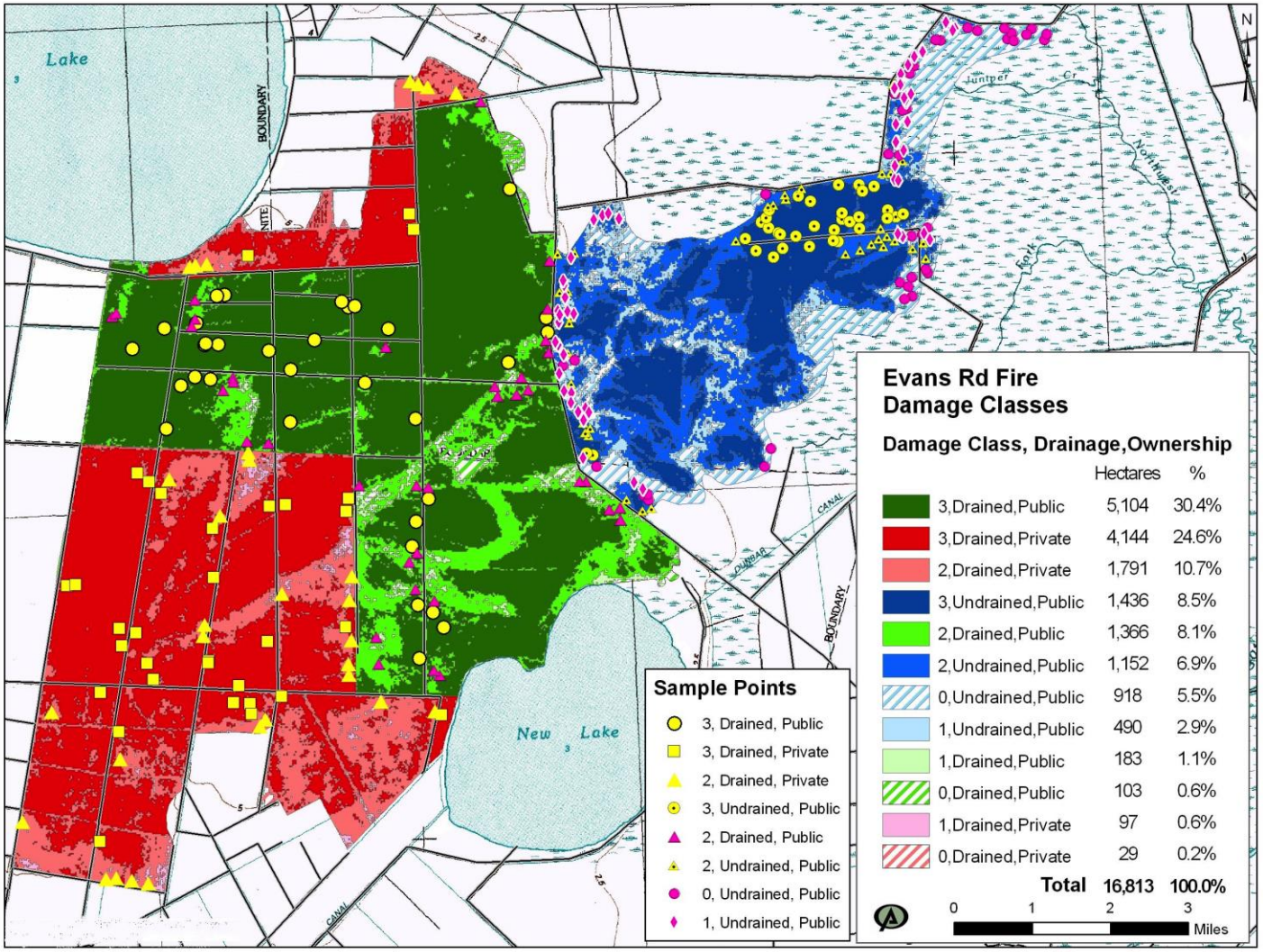
Organic Soil Fire Ignition Progression

Post Surface Water Pumping and Culvert Dams

Damage Classes



Field Survey



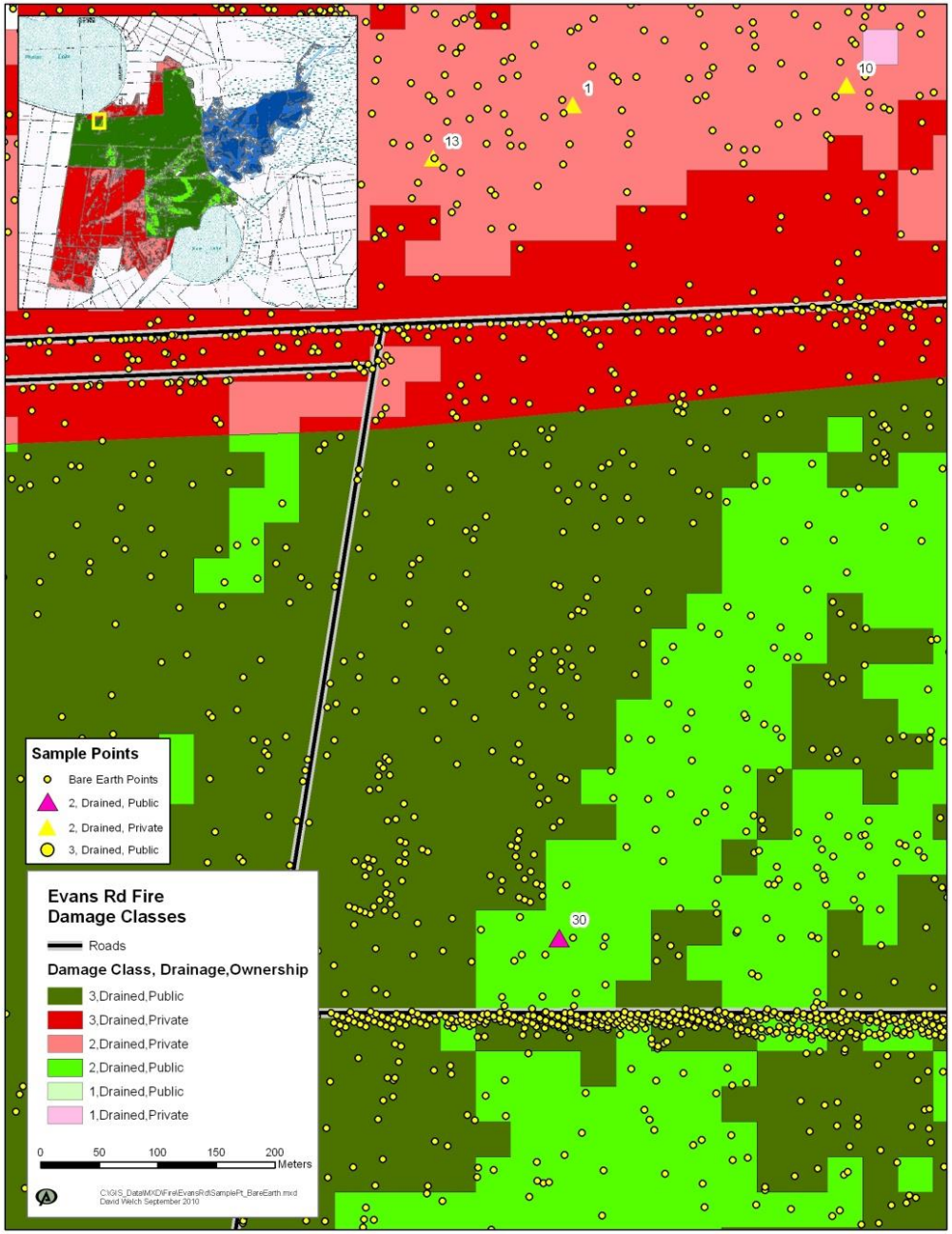
Damage Class 3, Drained, Private

Damage Class 3,Undrained, Public

PLNWR/Farm Border Gated Culvert
Damage Class 3, Drained, Private

Low and High Pond Pine Pocossin Gallberry and Fetterbush Shrub Vegetation

Vegetation consisted of high pocosin (shrub canopy heights of 3–4.5 m) and low pocosin (shrub canopy heights of 0.6–1.8m) plant communities. High pocosin overstory trees include pond pine (*Pinus serotina* Michx), loblolly bay (*Gordonia lasianthus* (L.) Ellis), and red bay (*Persia borbonia* (L.) Spreng). Pocosin understory shrubs include gallberry (*Ilex glabra* (L.) Gray), tall gallberry (*Ilex coriacea* (Pursh) Chapm.), fetterbush (*Lyonia lucida* (Lam.) K. Koch), and titi (*Cyrilla racemosa* (L.)). Herbaceous vegetation is dominated by bracken fern (*Pteridium aquilinum* (L.) Kuhn.).



