Carbon Sequestration in Coastal Freshwater Peatlands: A Market Credit Tool for Restoration

Funded by

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Curtis Richardson[1], Neal Flanagan[1], Hongjun Wang[1], & Mengchi Ho[1]

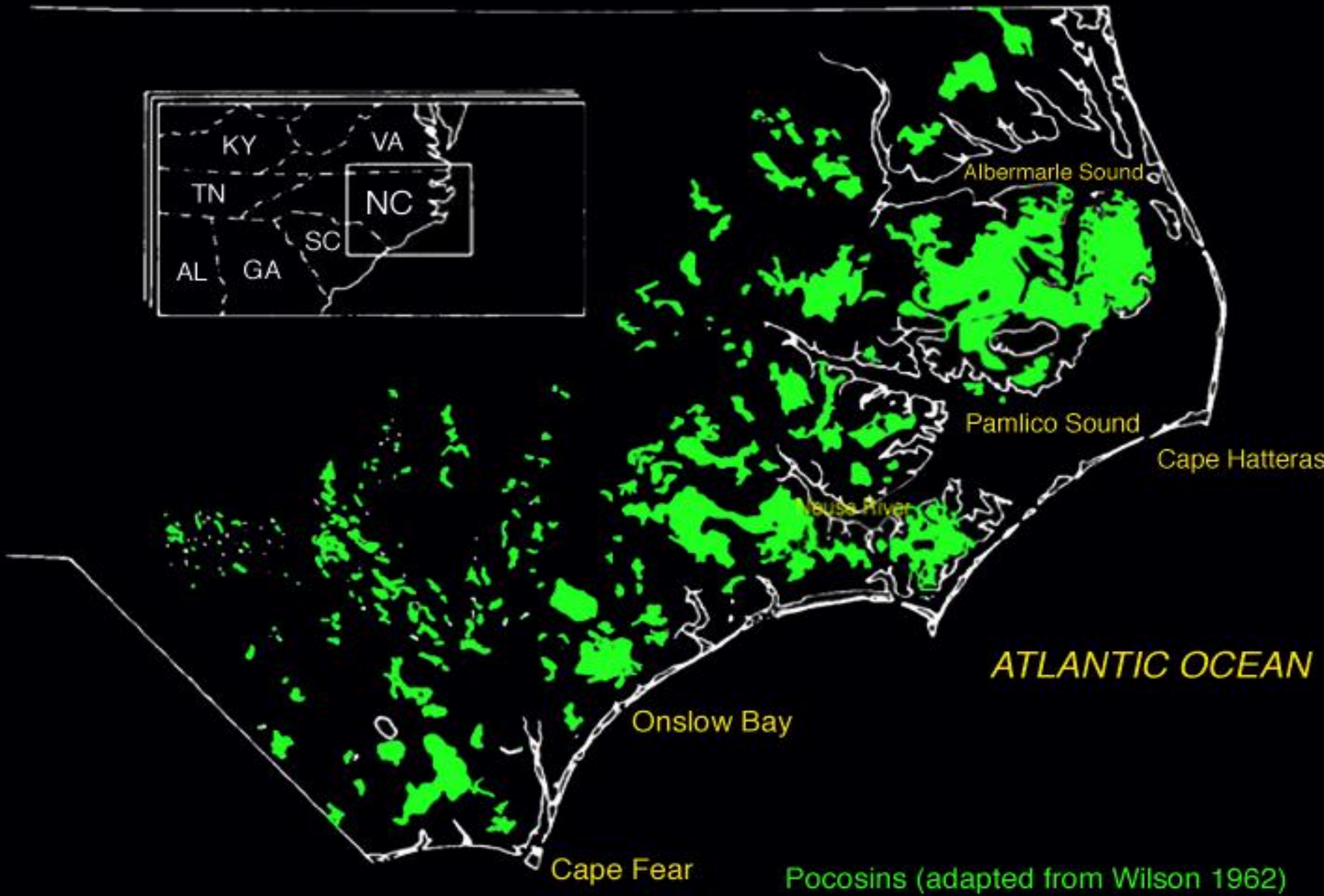
&

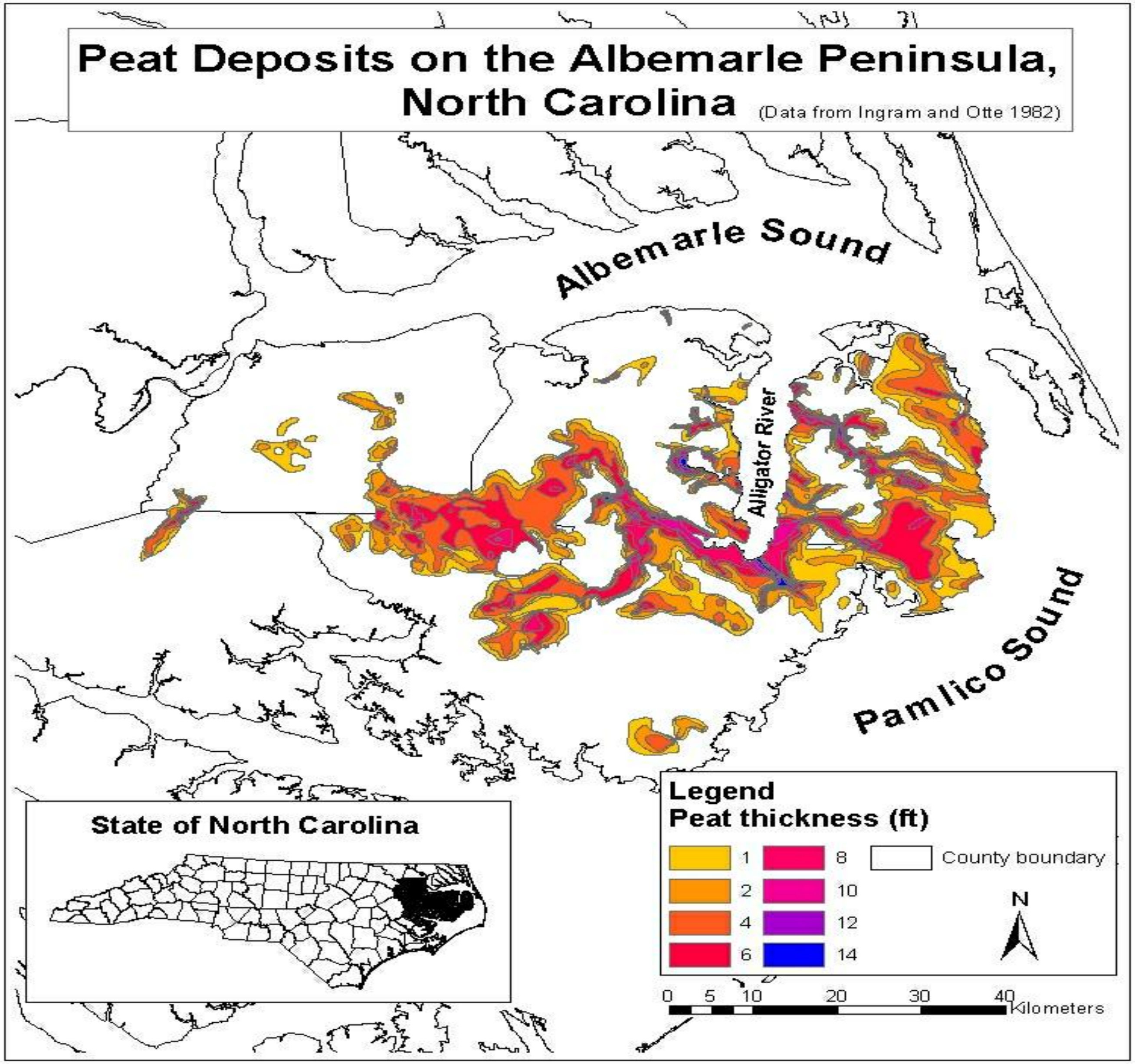
Sara Ward[2], and Tom Augspurger[2]

[1]***Duke University Wetland Center, Nicholas School of the Environment***
[2]*U.S. Fish and Wildlife Service, Region 4*

Outline

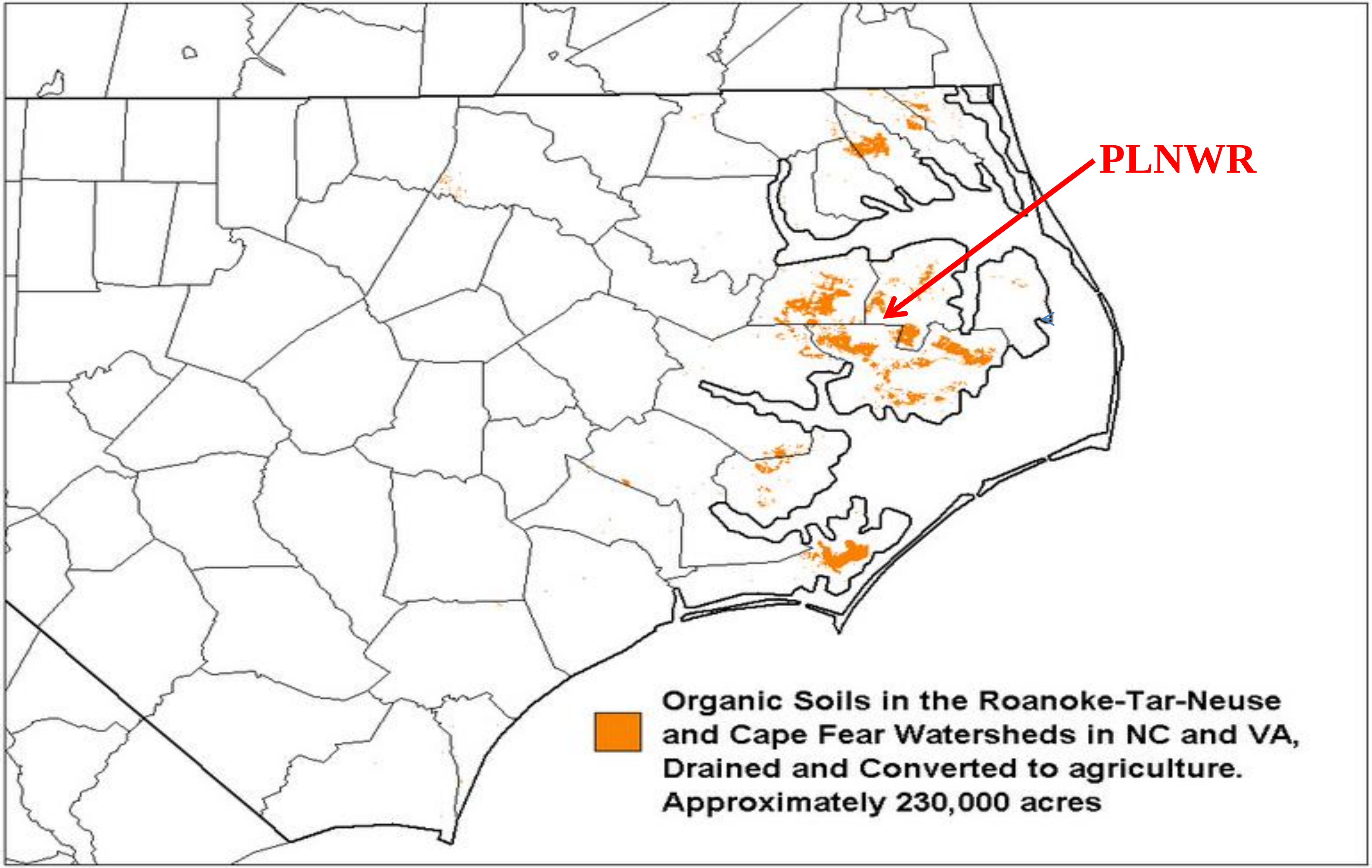
- **Importance of restoring agricultural peatlands and drained wetlands**
- **Conceptual C credit accounting plan USFWS**
- **Experimental site description**
- **Questions**
  - **Does hydrologic restoration increase GHG flux?**
  - **Does restoration increase C and N Sequestration?**
  - **What controls C sequestration ?**
- **Conclusions**


KY
VA
TN
NC
SC
AL
GA
Albermarle Sound
Pamlico Sound
Cape Hatteras
ATLANTIC OCEAN
Onslow Bay
Cape Fear
Pocosins (adapted from Wilson 1962)


Peat Deposits on the Albemarle Peninsula, North Carolina
(Data from Ingram and Otte 1982)
Albemarle Sound
Alligator River
Pamlico Sound
State of North Carolina
Legend
Peat thickness (ft)
1
2
4
6
8
10
12
14
County boundary
N
0 5 10 20 30 40 Kilometers

(325 Tg C)

Drained and converted organic soils in agriculture that have potential for increased greenhouse gas losses (unpublished map from NC RAMSAR working group)



Wetland Restoration

Recommended expansion of restoration at Pocosin Lakes NWR


Photo: S.Ward, USFWS

Why?