LiDAR Ground Return Data

- LiDAR canopy return points were used to delineate low and high pocosin vegetation for estimating above ground vegetation consumption
- LiDAR ground return points were used to determine pre-burn elevation for organic soil consumption

Trimble Survey Equipment
Trimble R8 Model 3 Dual Frequency GPS GNSS RTK Set
Base Station, Transmitter, and Rover

Example of Estimate of Vegetation Carbon Consumption

Red maple biomass was derived from the following equation for individual trees:

$\log_{10}$ tree biomass = (-0.8602 + 1.7963 *($\log_{10}$(d)))

where d was the average stand diameter (Maclein and Wein 1976 cited in Jenkins 2003). Equation results were multiplied by a foliage ratio using an equation for hardwoods:

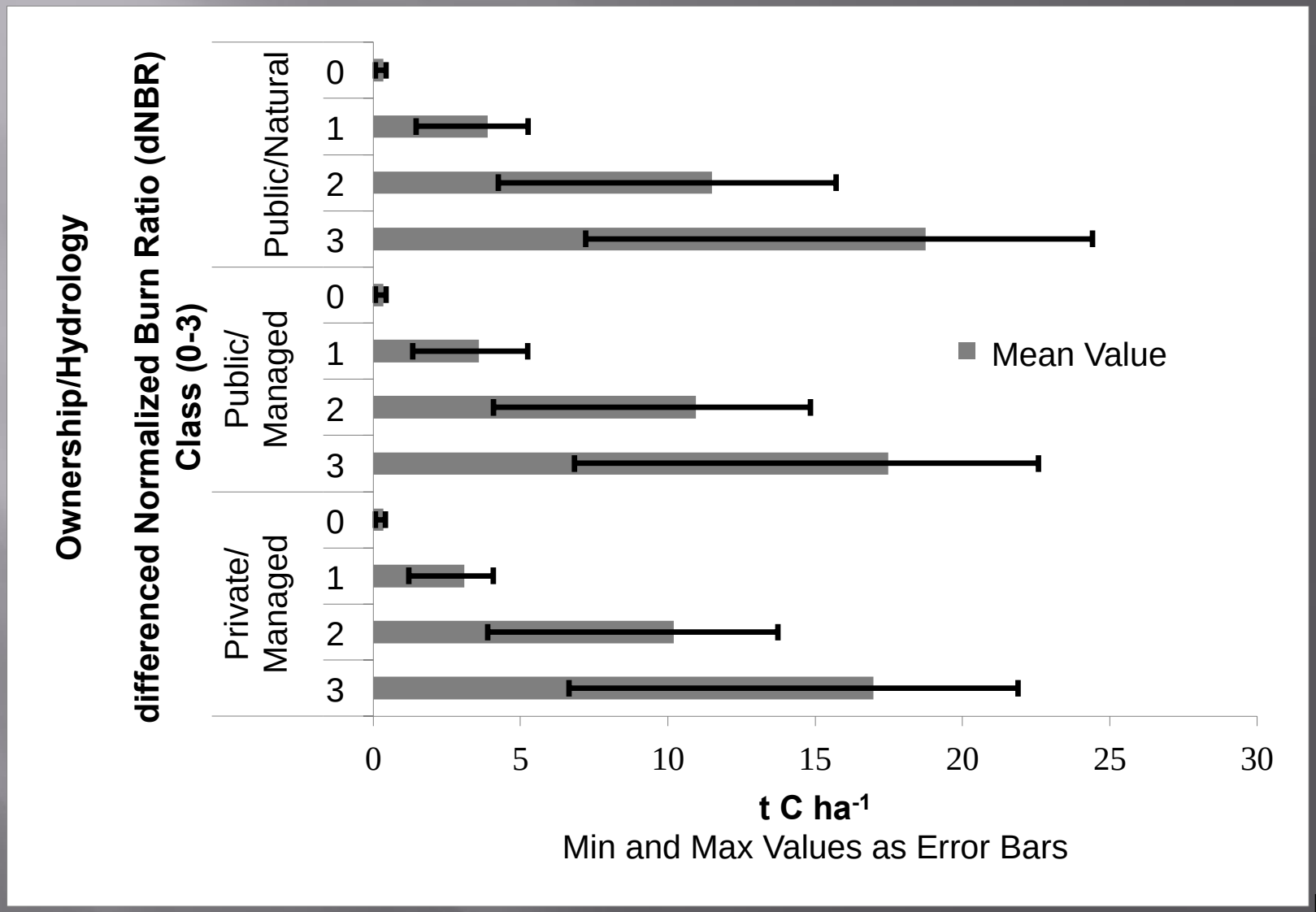
foliage ratio = exp(-4.0813 +(5.8816/d))

where d was the average stand diameter (Jenkins 2003). Average stand diameters and tree densities were obtained through field measures of low and high pocosins and applied to equations in order to obtain biomass on a per area basis.

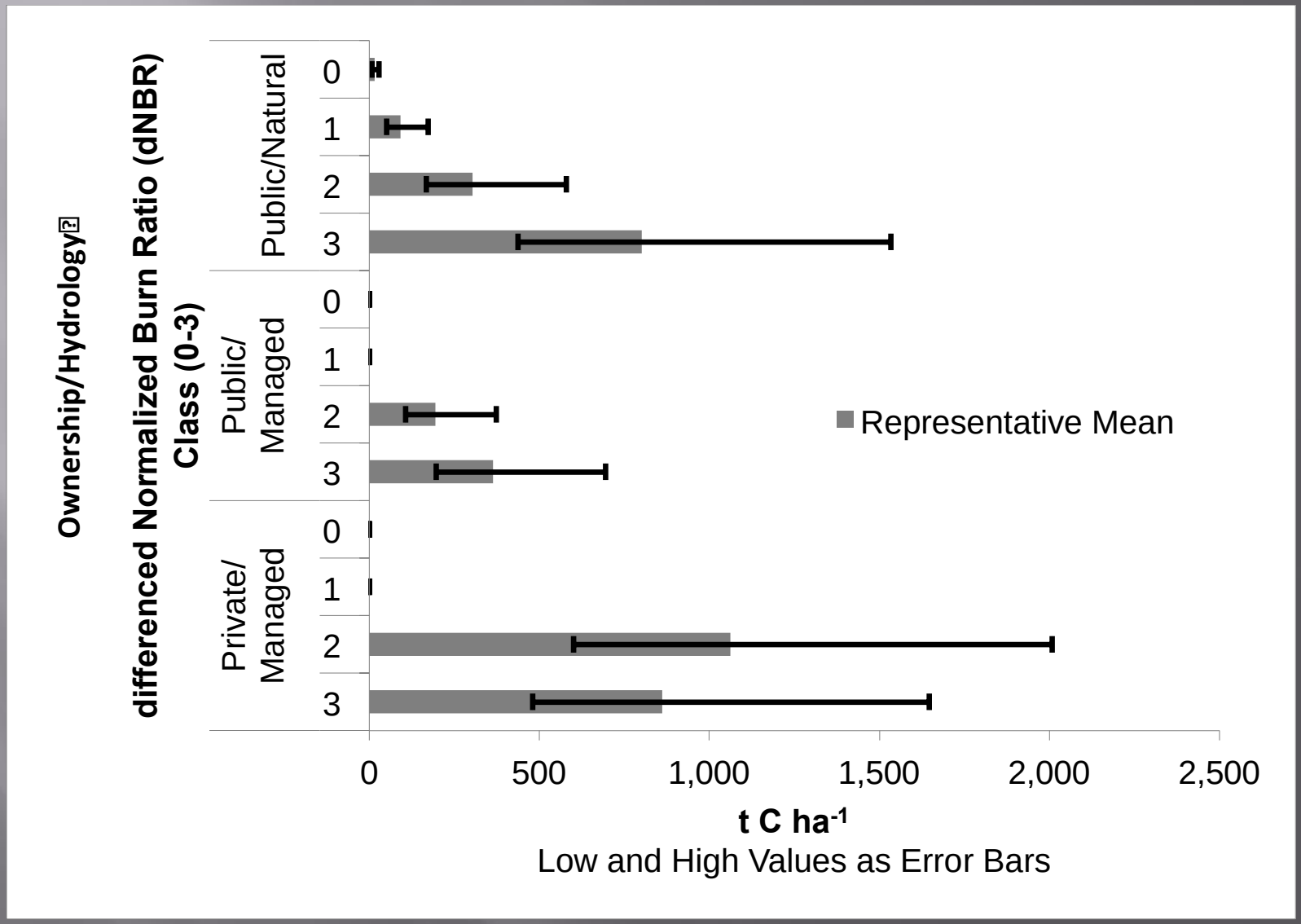
Example of Estimate of Soil Carbon Consumption

- $SOC_i = [D_i \times \rho_{bi} \times (OM_i \times 0.5)/100] \times 10$
  - Adapted from Tan, et al. 2004
- SOC_i: soil organic C content (kg/m^2) for horizon *I* (top O or Oa horizon)
- D_i is the depth of soil consumed (cm)
- ρ_{bi} is the soil bulk density (g/cm^3)
- OM_i is the organic matter weight percentage
  - Assume that organic matter is 50% carbon
  - 10 is a conversion factor
- Scale up to metric tons per polygon using soil map units
- Add polygons to sum for entire fire area

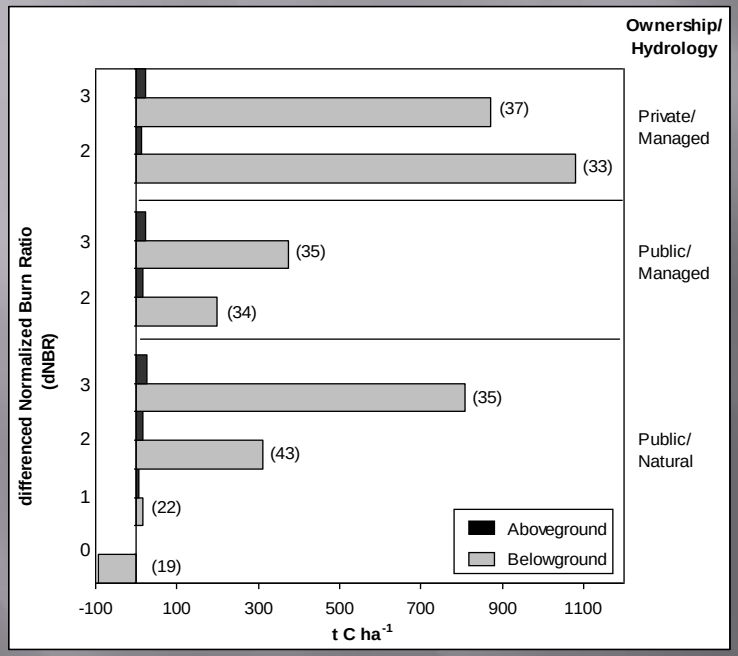
Above-Ground Carbon Emissions



Below-Ground Carbon Emissions



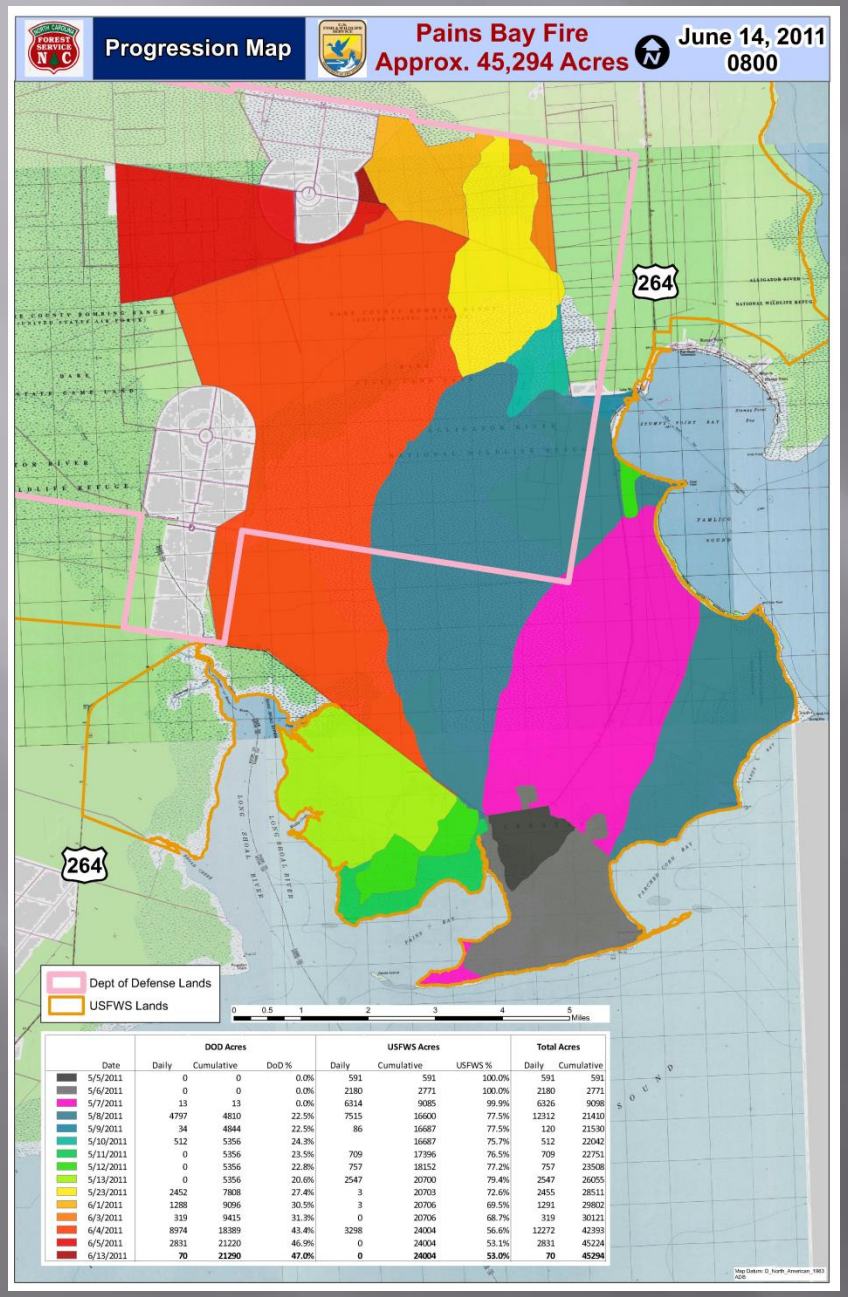
Comparison of Above- and Below-Ground Carbon Emissions



The 2008 Evans Road Fire (16,813 ha) had a mean peat burn depth of 0.42 m and a maximum burn depth of 1.7 m, resulting in estimated below-ground fire emissions of 9.16 Tg C and above-ground fire emissions of 0.31 Tg C, for total fire emissions of 9.47 Tg C (1 Tg equals 10^{12} grams or 1,000,000 metric tons).

In contrast the 1985 Allen Road Fire (~40,000 ha) had total emissions of 1–3.8 Tg C and peat burn depths ranging from 0.01 to 0.10 m.