- Peatland restoration allows substantive C and N sequestration benefits
- Refuge habitat improvement
- Reduces nutrient runoff to estuaries

1) Amount retained that would be lost without restoration (stop loss)

$$\text{Rate of peat loss (ft/yr)} \times \text{Bulk density (kg/ft}^3) \times \text{Peat N or C content (\%)} \times \text{CF} = \text{lb/ac/yr sequestered}$$

where CF = conversion factors for ft^2/ac and lb/kg

- Rate of peat loss when drained 0.03 ft/yr
- Bulk density 0.2 g/cm^3
- Peat nitrogen content 1.35%
- Peat carbon content 43%

= 190 lb N/ac/yr and 6100 lb C/ac/yr

Off-Set Accounting

Components of estimate:	Sequestration (lb/ac/yr) Nitrogen	Carbon
1) amount retained that would otherwise be lost without hydrology restoration	190	6100
2) amount retained in peat as soil genesis is re-established	7	230
3) amount retained in the above ground biomass	0.6	140
TOTAL:	200	6500

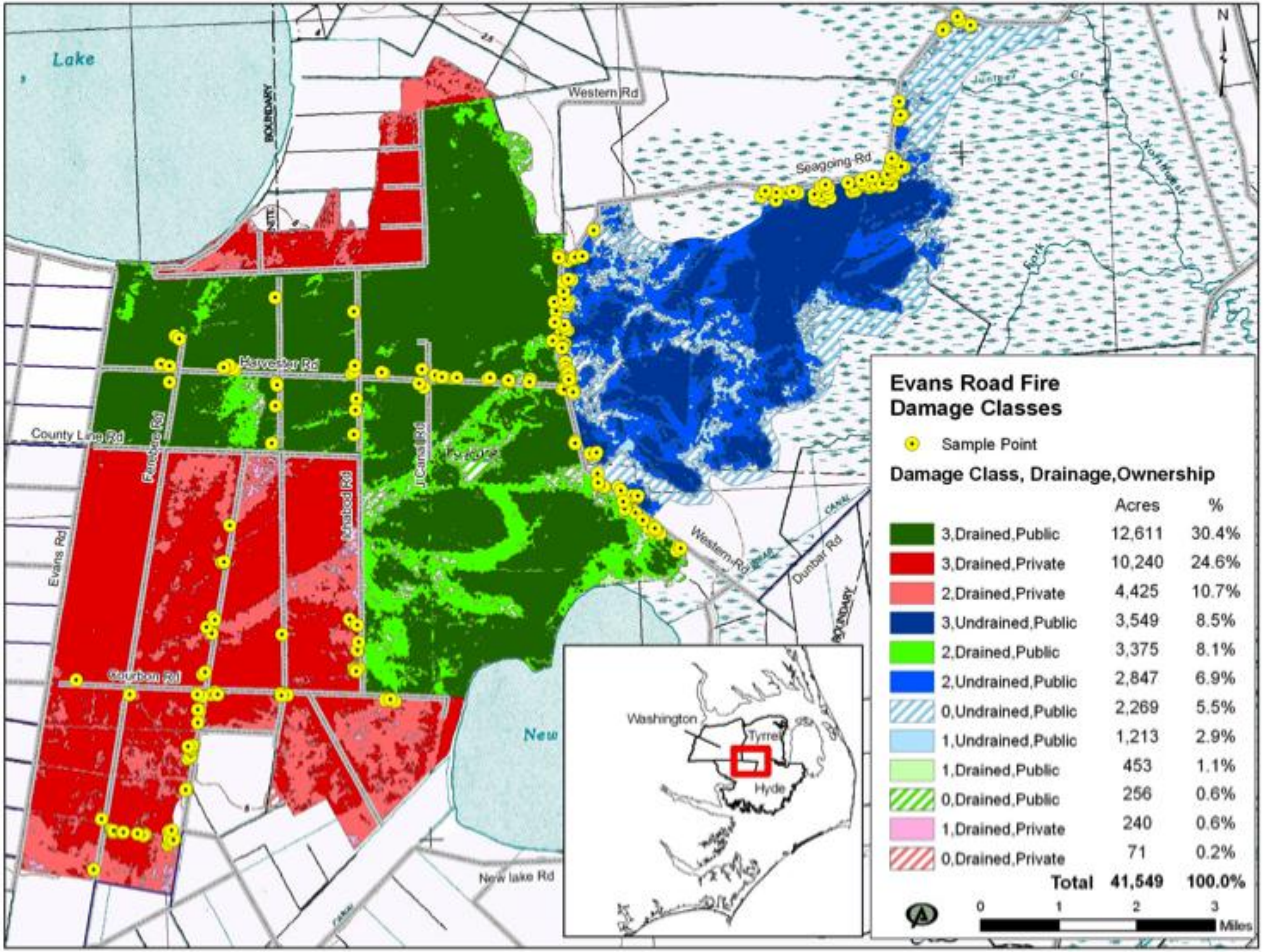
(Peat Fire June –September 2008)

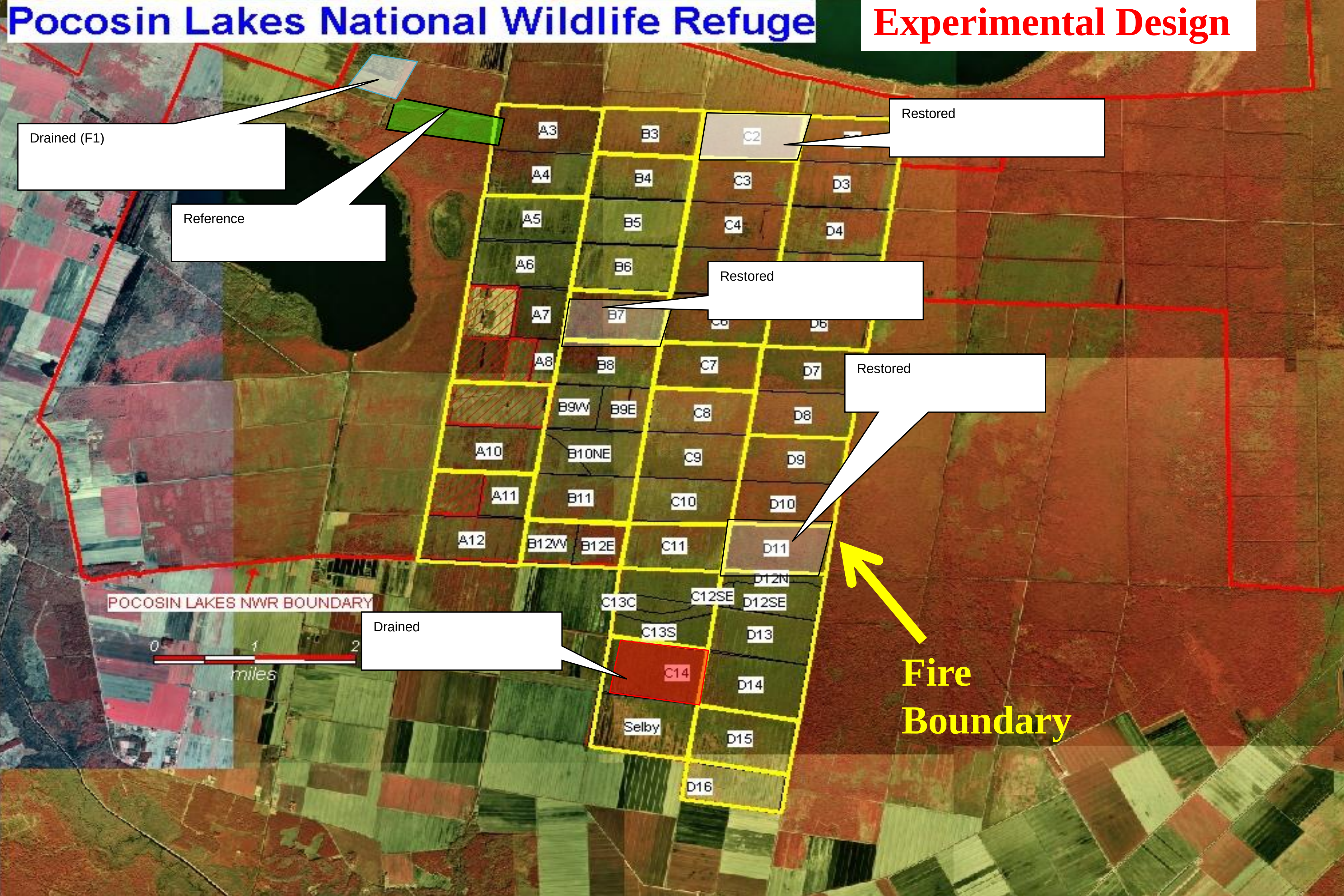
(How much C was lost?)