Pains Bay Fire



Pains Bay Fire Chronology

The chronology of the Pains Bay Fire :

May 4, 2011 – Fire starts from lightning strike near Pains Bay
May 6, 2011 – Fire jumps Hwy 264
May 7, 2011 – Fire enters the DCBR
May 8, 2011– Fire increases to 21,410 acres
May 10, 2011 – The fire is being managed by a Type 1 IMT
May 23, 2011 – Thirty mile per hour winds cause fire to jump low pocossin firelines and jump Jackson Rd.
June 3, 2011 – Backfire Bow Tie Tract
June 4, 2011 – Backfire east of Air Force Impact Area
June 5, 2011 – Fire jumps into Navy Impact Area. Backfire area.
June 14, 2011 – The fire had reached 45,294 acres in size with significant organic soil groundfire
July 19, 2011 – Fire declare 100% contained.
August 24, 2011 – Pains Bay Fire declared out at a cost of $14.2 Million

Pains Bay Fire Carbon Budgets

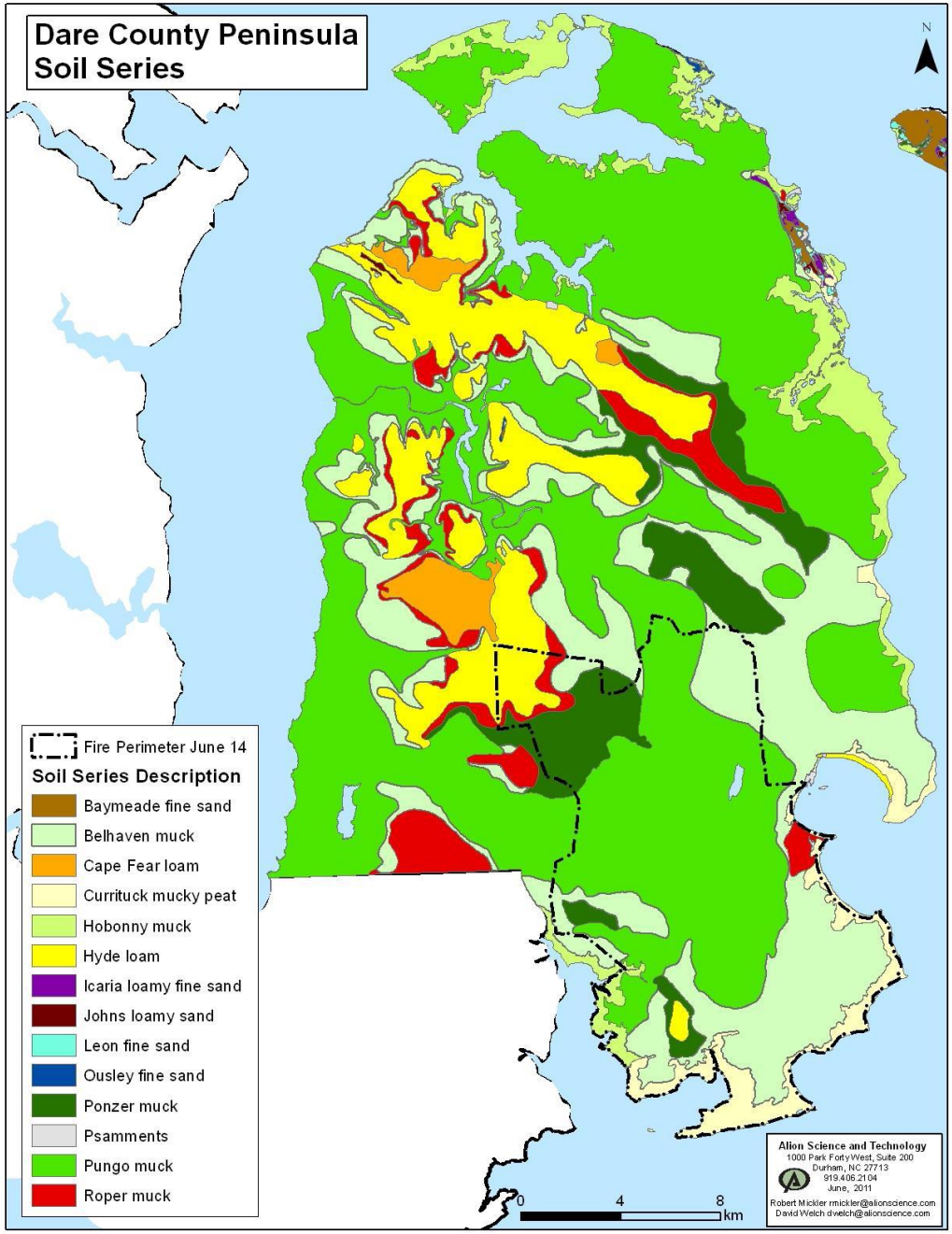
Fine and Course Fuels,Vegetation, Organic Soil Groundfire

Pains Bay Fire Carbon Budget Smoke and Smoke

Super Fog at Morning Fire Brief with church steeple in background and fire fighters in foreground

- Multiple super fog events and road closures
- NC DAQ Code Red Air Quality
- EPA Ambient Air Quality Standards for PM
- Smoke on highways and road closures