16,814 ha Burned

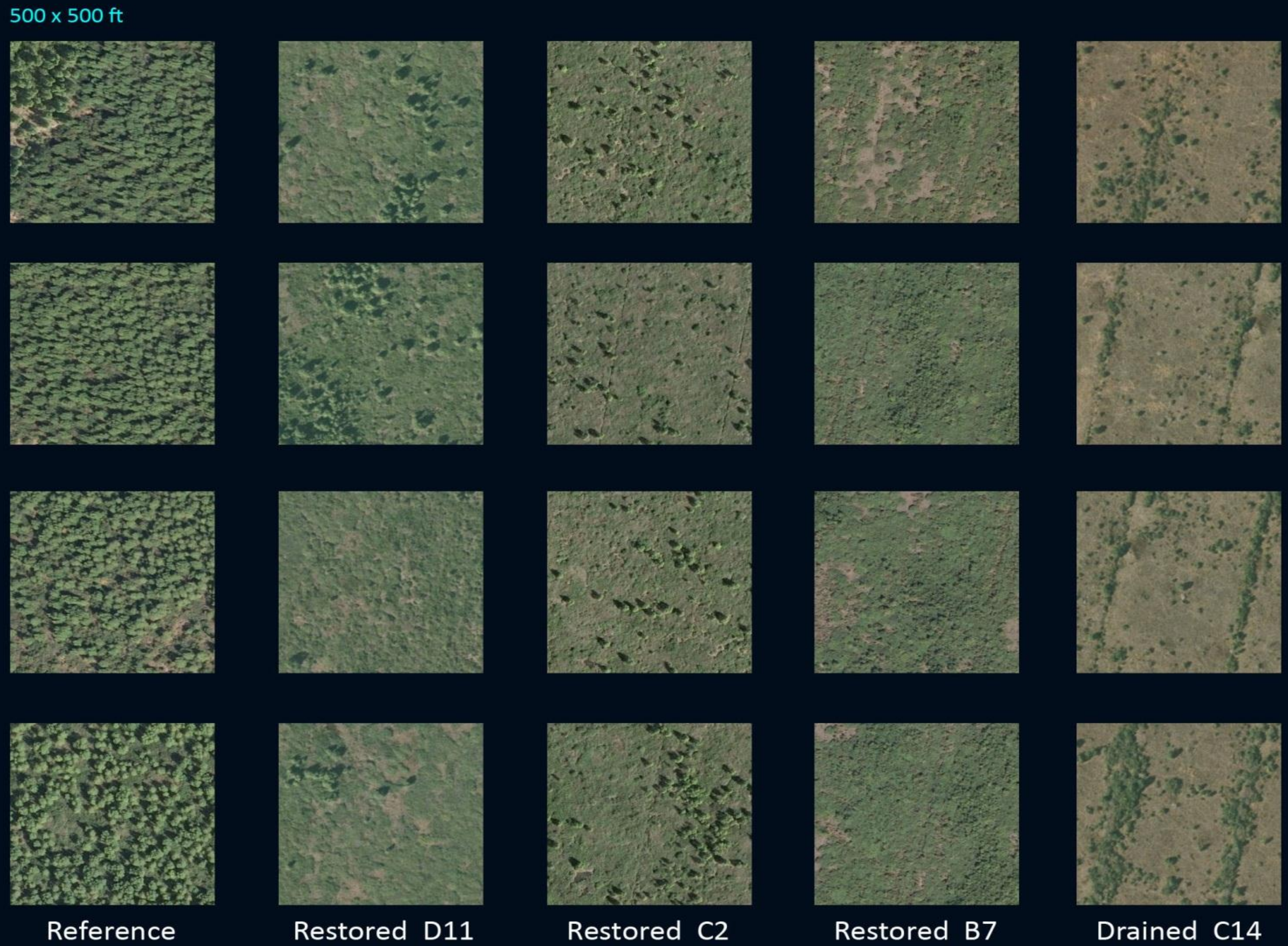
Large Scale Hydrology-Carbon Sequesration Experiment

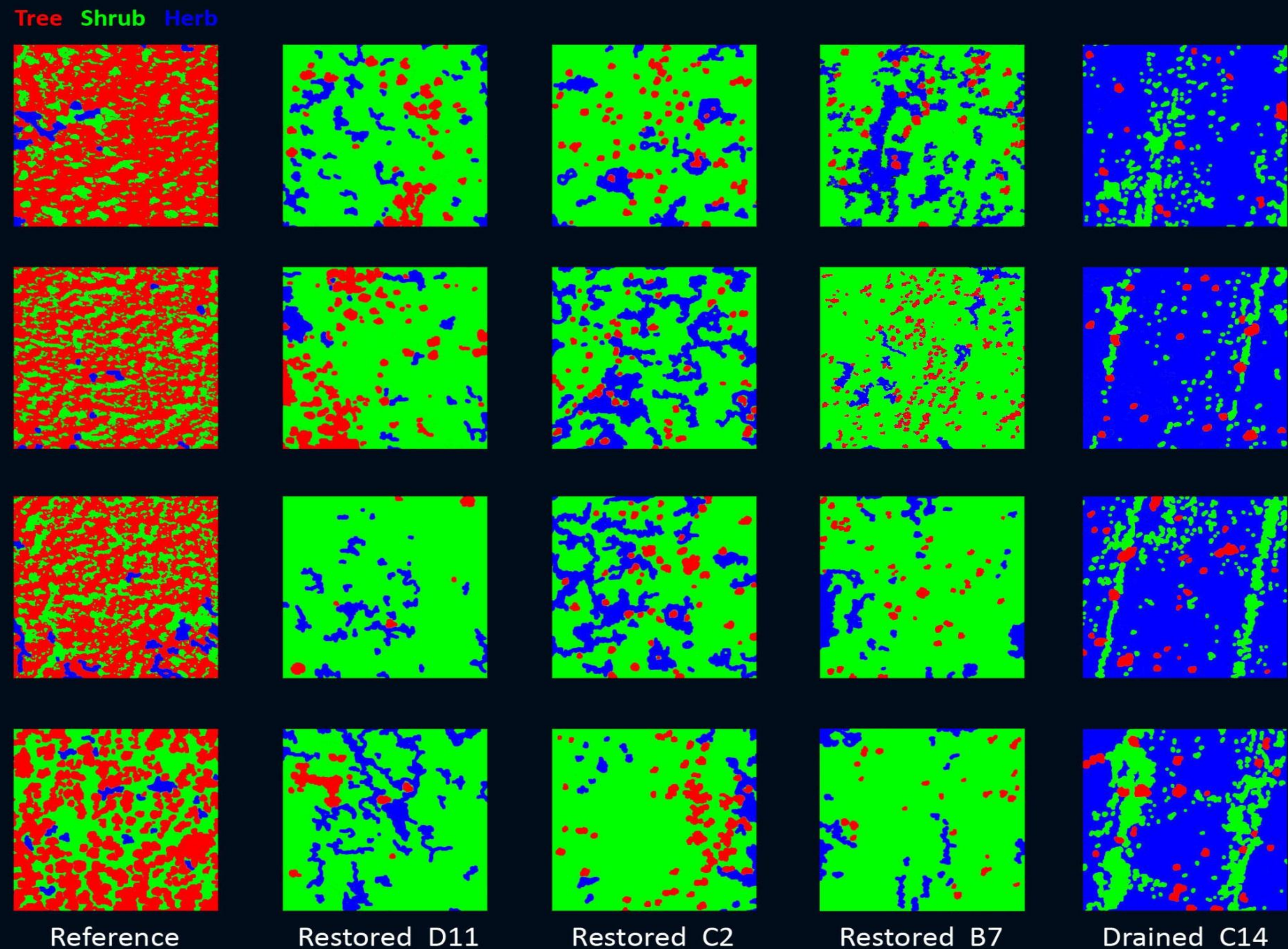
Pocosins Lake National Wildlife Refuge
in
Coastal NC


Evans Road Fire
Damage Classes
Sample Point
Damage Class, Drainage,Ownership
Acres %
3,Drained,Public 12,611 30.4%
3,Drained,Private 10,240 24.6%
2,Drained,Private 4,425 10.7%
3,Undrained,Public 3,549 8.5%
2,Drained,Public 3,375 8.1%
2,Undrained,Public 2,847 6.9%
0,Undrained,Public 2,269 5.5%
1,Undrained,Public 1,213 2.9%
1,Drained,Public 453 1.1%
0,Drained,Public 256 0.6%
1,Drained,Private 240 0.6%
0,Drained,Private 71 0.2%
Total 41,549 100.0%
0 1 2 3
Miles
N
Lake
New
Western Rd
Seagoing Rd
Harvester Rd
County Line Rd
Evans Rd
J Canal Rd
Dunbar Rd
New lake Rd
BOUNDARY
Washington
Tyrrell
Hyde

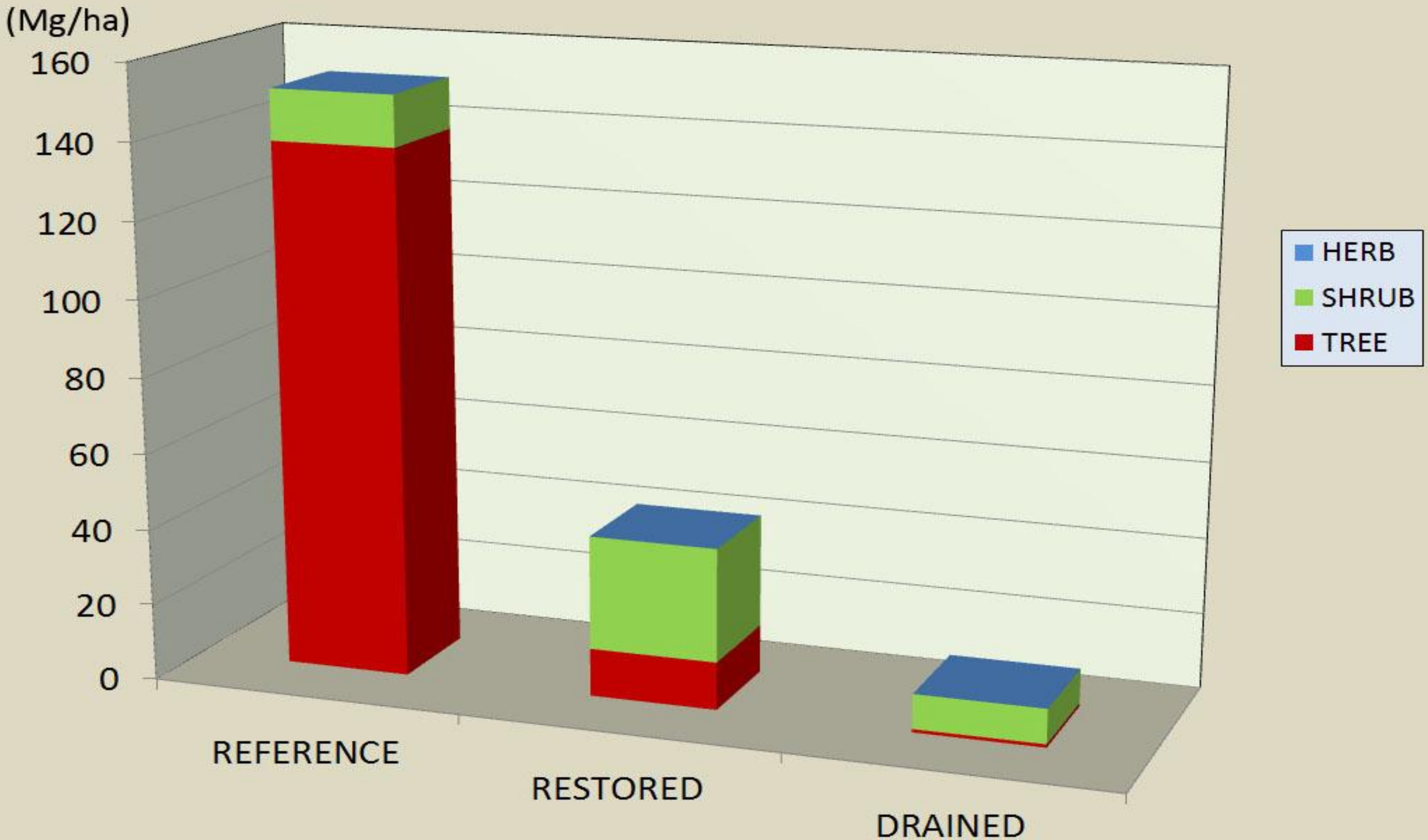

Pocosin Lakes National Wildlife Refuge
Experimental Design
Drained (F1)
Reference
Restored
Restored
Restored
Drained
A3
A4
A5
A6
A7
A8
A10
A11
A12
B3
B4
B5
B6
B7
B8
B9W
B9E
B10NE
B11
B12W
B12E
C2
C3
C4
C7
C8
C9
C10
C11
C12SE
C13C
C13S
C14
Selby
D3
D4
D7
D8
D9
D10
D11
D12N
D12SE
D13
D14
D15
D16
POCOSIN LAKES NWR BOUNDARY
0
1
2
miles
Fire Boundary