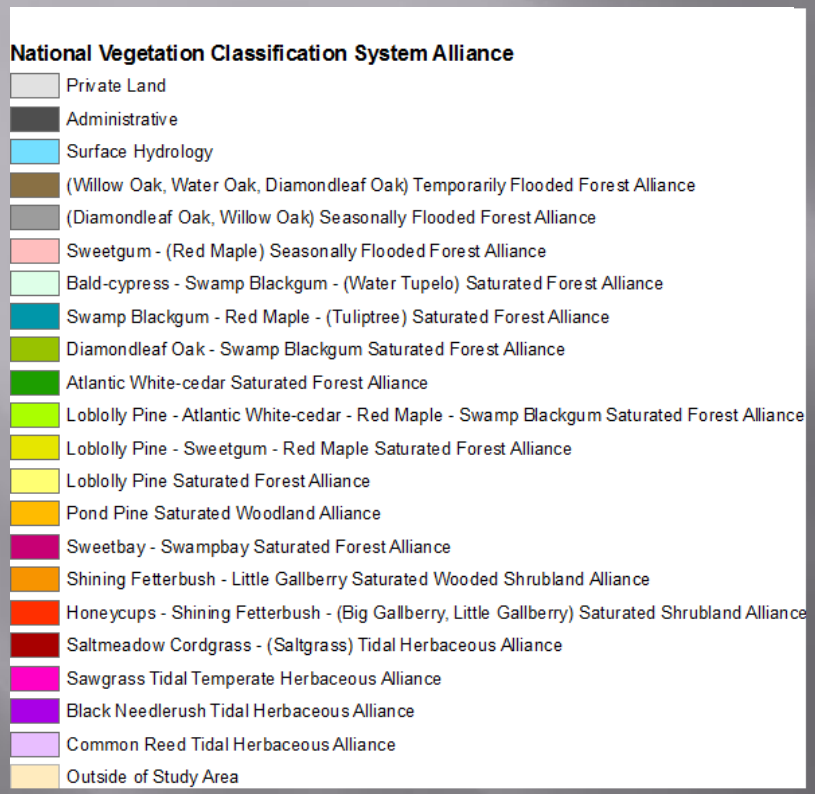
Putting Out the Fire

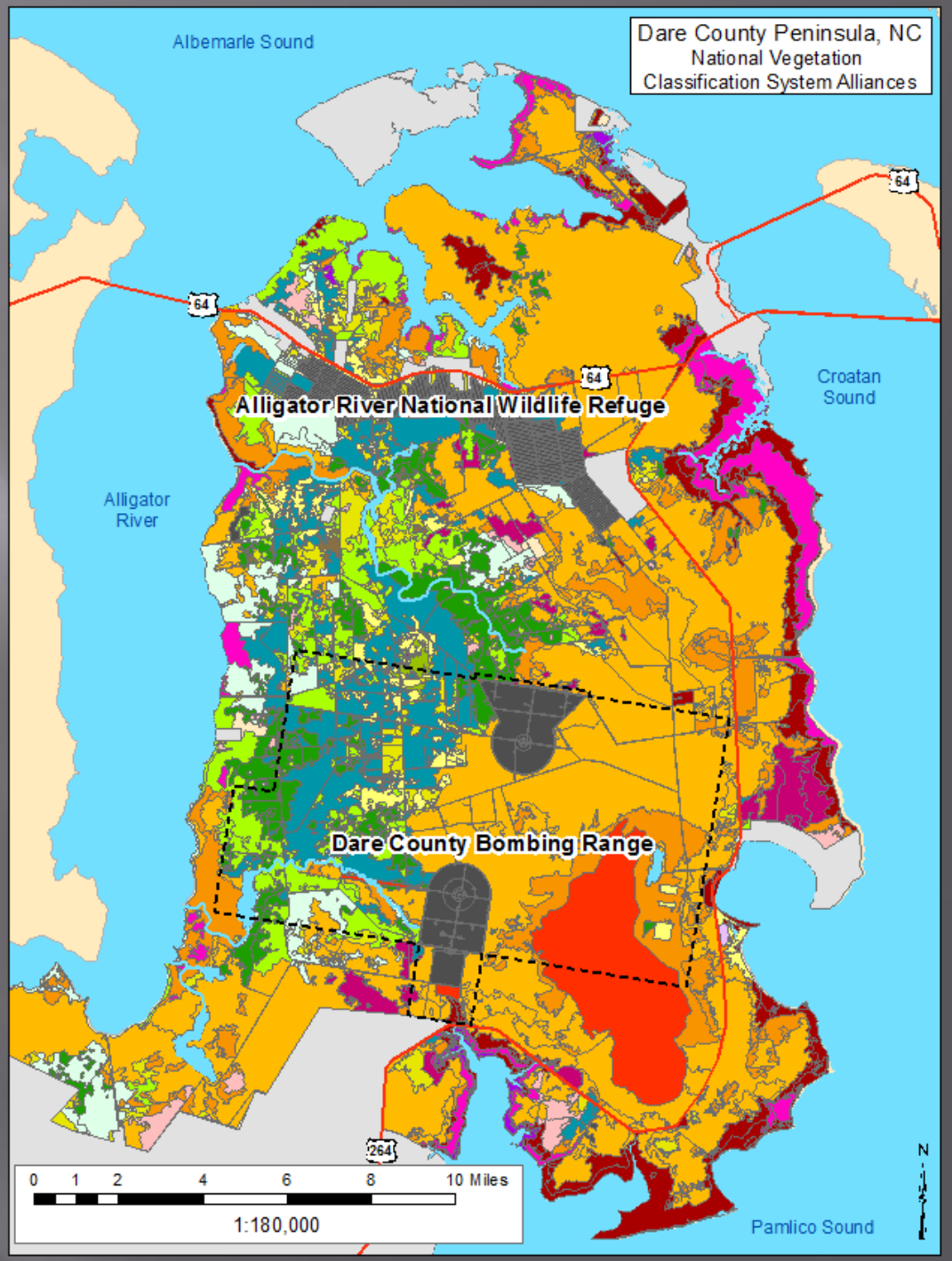


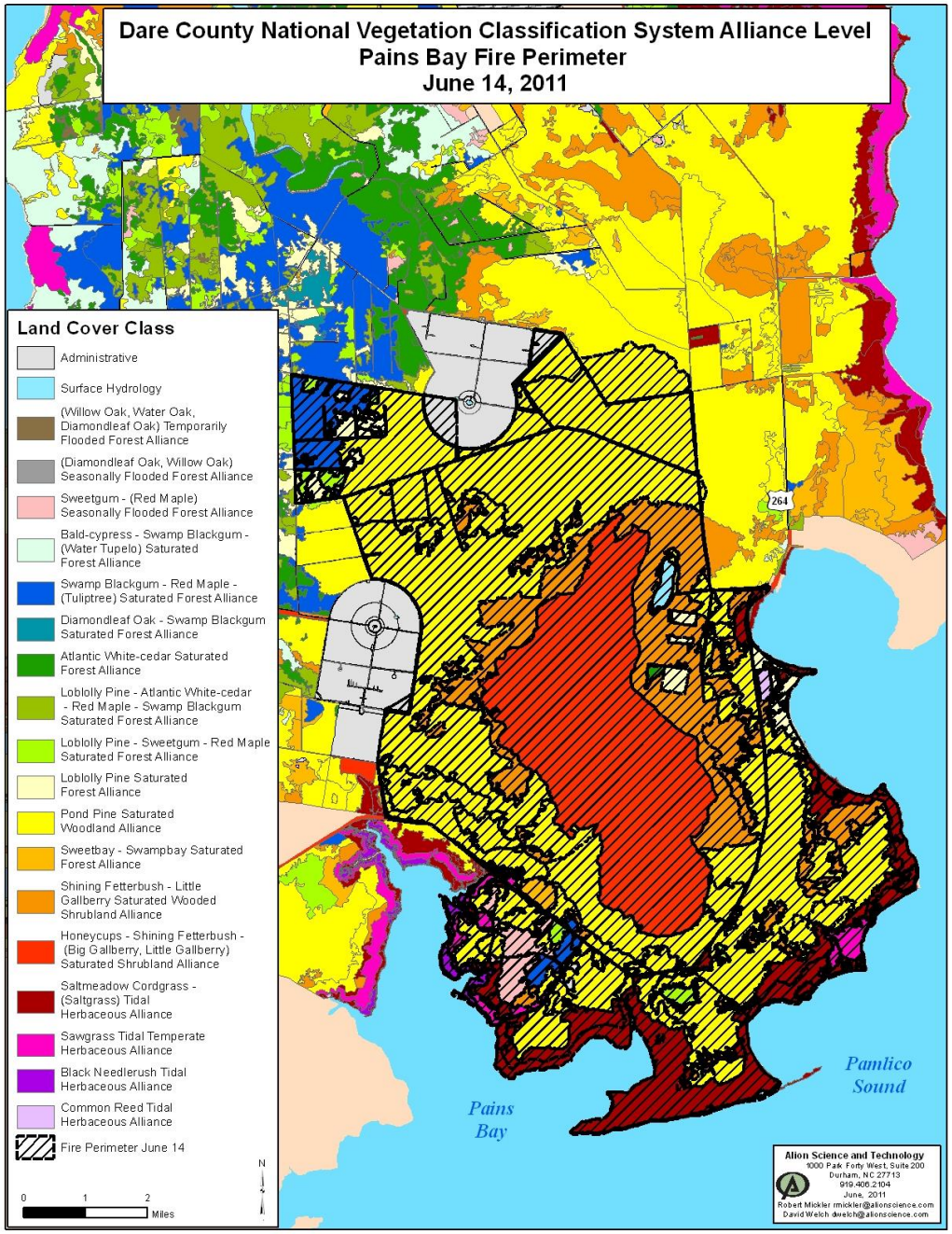
Pains Bay Fire Soil Series

The Dare County peninsula soil series are dominated by deep histosols. Cape Fear and Hyde loam soils are in rapid transition to organic soils such as Roper muck as the last of the Holocene and eroded Pleistocene mineral soils are overlaid by accumulating organic soil horizons and the Albemarle-Pamlico region continues to undergo subsidence (1.2 meter since European settlement of the Roanoke Colony in the 1580s).