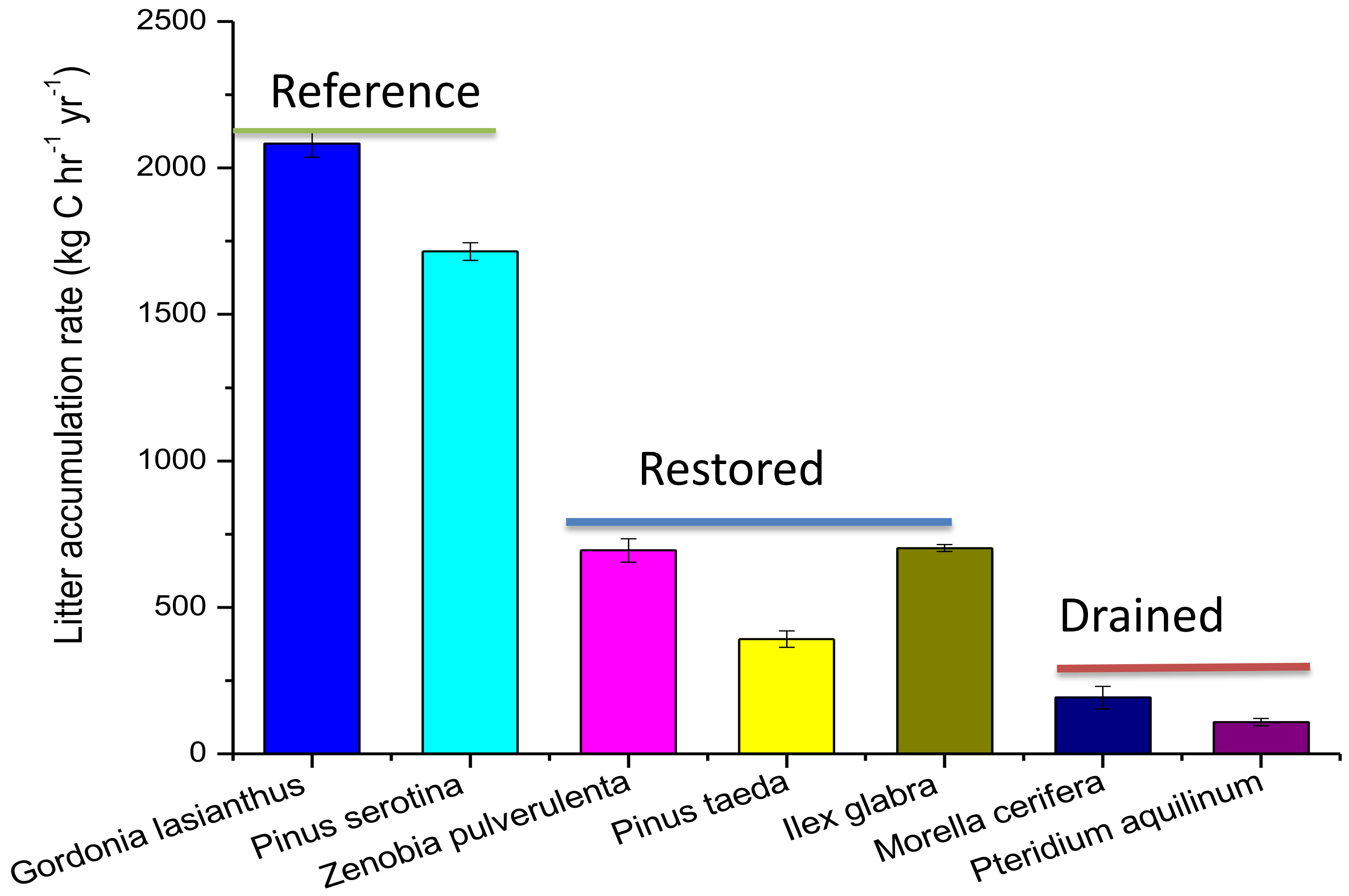

Lake Phelps
Pungo Lake
Reference REF
Restored B-7, C-2, D-11
Drained C-14
Outflow Sampler


500 x 500 ft
Reference
Restored D11
Restored C2
Restored B7
Drained C14

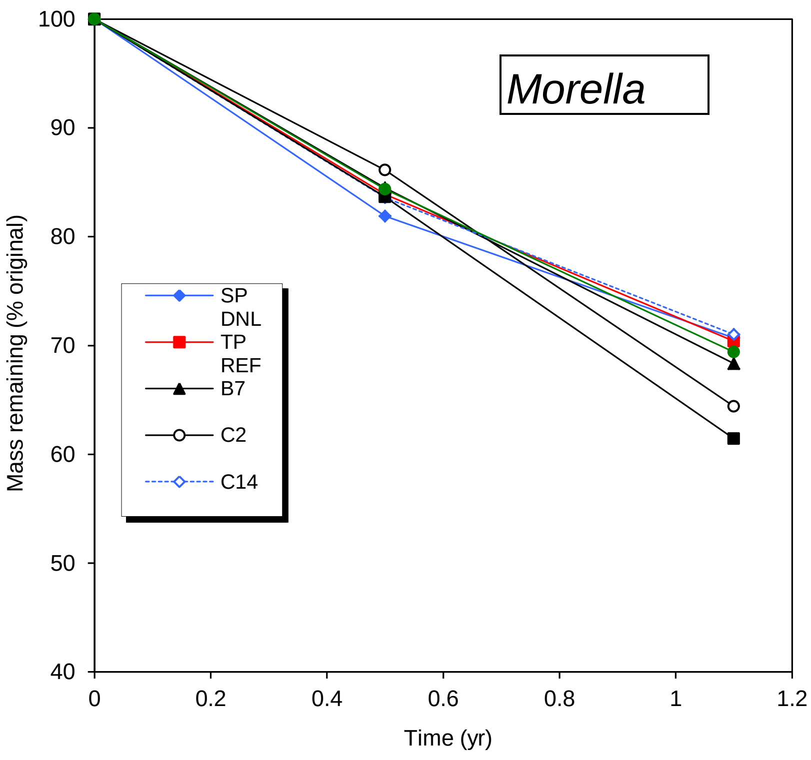

Tree
Shrub
Herb
Reference
Restored D11
Restored C2
Restored B7
Drained C14

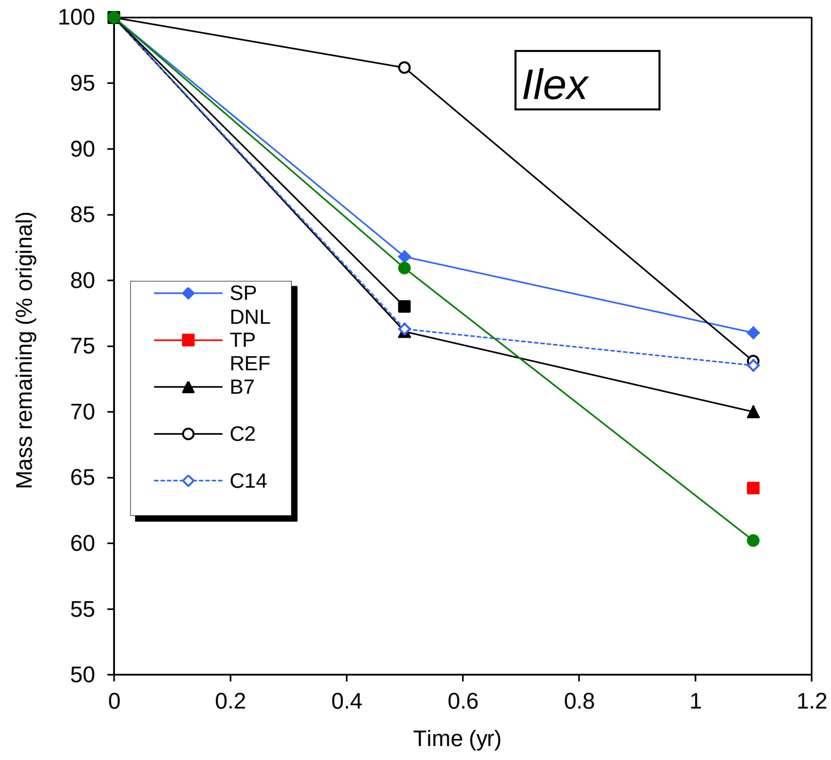
Above-ground Biomass in Three Hydrologic Regimes in Pocosin Lakes National Wildlife Refuge