Dare County Vegetation Classification

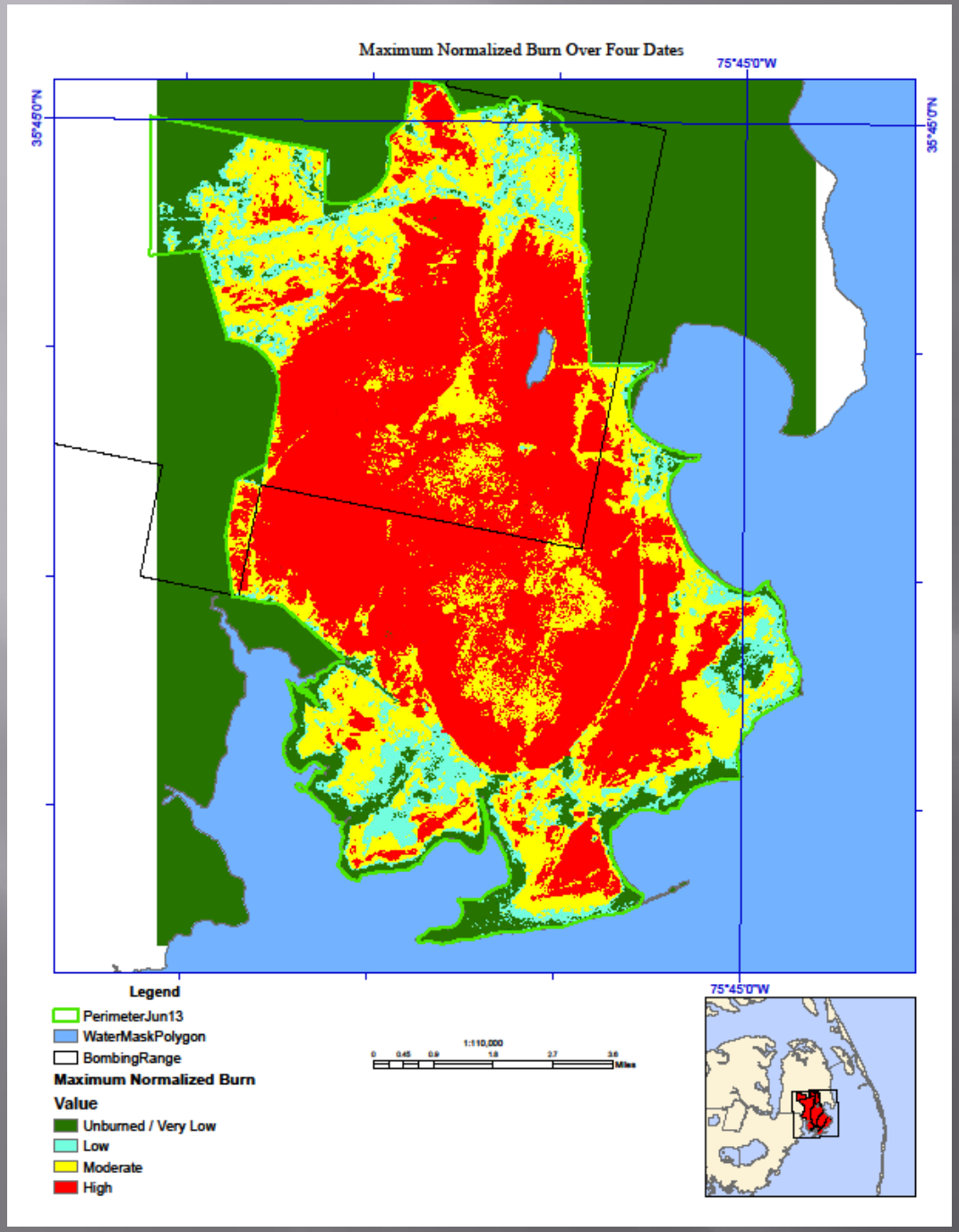






Pains Bay Fire Vegetation

Pains Bay Fire vegetation dominated by low pocossin shrub, pond pine woodlands, and tidal herbaceous communities. Elevations range from the highest point in the low pocossin dome to at sea level in saltmeadow and black needlerush vegetation. With the exception of the northwest corner of the fire, the area is comprised of deep organic (peat) histosol soil series.



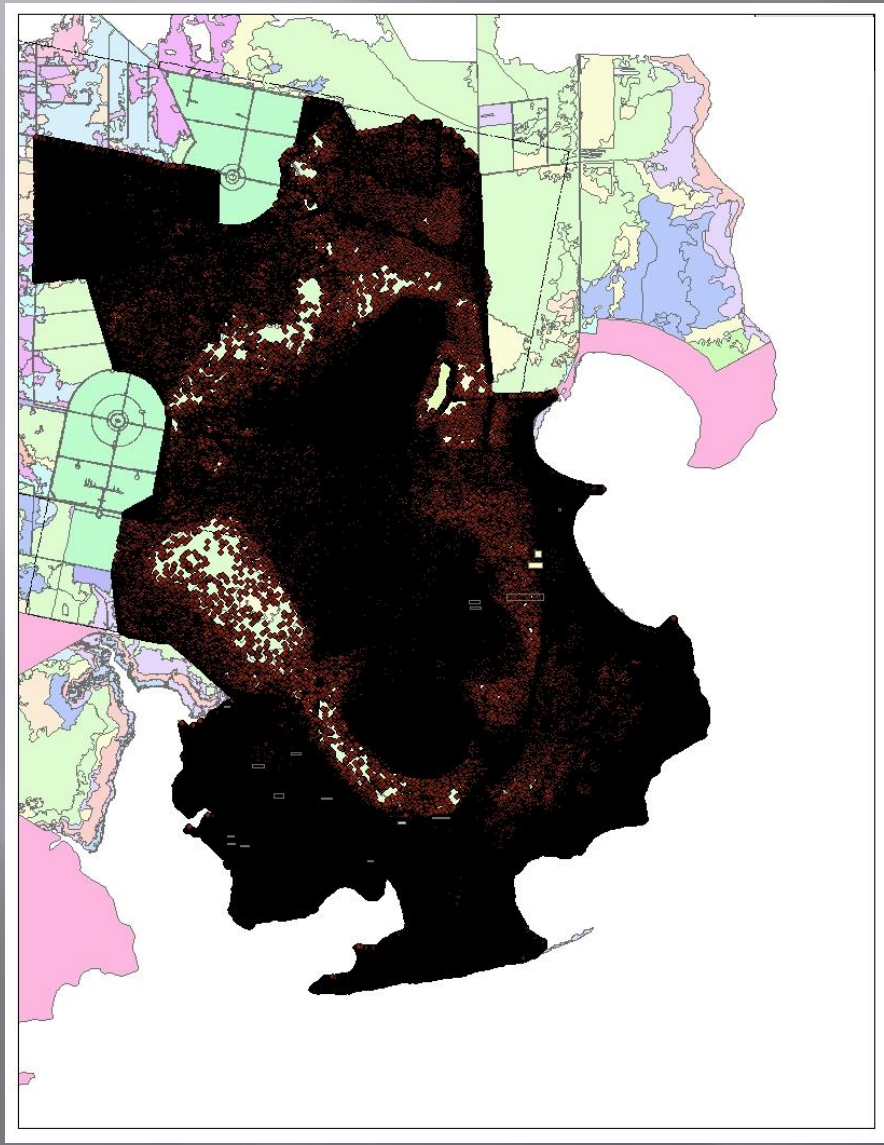
Pains Bay Fire Normalized Burn Ratio

A dNBR mosaic image was constructed from USGS images from four dates during the flaming phase of the fire. Each of the four images was gridded and the maximum grid value was determined for each grid cell to comprise the mosaic dNBR image. The mosaic eliminates the greening that occurred post flaming phase over the time period of the four DNBR images.

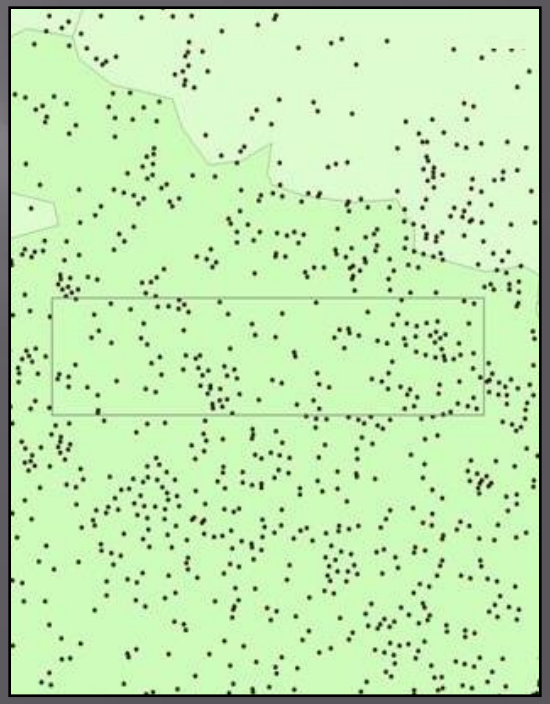
Pains Bay Fire
Vegetation Class and Acreage Consumption

	BurnRatio																Total
	0			1			2					3					
	GroundFireClass			GroundFireClass			GroundFireClass					GroundFireClass					
	0	1	2	0	1	2	0	1	2	3	4	0	1	2	3	4	
Vegetation																	
Administrative	89	12	8	152	44	11	172	73	9	.	.	49	15	0	.	.	635
Atlantic White-Cedar	.	.	.	.	.	1	.	0	14	1	.	13	5	9	12	.	56
Black Needlerush Tid	201	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	203
Common Reed Tidal He	7	.	.	20	.	.	37	.	.	.	.	0	.	.	.	.	64
Honeycups - Shining	.	.	.	.	.	.	1,045	693	0	.	.	2,923	3,370	39	.	.	8,070
Loblolly Pine - Atla	.	.	.	4	.	.	.	.	.	.	.	.	.	9	.	.	12
Loblolly Pine - Swee	106	78	.	27	9	.	101	27	.	.	.	47	2	.	.	.	397
Loblolly Pine Satura	126	101	.	142	50	.	120	94	5	0	.	3	59	46	97	.	842
Pond Pine Saturated	439	127	1	1,509	1,306	12	2,944	3,894	593	13	0	3,178	6,020	2,158	212	39	22,446
Private Land	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Saltmeadow Cordgrass	1,593	2	.	944	3	.	1,390	18	0	.	.	312	5	4	.	.	4,270
Sawgrass Tidal Tempe	230	.	.	102	.	.	184	.	.	.	.	.	.	.	.	.	516
Shining Fetterbush -	32	0	.	100	9	.	564	242	53	9	.	1,514	2,097	920	354	26	5,919
Surface Hydrology	34	2	.	100	9	.	44	25	0	.	.	2	3	0	.	.	220
Swamp Blackgum - Red	456	272	.	110	59	.	36	23	.	.	.	6	.	.	.	.	962
Sweetbay - Swampbay	1	0	.	3	.	.	23	12	.	.	.	61	34	.	.	.	134
Sweetgum - (Red Mapl	10	1	.	57	28	.	267	116	.	.	.	31	19	0	.	.	528
Total	3,324	595	9	3,272	1,518	25	6,926	5,218	674	22	0	8,138	11,628	3,187	676	64	45,276

Pains Bay Fire
LIDAR Ground Points and Elevation Transects



There are 1.52 million pre-burn LIDAR ground points within the Pains Bay Fire perimeter. East/West transects were randomly selected within vegetation and dNBR class, and 50 LIDAR points were co-located and ground surveyed for post-fire elevations.



Field Survey Equipment

- Trimble R4 GPS Receiver - A Base Station and Rover Receiver for RTK GPS / GNSS Surveying
- Trimble TSC2 Controller and Trimble Survey Controller Software
- Trimble RTX Verizon Cellular Data
  Correction Services – Cellular Network of GNSS Reference Stations

Honeycups Shining Fetterbush Saturated Shrubland Alliance
dNBR Class 3

Honeycups Shining Fetterbush Saturated Shrubland Alliance
dNBR Class 2

Pond Pine Saturated Woodland Alliance
dNBR Class 3

Pond Pine Saturated Woodland Alliance
dNBR Class 2

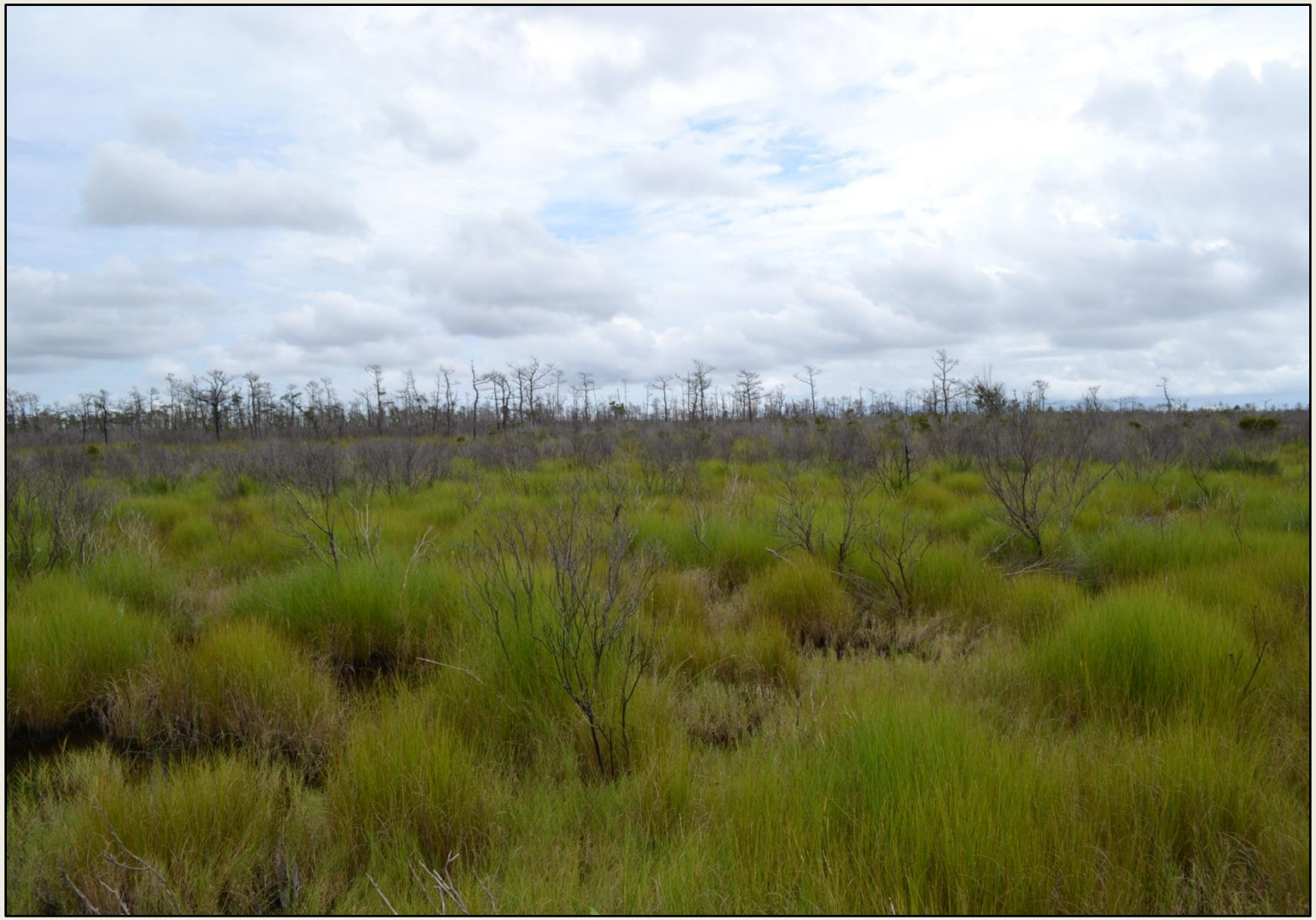
Pond Pine Saturated Woodland Alliance
dNBR Class 1

Pond Pine Saturated Woodland Alliance
dNBR Class 0

Saltmeadow Cordgrass Tidal Herbaceous Alliance
dNBR Class 3

Saltmeadow Cordgrass Tidal Herbaceous Alliance
dNBR Class 2

Saltmeadow Cordgrass Tidal Herbaceous Alliance
dNBR Class 1



Pains Bay Fire Soil Carbon Emissions (t Carbon) by Vegetation Alliance and dNBR Class

	dNBR Class				
Vegetation Type	0	1	2	3	Grand Total
Pond Pine Saturated Woodland Alliance	19,915	276,690	1,089,799	1,799,167	3,185,571
Honeycups - Shining Fetterbush - (Big Gallberry, Little Gallberry) Saturated Shrubland Alliance	0	0	192,344	807,846	1,000,190
Shining Fetterbush - Little Gallberry Saturated Wooded Shrubland Alliance	0	13,099	106,732	704,845	824,676
Saltmeadow Cordgrass - (Saltgrass) Tidal Herbaceous Alliance	31,943	20,149	34,476	8,119	94,687
Sawgrass Tidal Temperate Herbaceous Alliance	28,132	12,183	21,268	0	61,583
Loblolly Pine Saturated Forest Alliance	6,006	6,826	8,861	12,549	34,241
Loblolly Pine - Sweetgum - Red Maple Saturated Forest Alliance	5,819	0	8,895	0	14,714
Swamp Blackgum - Red Maple - (Tuliptree) Saturated Forest Alliance	6,871	4,364	0	0	11,236
Sweetgum - (Red Maple) Seasonally Flooded Forest Alliance	0	0	9,536	0	9,536
Sweetbay - Swampbay Saturated Forest Alliance	0	0	0	1,989	1,989
Black Needlerush Tidal Herbaceous Alliance	1,087	0	0	0	1,087
Grand Total	99,774	333,311	1,471,912	3,334,514	5,239,510