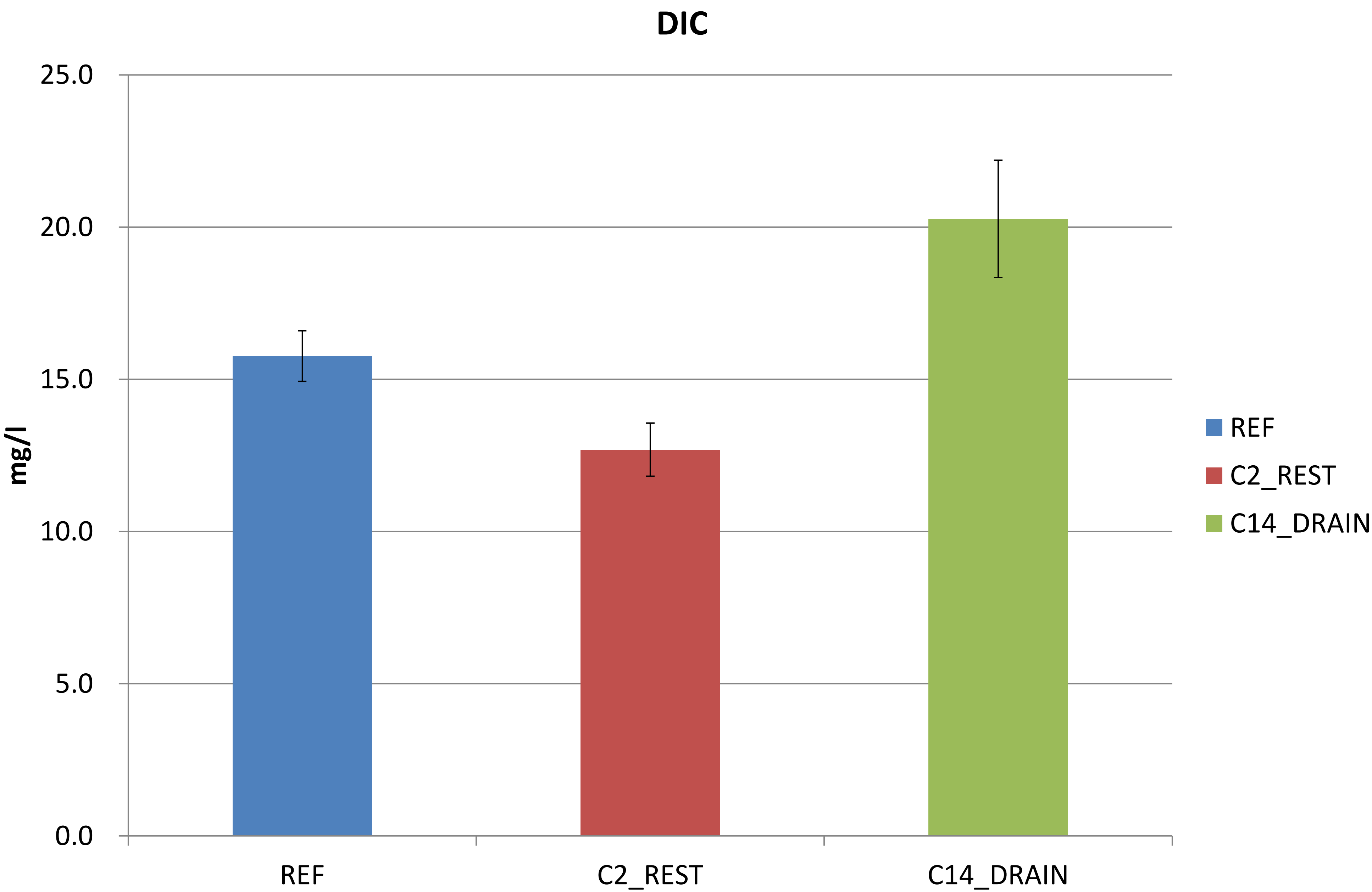


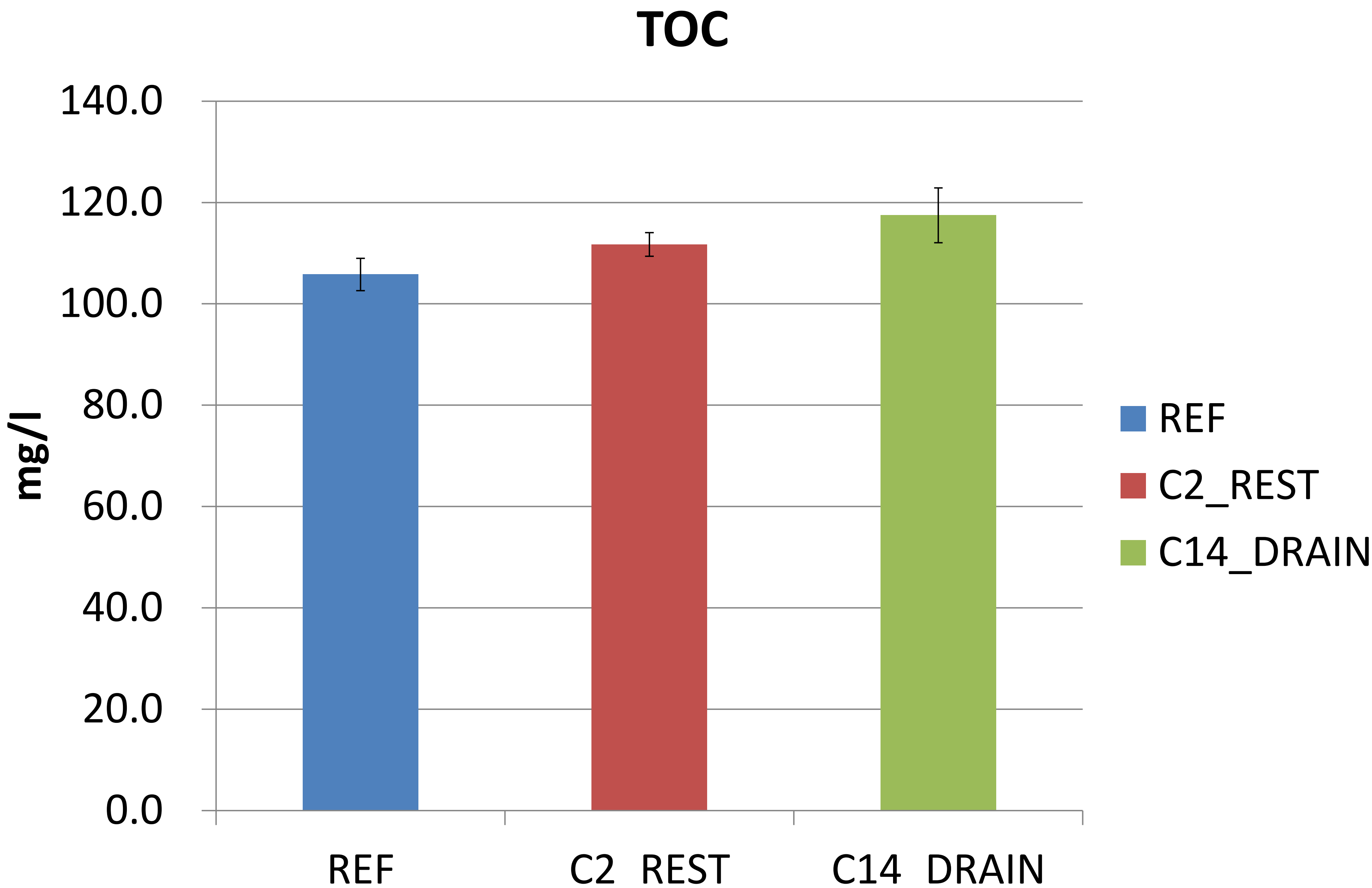
Litter Accumulation Rates in Pocosins by Species & Hydrology Treatments



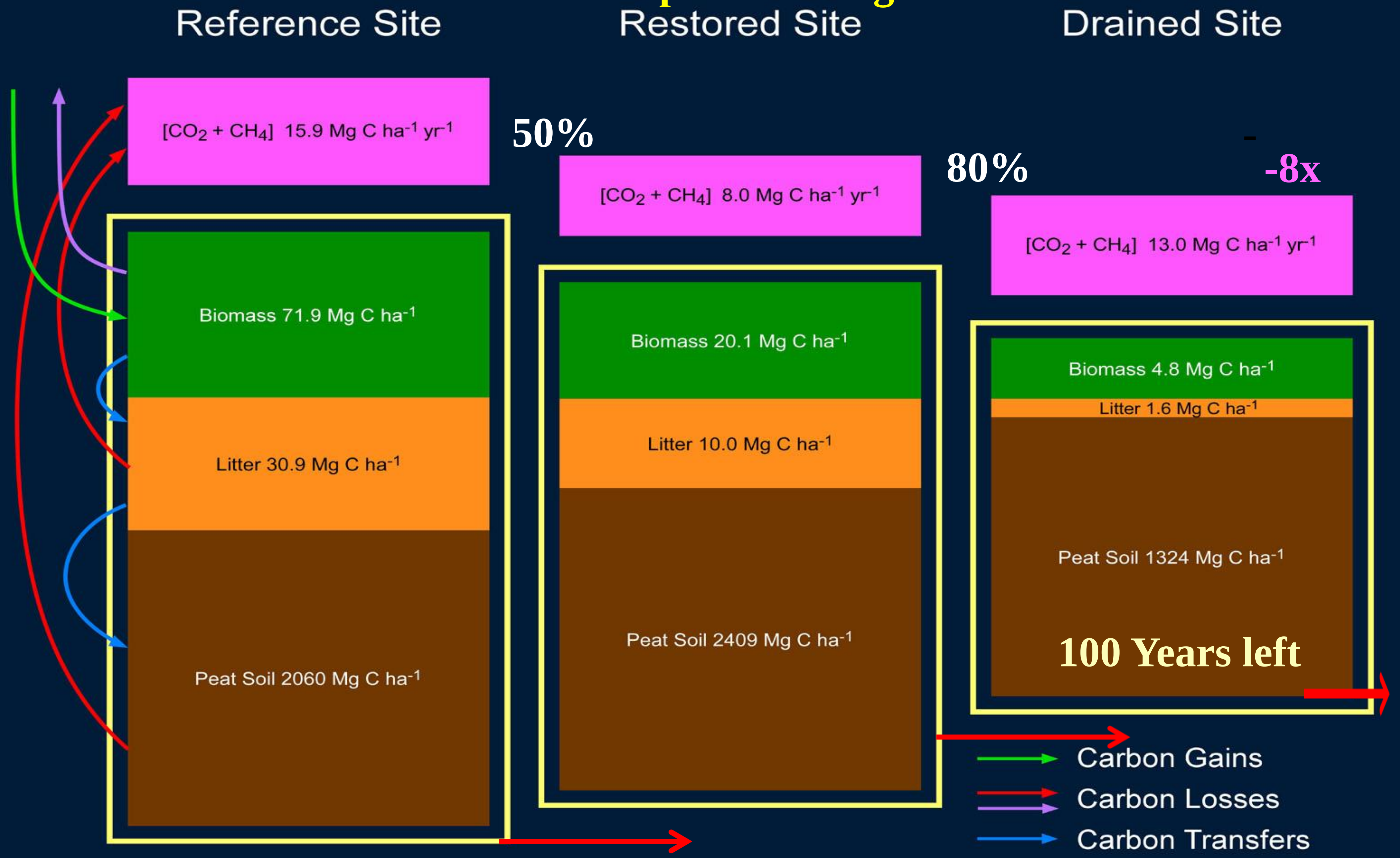


Decomposition rates in drained, restored and reference pocosins (Preliminary data from Tim Moore, McGill)


DIC
25.0
20.0
15.0
10.0
5.0
0.0
mg/l
REF
C2_REST
C14_DRAIN
REF
C2_REST
C14_DRAIN


TOC
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
mg/l
REF
C2_REST
C14_DRAIN
REF
C2_REST
C14_DRAIN

Incomplete C Budget

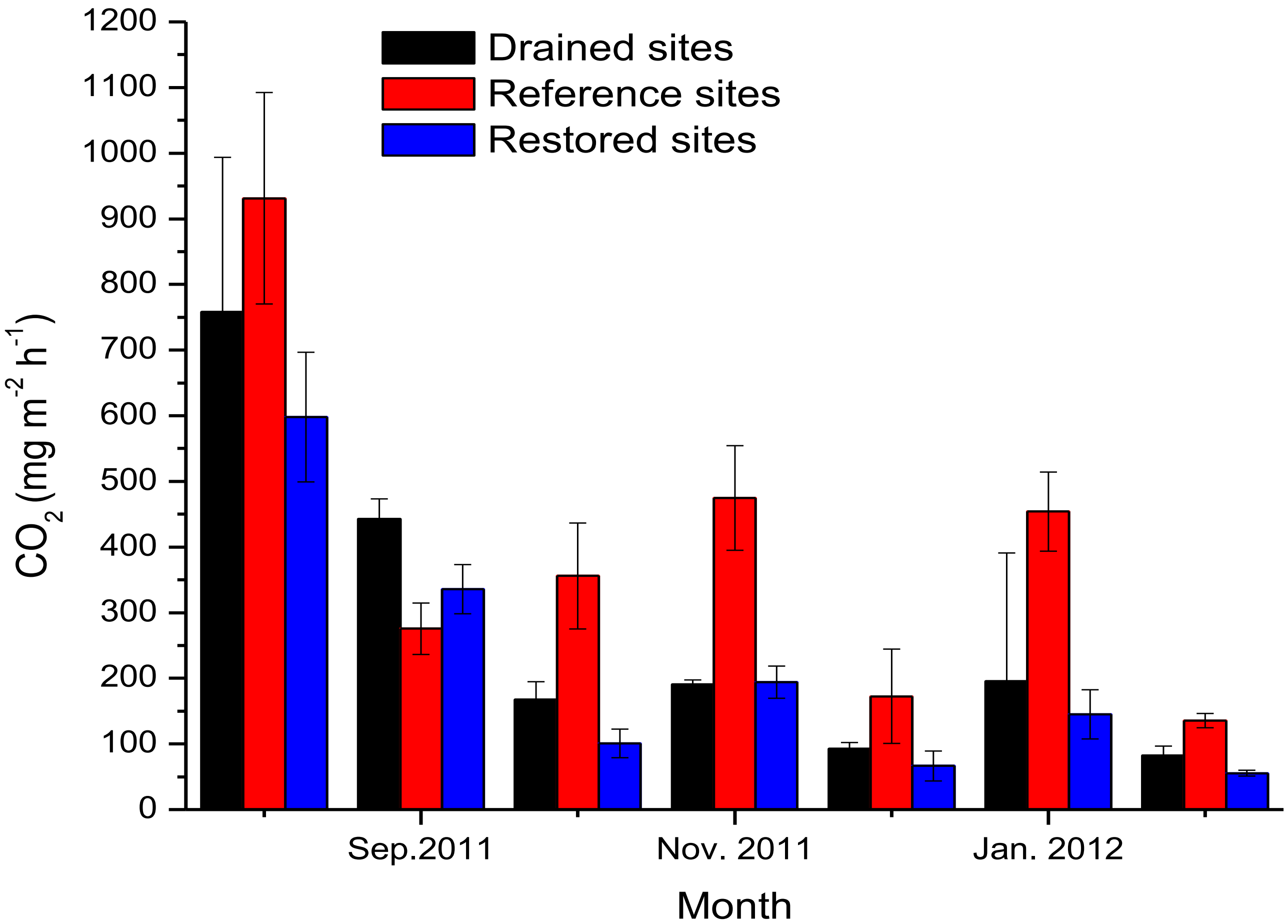


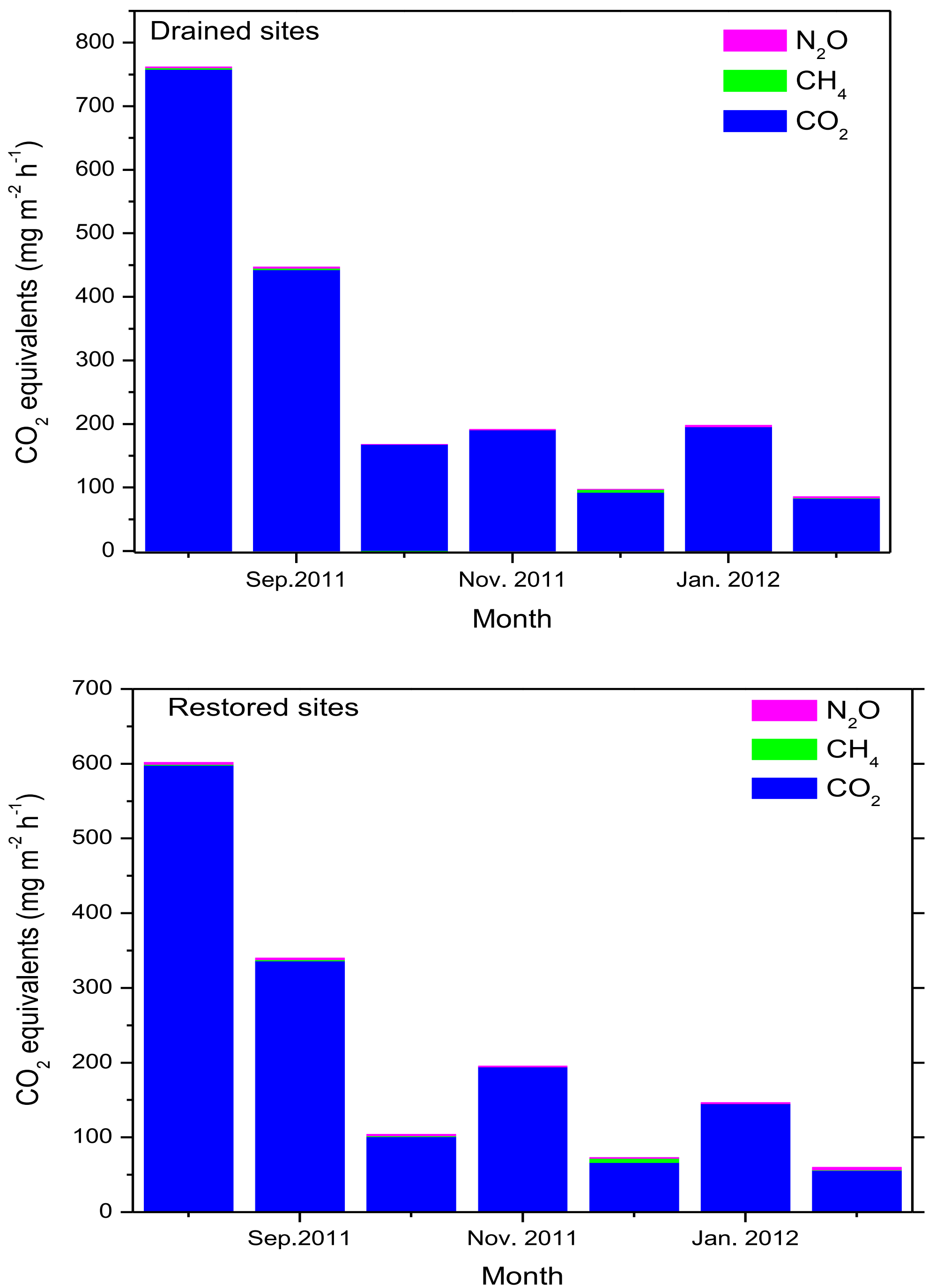
Does Hydrologic Restoration Alone Control GHG Flux?

&

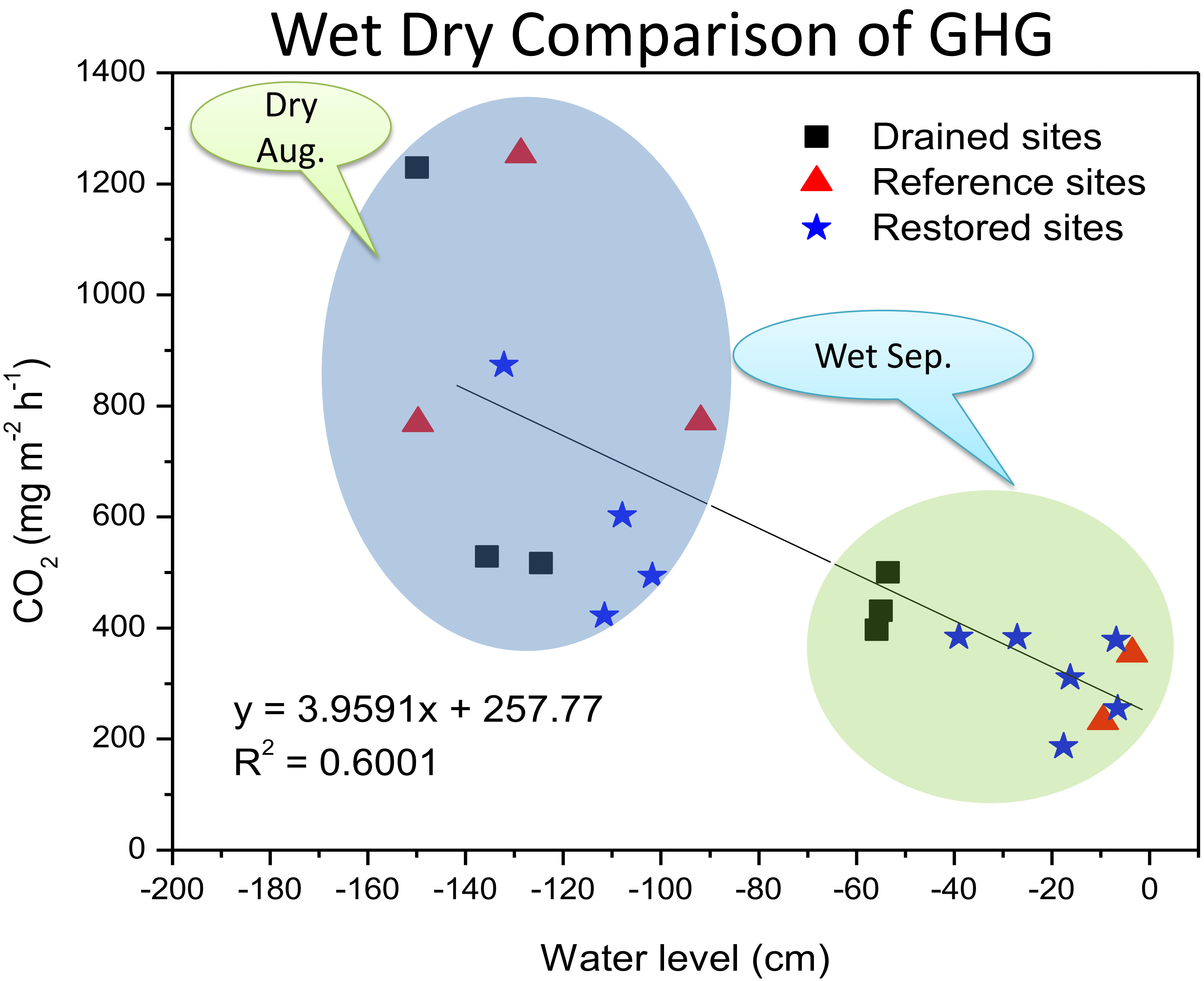
Which GHG is the Dominant Contributor?

Average By Treatment


Drained sites
Reference sites
Restored sites
CO2 (mg m-2 h-1)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Sep.2011
Nov. 2011
Jan. 2012
Month

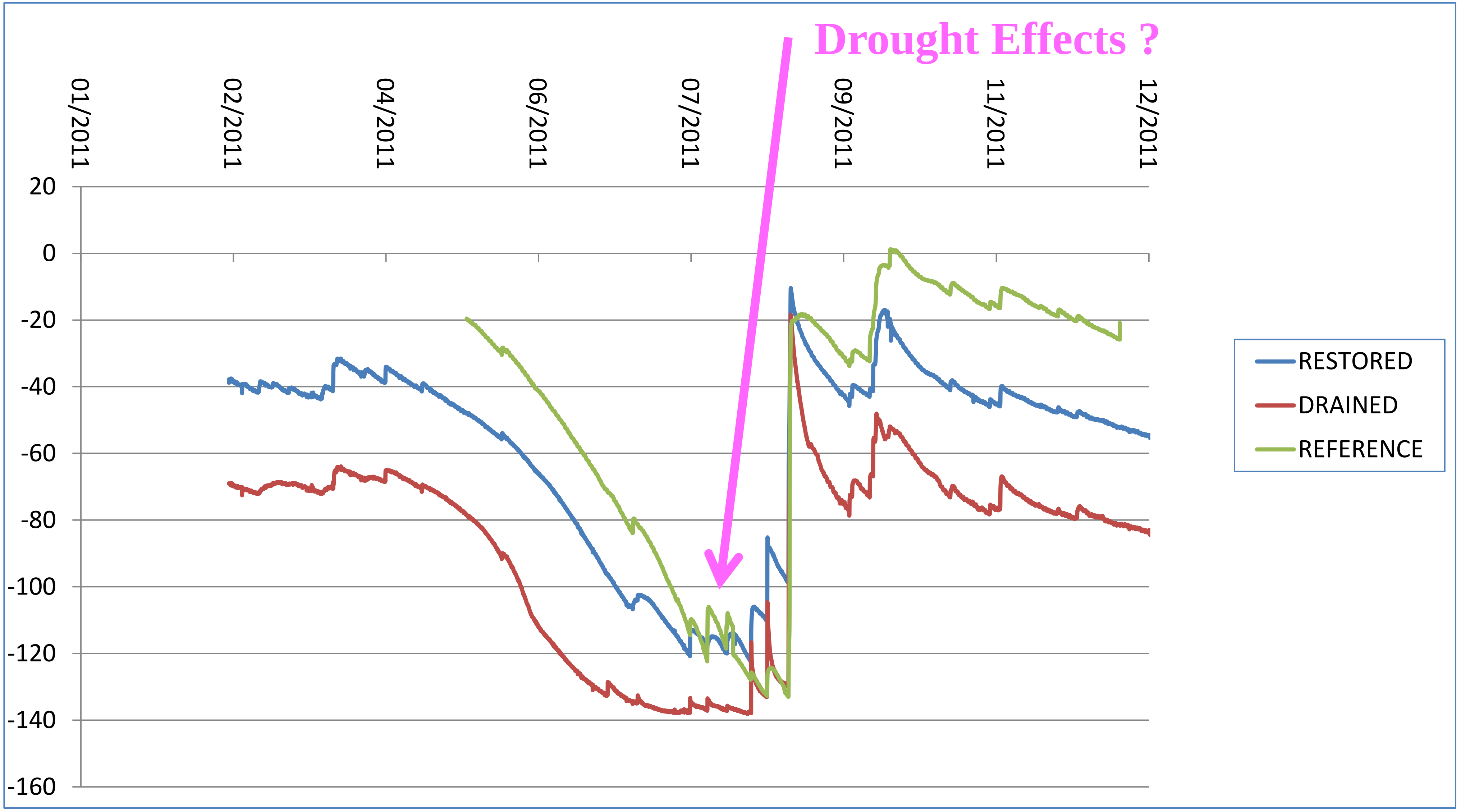


Drained sites
N_2O
CH_4
CO_2
CO_2 equivalents (mg m^{-2} h^{-1})
0
100
200
300
400
500
600
700
800
Sep.2011
Nov. 2011
Jan. 2012
Month
Restored sites
N_2O
CH_4
CO_2
CO_2 equivalents (mg m^{-2} h^{-1})
0
100
200
300
400
500
600
700
Sep.2011
Nov. 2011
Jan. 2012
Month



Wet Dry Comparison of GHG
Dry Aug.
Wet Sep.
Drained sites
Reference sites
Restored sites
y = 3.9591x + 257.77
R^2 = 0.6001
CO_2 (mg m^{-2} h^{-1})
Water level (cm)
0
200
400
600
800
1000
1200
1400
-200
-180
-160
-140
-120
-100
-80
-60
-40
-20
0

Average By Treatment



Questions

- **How does this peat exist under such low summer water tables?**
- **What controls CO_2 production in unsaturated peatlands? Phenolic cpds possible microbial block (Bridgham and Richardson, 2003)**
- **What are the responses of these peatlands to drought and can they resist drought effects? (Wang Ho and Richardson 2012)**

Drought

- Low precipitation, drainage for agriculture and forest
- Aerobic decay
- More CO2

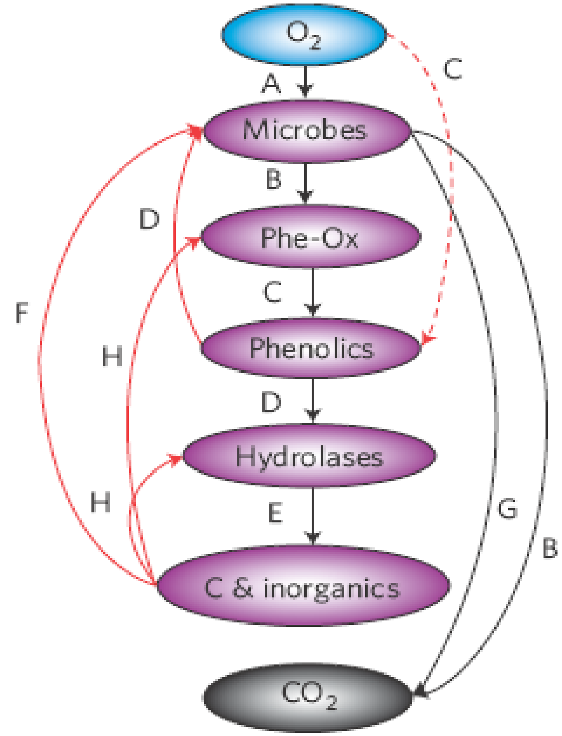


Figure 2 | The biogeochemical 'cascade', whereby constraints on decomposition are removed by severe drought in oligotrophic peatlands. Oxygen stimulates bacterial growth rates (A), modest CO_2 release and *de novo* synthesis of phenol oxidase (B), leading to a decline in inhibitory phenolics (C). Lower inhibitor abundances enable further stimulation of microbial metabolism and edaphic hydrolases (D). Increased cleavage of carbon and nutrients through stimulated hydrolases (E) provides resources and more favourable pH (when waterlogging returns) for enhanced microbial activity and abundance (F), and hence *de novo* production of hydrolases, phenol oxidases and maximum CO_2 emissions (G), but also a direct nutrient-driven stimulation of enzyme activities (H). Positive feedbacks accelerating carbon losses are shown (red) including physicochemical phenolic removal (dotted line).

Fenner and Freeman, 2011

- **Drought unlocks carbon historically restored in boreal peatland**

Generally, such phenomenon occurs in ***saturated peatlands,***

However, unsaturated peatlands?

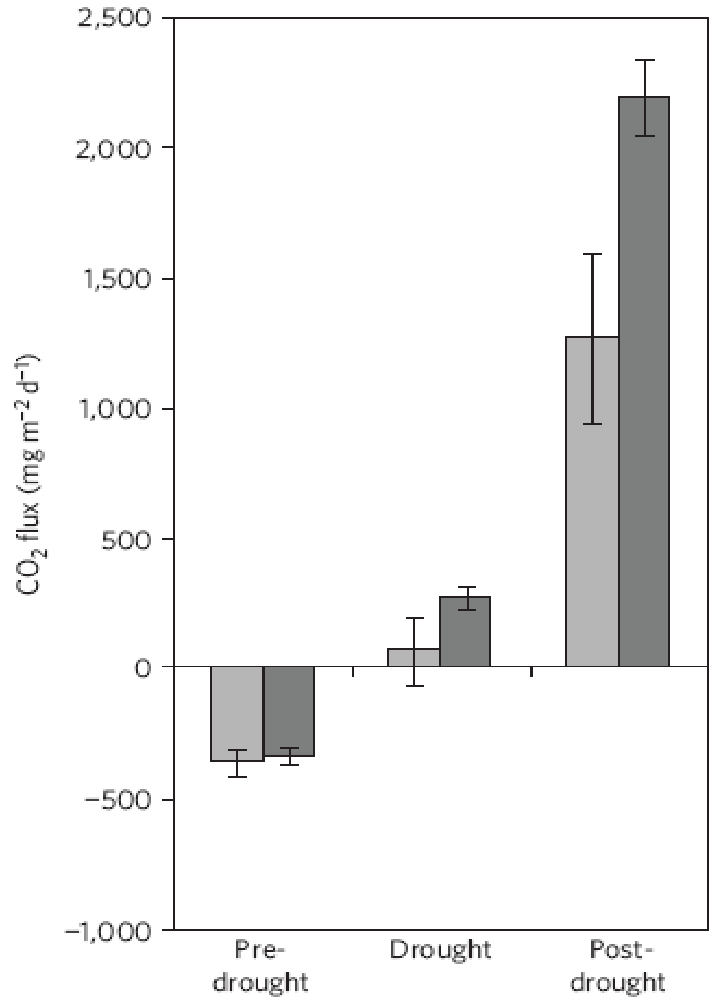


Figure 3 | Effects of the 2006 severe natural drought (water table 30 cm below surface) on oligotrophic peatland net CO_2 flux. CO_2 losses increase during the drought but are further accelerated during the re-wet phase. Light and dark shading denote replicate wetlands A and B respectively. The mean of five sampling stations averaged over distinct four-month periods (before, during and 1 year after the event, at 10 cm depth) is shown. Error bars denote s.e.m.

Fenner and Freeman, 2011

(Wang , Ho and Richardson in Prep, Poster 336)

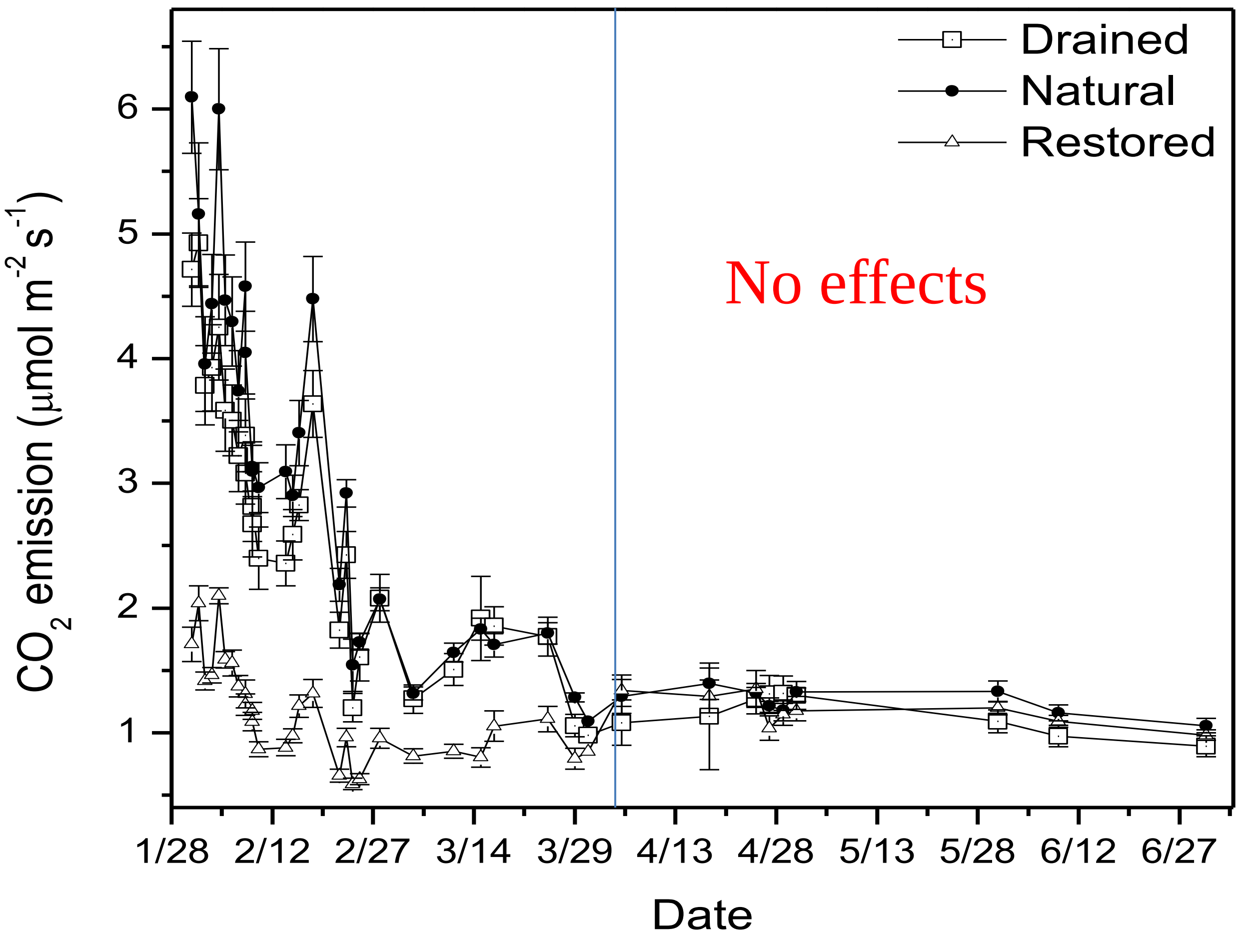


Figure 3. Temporal variation of CO_2 emission during drought incubation of peat monoliths from drained, natural and restored Pocosin peatland sites.

High nitrogen in natural site

Low C quality (C/N low) in drained site

(Wang , Ho and Richardson in Prep, poster 336)

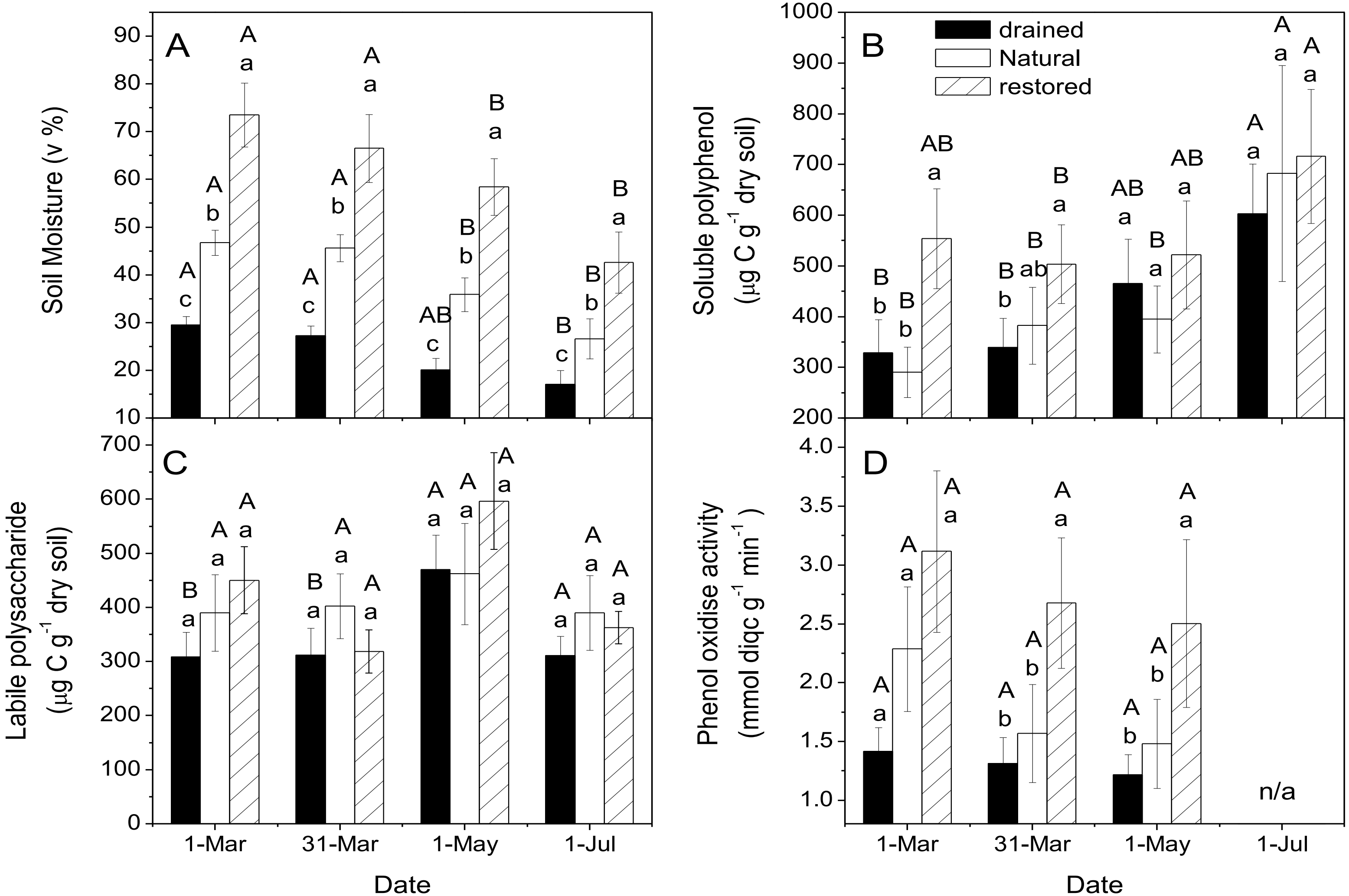


Figure 1. Temporal variations of soil moisture (A), soluble and polyphenol (B), labile polysaccharide (C) and phenol oxidase activity(D) during the drought incubation of peat monolith from natural, drained & restored Pocosin sites.

(Wang , Ho and Richardson in Prep, poster 336)

Phenolics-latch for CO_2 production

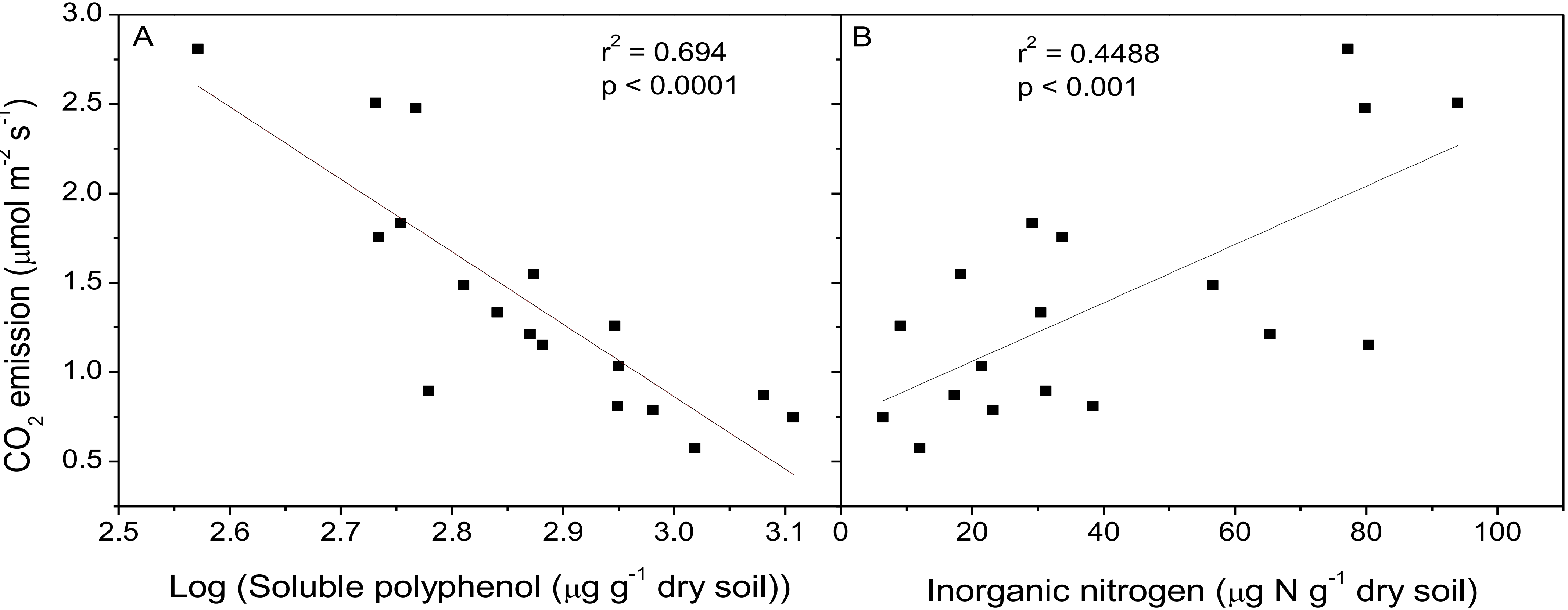


Figure 4. Soluble polyphenol (A) and inorganic nitrogen (B, NH_4^++ NO_x^-) vs. CO_2 emission during the initial 60-day drought incubation of all peat monoliths

Properties of Soil and Plants in the Pocosin Study Sites in Coastal NC

	Natural site	Drained site	Restored site
pH[p]	3.7±0.0[b]	4.3±0.1[a]	3.9±.01[b]
LOI (%)[s]	95.7±0.6[a]	**92.0±1.2[b]**	96.3±0.7[a]
Total N (%)[s]	1.5±0.1[a]	1.2±0.1[b]	1.3±0.1[ab]
Total C (%)[s]	53.4±1.0[a]	53.1±0.8[a]	56.0±1.1[a]
Total P (μg g^{-1})[s]	327.2±25.3[a]	378.1±45.2[a]	395.6±54.9[a]
NOx^{-}-N (μg g^{-1})[k,s]	7.6±1.0[b]	16.3±3.1[a]	13.0±0.9[ab]
NH_4^{+}-N (μg g^{-1})[k,s]	87.1±21.5[a]	45.8±8.1[ab]	4.1±1.7[b]
C/N in leaves	48.7±4.2[a]	**29.3±3.2[b]**	51.1±3.3[a]
C/N in stems	135.6±10.7[a]	**75.9±14.4[b]**	144.4±10.4[a]
Phenolics (mg C g^{-1})[l]	56.1±6.1[a]	**14.9±1.0[b]**	63.3±6.1[a]

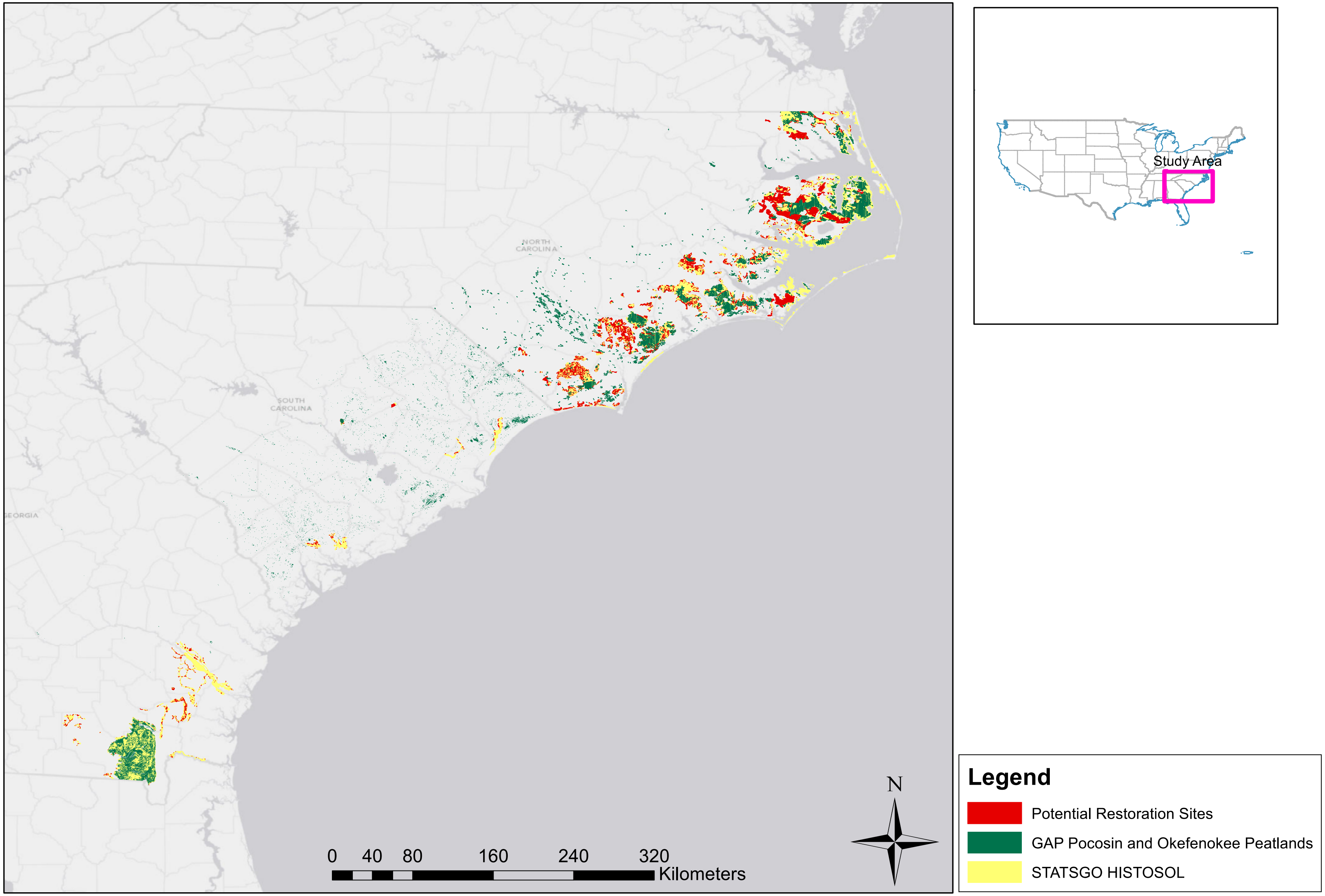
(Wang , Ho and Richardson in Prep, Poster 336)

Conclusion and application

- Build-up polyphenol inhibit CO_2 production under drought (weakens drought effects)
- Moderate drought might increase C accumulation (similar with restored site results)
- Altered species composition caused by drainage or by severe drought results in decreased polyphenol in soil & increased CO_2 flux
- Nitrogen deposition stimulates CO_2 flux

Major Peatlands in the SE Coastal Plain of the U.S.

Potential Peatland Restoration sites




Any Questions?