Pains Bay Fire Vegetation Carbon Emissions (t Carbon) By Vegetation Alliance and dNBR Class

Vegetation Type	dNBR Class	Litter Biomass	Shrub Biomass	Foliage Biomass	Total Biomass
Pond Pine Saturated Wodland Alliance	0	321	0	0	321
	1	4,001	4,026	688	8,716
	2	10,535	16,964	16,312	43,811
	3	24,640	31,410	26,848	82,898
Honeycups - Shining Fetterbush - (Big Gallberry, Little Gallberry) Saturated Shrubland Allia	2	3,015	12,614	23	15,652
	3	13,042	54,571	90	67,703
Shining Fetterbush - Little Gallberry Saturated Wooded Shrubland Alliance	0	14	0	0	14
	1	118	494	0	613
	2	1,506	6,300	12	7,817
	3	10,116	42,324	70	52,510
Saltmeadow Cordgrass - (Saltgrass) Tidal Herbaceous Alliance	0	0	0	829	829
	1	0	0	1,231	1,231
	2	0	0	2,929	2,929
	3	0	0	835	835
Sawgrass Tidal Temperate Herbaceous Alliance	0	0	0	202	202
	1	0	0	224	224
	2	0	0	647	647
Loblolly Pine Saturated Forest Alliance	0	141	0	0	141
	1	298	0	0	298
	2	543	0	0	543
	3	636	0	0	636
Loblolly Pine - Sweetgum- Red Maple Saturated Forest Alliance	0	212	0	0	212
	2	236	0	0	236
Swamp Blackgum - Red Maple - (Tuliptree) Saturated Forest Alliance	0	291	0	0	291
	1	108	0	0	108
Sweetgum - (Red Maple) - Seasonnaly Flooded Forest Alliance	2	95	0	0	95
Black Needlerush Tidal Herbaceous Alliance	0	68	0	0	68
Grand Total					289,578

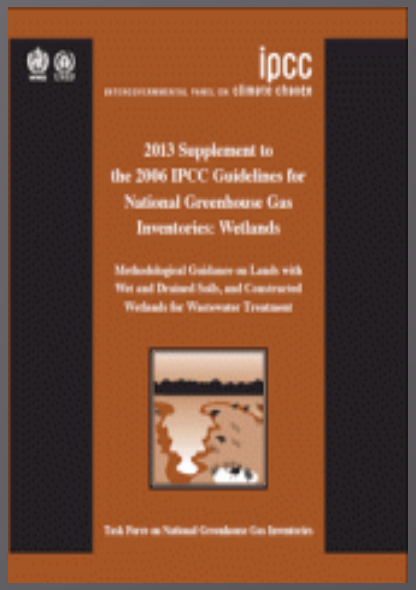
Comparison of Above- and Below-Ground Carbon Emissions

The 2011 Pains Bay Fire resulted in estimated below-ground fire emissions of 5.2 Tg C and above-ground fire emissions of 0.29 Tg C, for total fire emissions of 5.49 Tg C (1 Tg equals 10^{12} grams or 1,000,000 metric tons).

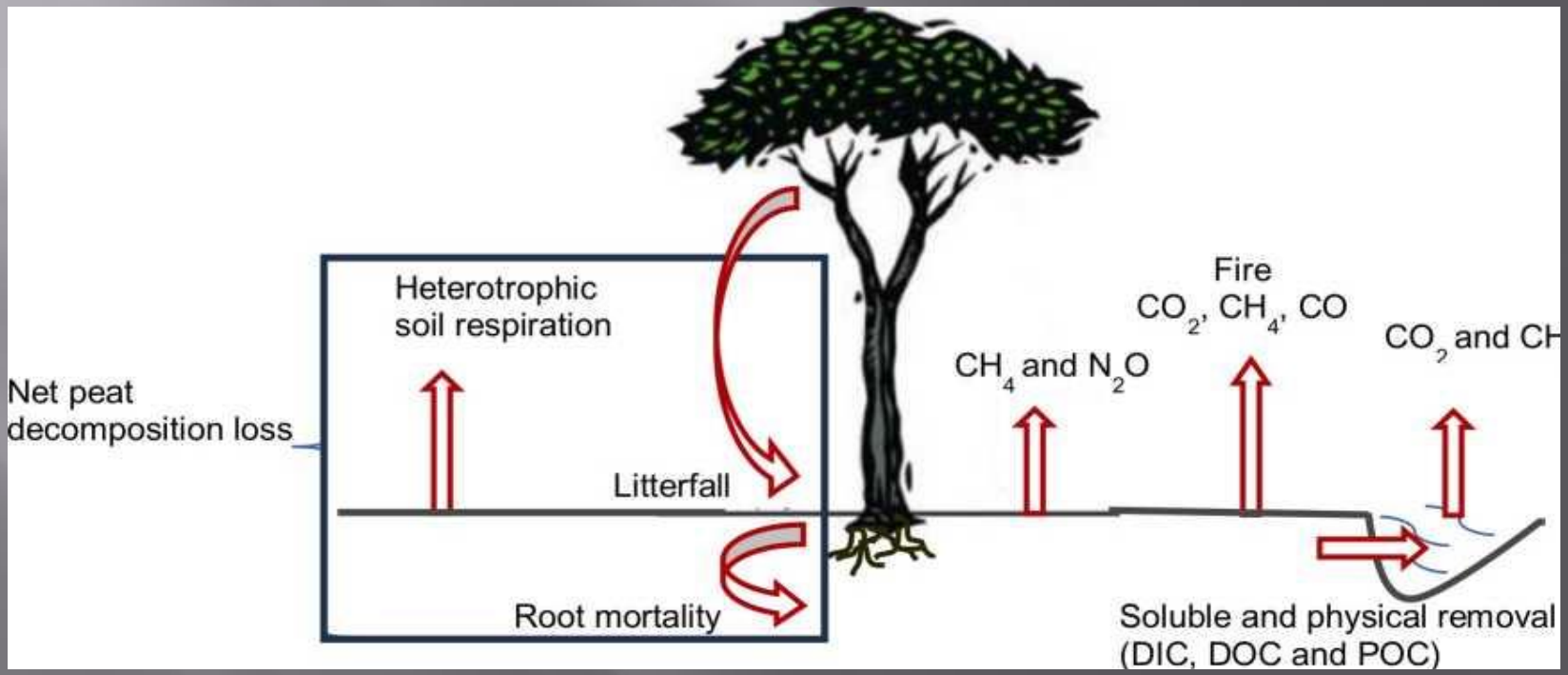
Are North Carolina Carbon Emissions Important ?

- Global fires burn an estimated 350 to 450 Mha of forest and grassland every year, equivalent to 3.85% of the global land area.
- Global carbon emissions from wildland fire are 1.7 to 3.5 billion tonnes C each year.
- Temperate peatland fires may globally contribute 320,000,000 tonnes C annually during drought years. This contribution represents as much as 19% of the interannual variability of atmospheric C from global wildland fire.
- North Carolina's estimated total area of peatland soils is 0.27 Mha with a total C pool of 327,000,000 tonnes.
- The Evans Road Fire emitted 9,470,000 tonnes C or 2.9% of North Carolina's peatland C.
- The Pains Bay Fire emitted 5,490,000 tonnes C or 1.7% of Noth Carolina's peatland C.

2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands



The United Nations Intergovernmental Panel on Climate Change Guidelines provide a science view of climate change and its political and economic impacts, and guidance for carbon stock changes in five carbon pools, above and below-ground biomass, dead wood, litter and soil for managed land on organic soils.



Questions

Funding sponsors: