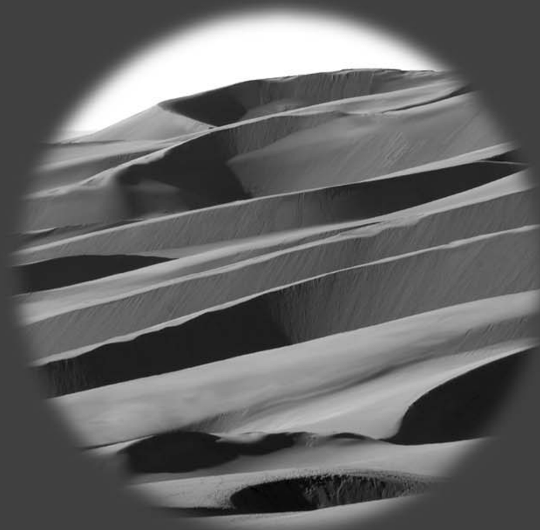
Fire, Earth, and Water: Soil Moisture Dynamics across a Wildfire Burn Boundary Resulting from the 2011 Labor Day Bastrop County Complex Fire



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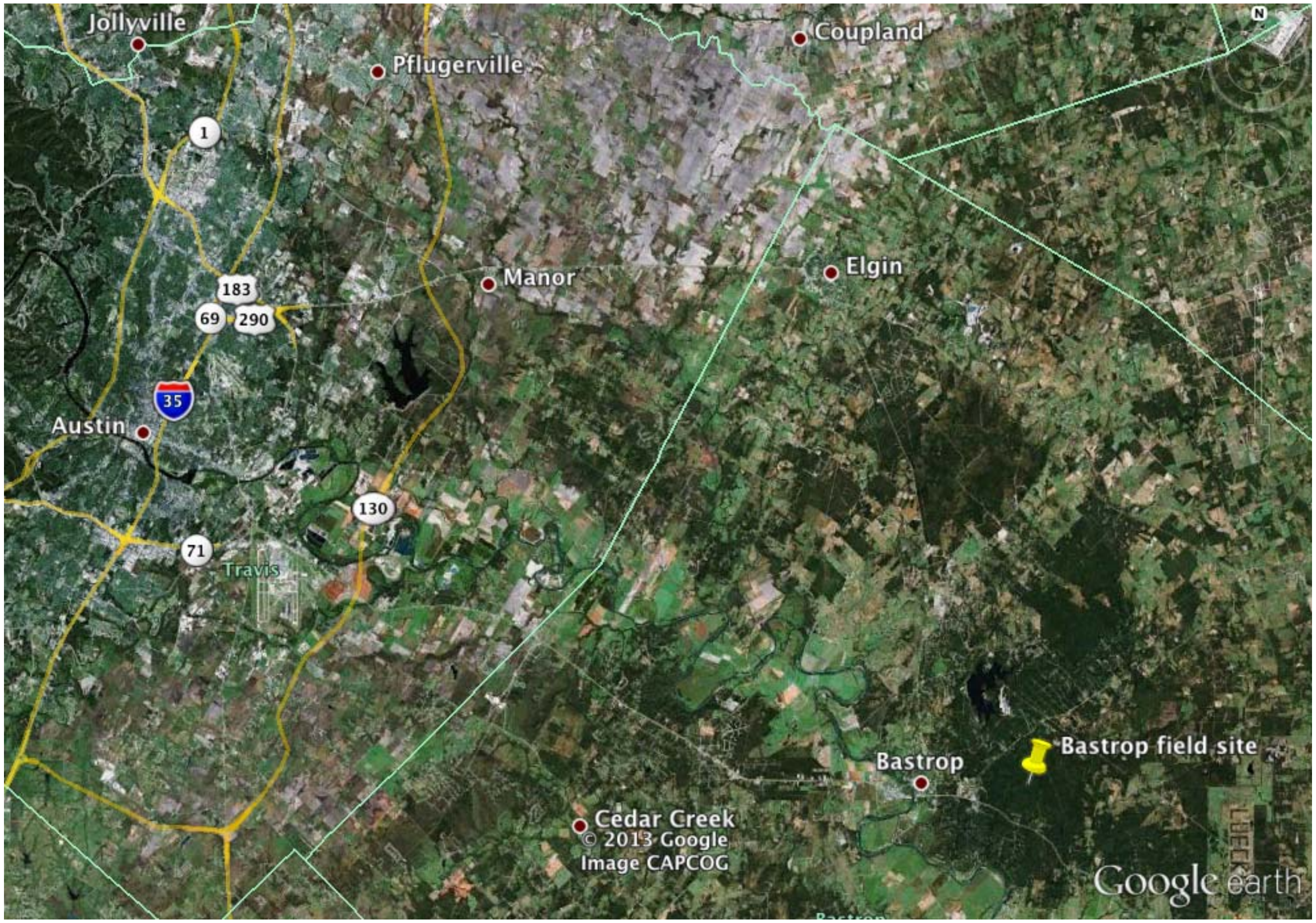
Research questions

- How does wildfire affect soil moisture dynamics?
- What effect do the subsequent changes in vegetative cover have on soil moisture?
- How effective and consistent are various techniques for monitoring any soil moisture differences across the burn boundary?

Bastrop State Park

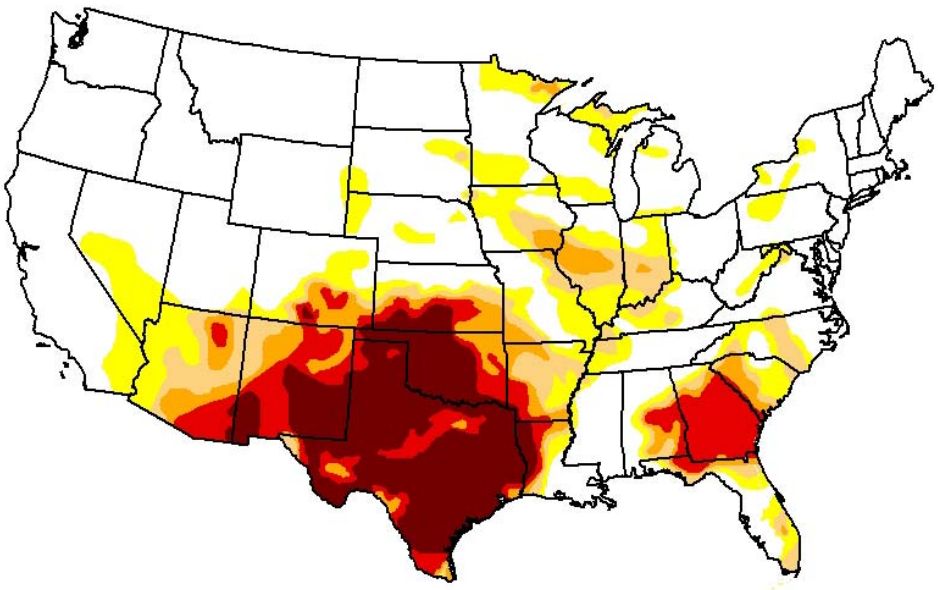


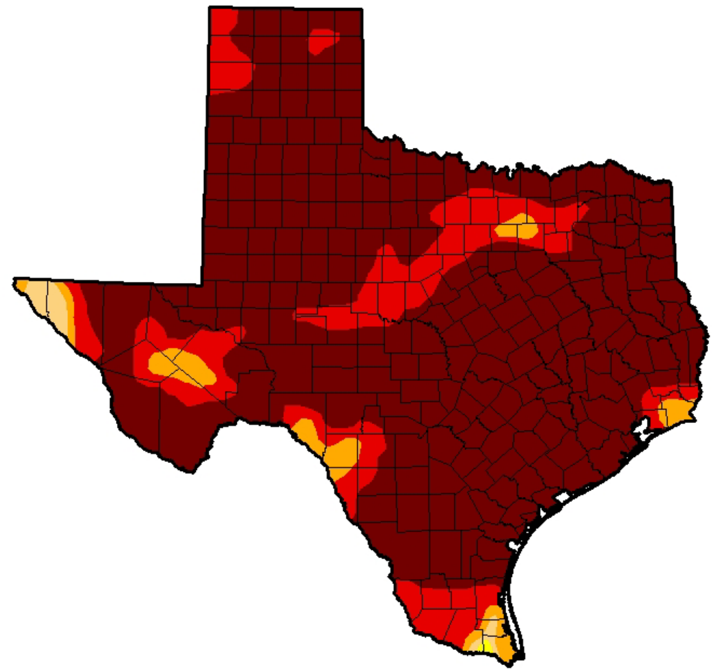
- ~50 km SE of Austin
- 6,500-acre park
- Home to “Lost Pines”
- Loblolly pine dominates

Sept. 4 2011 wildfire

- More than 33,000 acres were burned
- Burned 96% of Bastrop State Park

September 2011 drought conditions

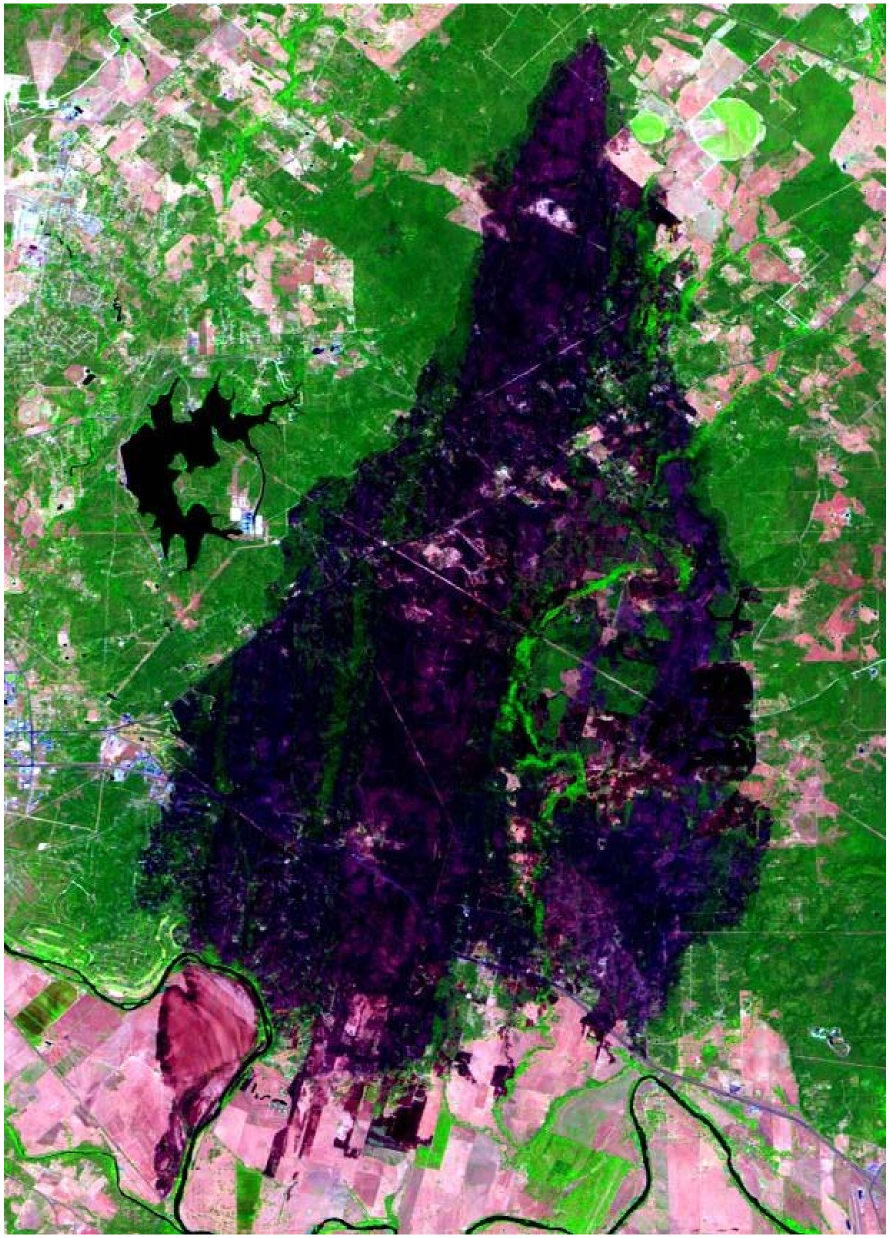


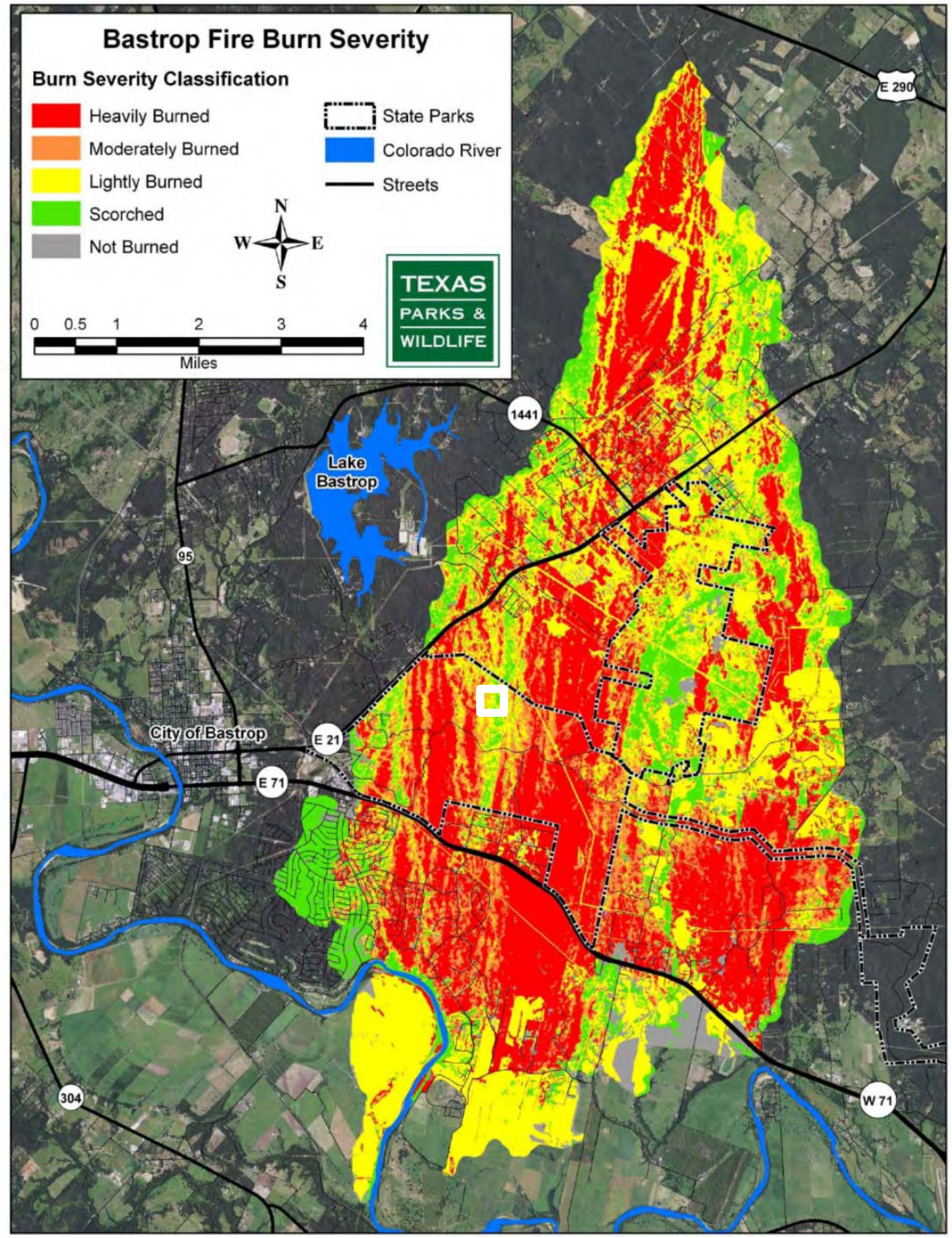


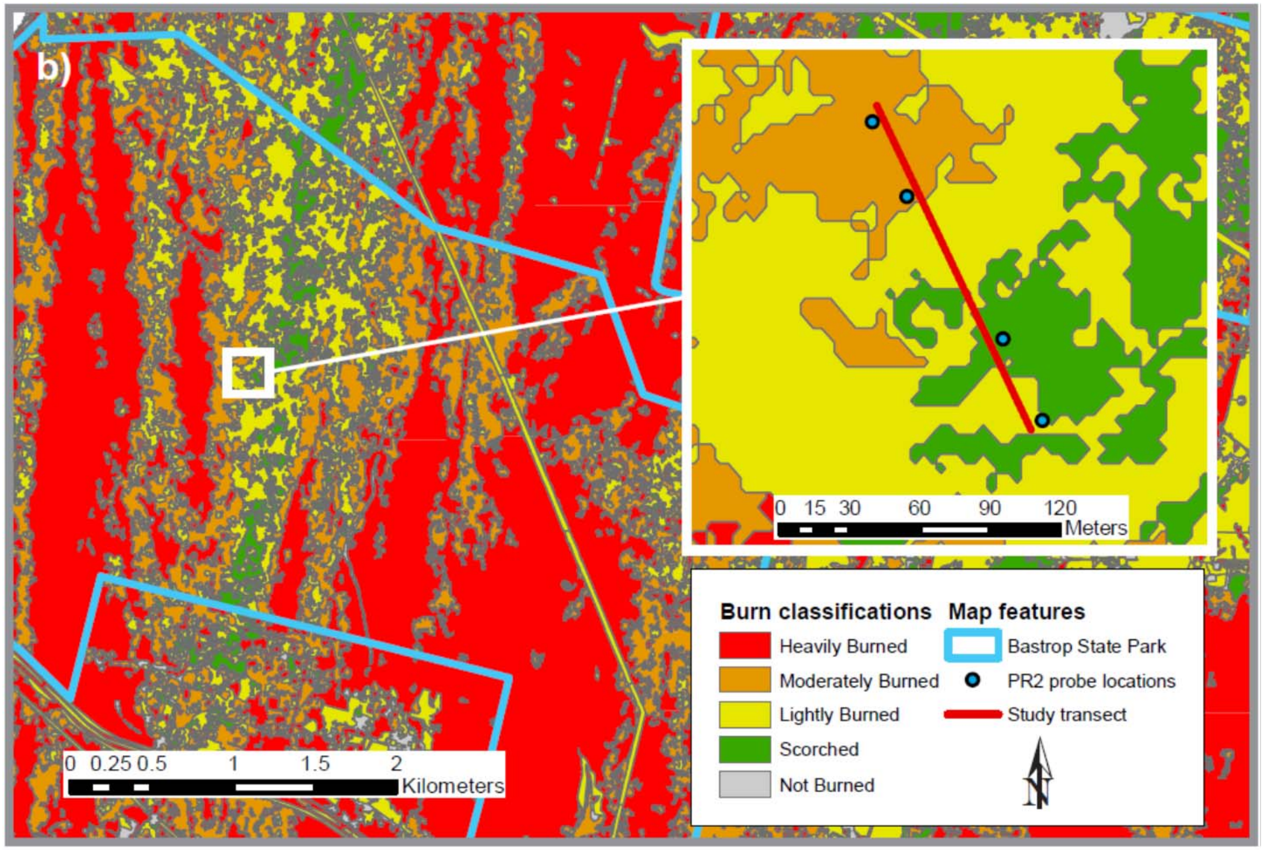
Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

http://droughtmonitor.unl.edu/




Bastrop Fire Burn Severity
Burn Severity Classification
Heavily Burned
Moderately Burned
Lightly Burned
Scorched
Not Burned
State Parks
Colorado River
Streets
N
W
E
S
0 0.5 1 2 3 4
Miles
TEXAS PARKS & WILDLIFE
Lake Bastrop
City of Bastrop
E 290
1441
95
E 21
E 71
304
W 71



Facing North

Facing South

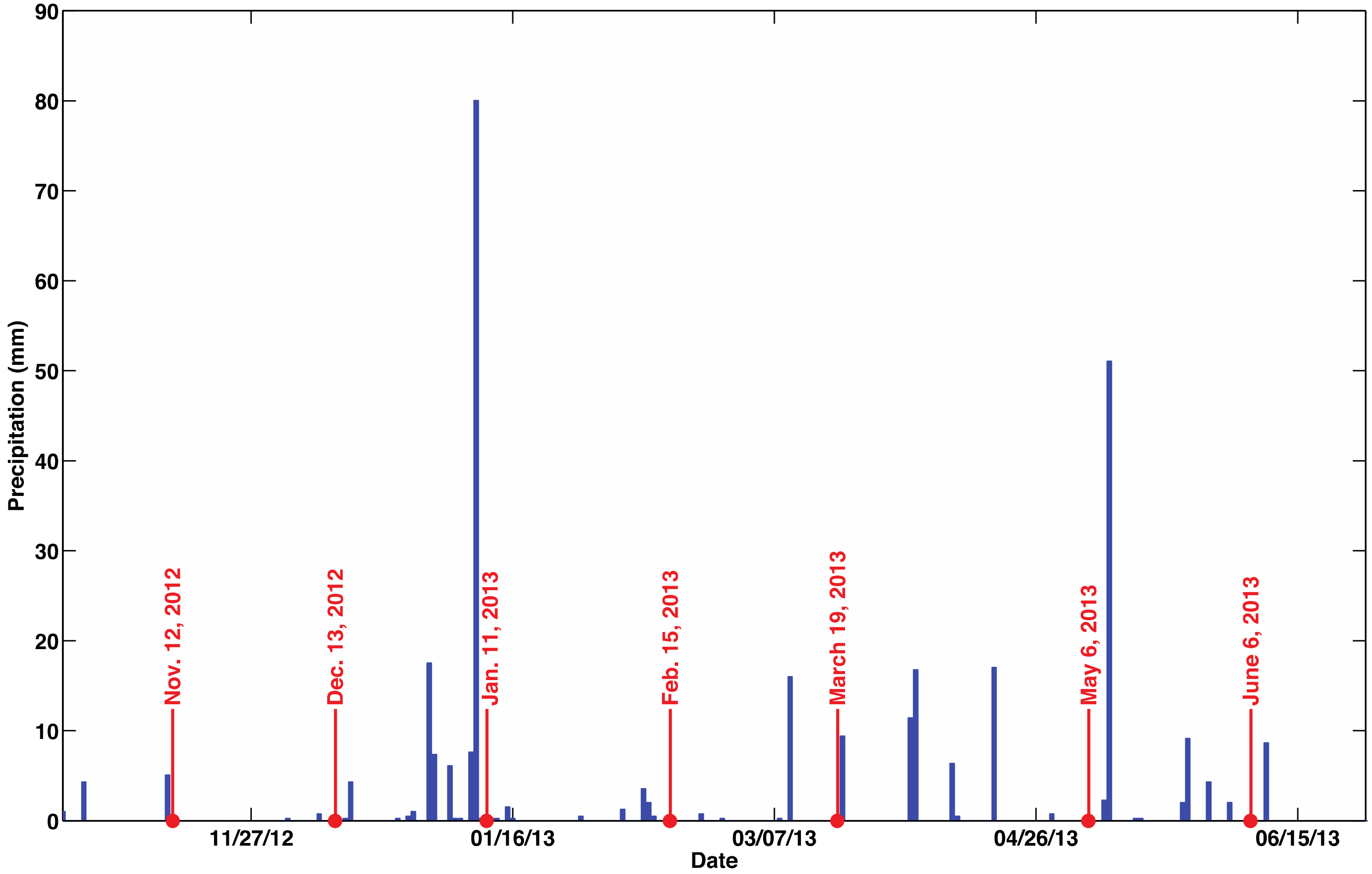
Field site

- On border of moderately burned and scorched areas
- Study transect runs north-south
- Work has become increasingly hazardous as trees fall

Methods

- Electrical resistivity imaging
- Surface water content (θ) measurements using electrical permittivity (dielectric constant) measurements
- Vertical θ profiles using electrical permittivity measurements
- In-situ infiltration measurements
- Soil texture analysis

Precipitation data and trip dates



Electrical resistivity (ER)

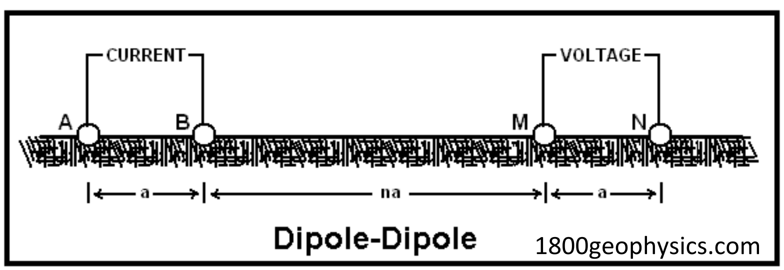
- Resistivity can be affected by soil moisture, geology, salinity
- Based on Ohm's law: R = V / I

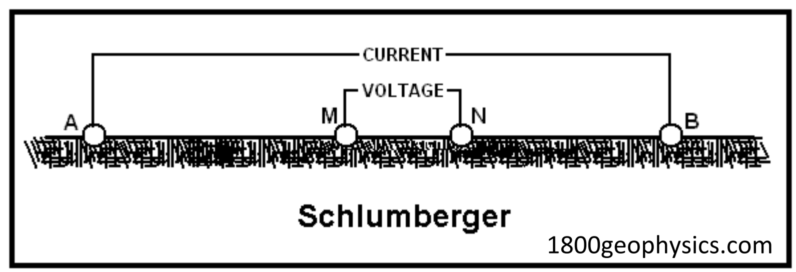
    R = calculated resistance

    V = potential difference measured

    I = injected current

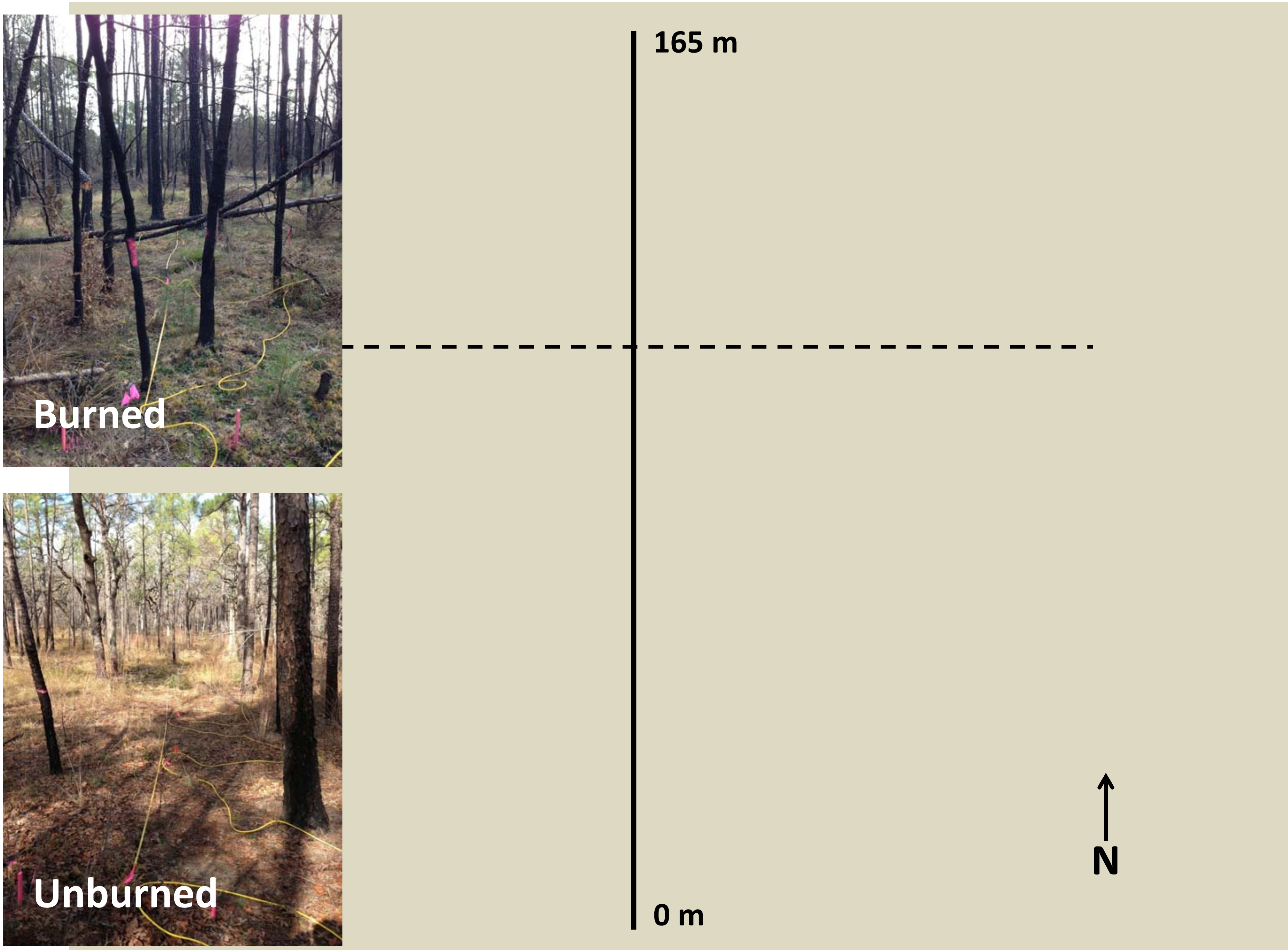
- Surveys conducted monthly using a 56 electrode array spaced 3 m (Advanced Geoscience Inc.) with dipole-dipole and schlumberger array configurations



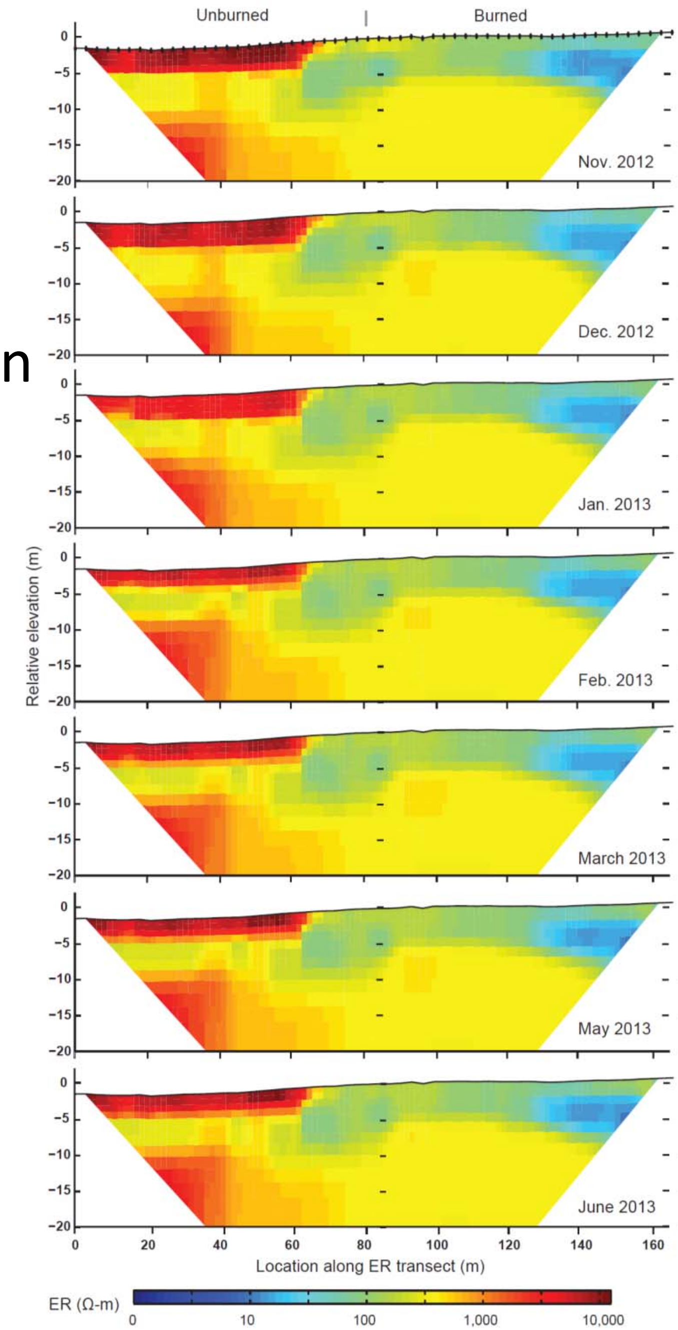


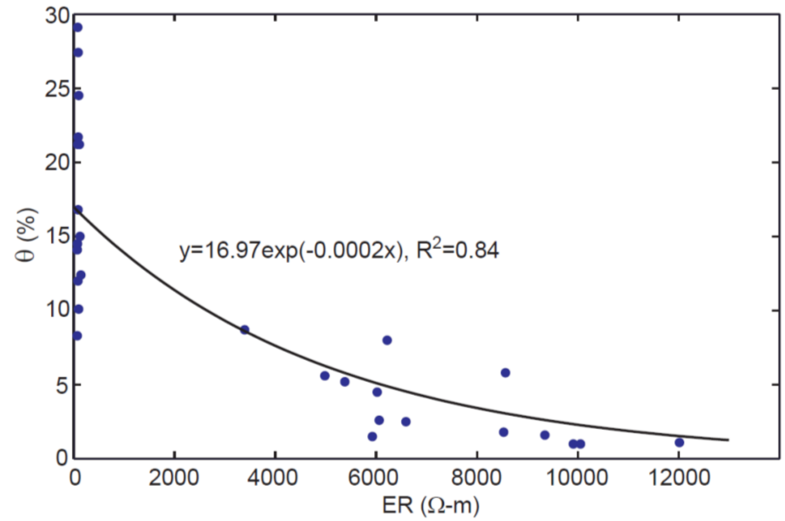
Unburned end, looking north

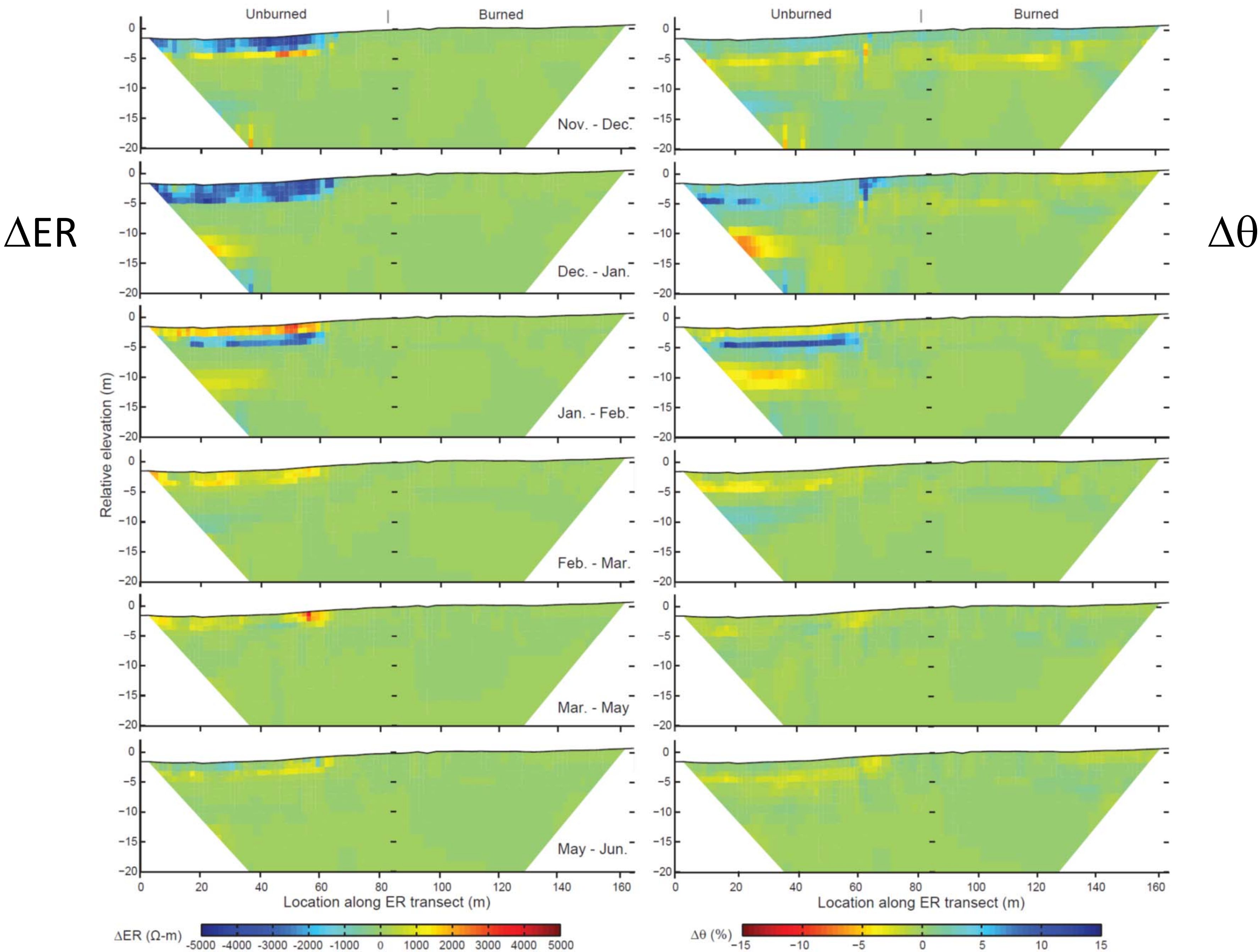
Burned end, looking south


Burned
Unburned
165 m
0 m
N

ER distribution



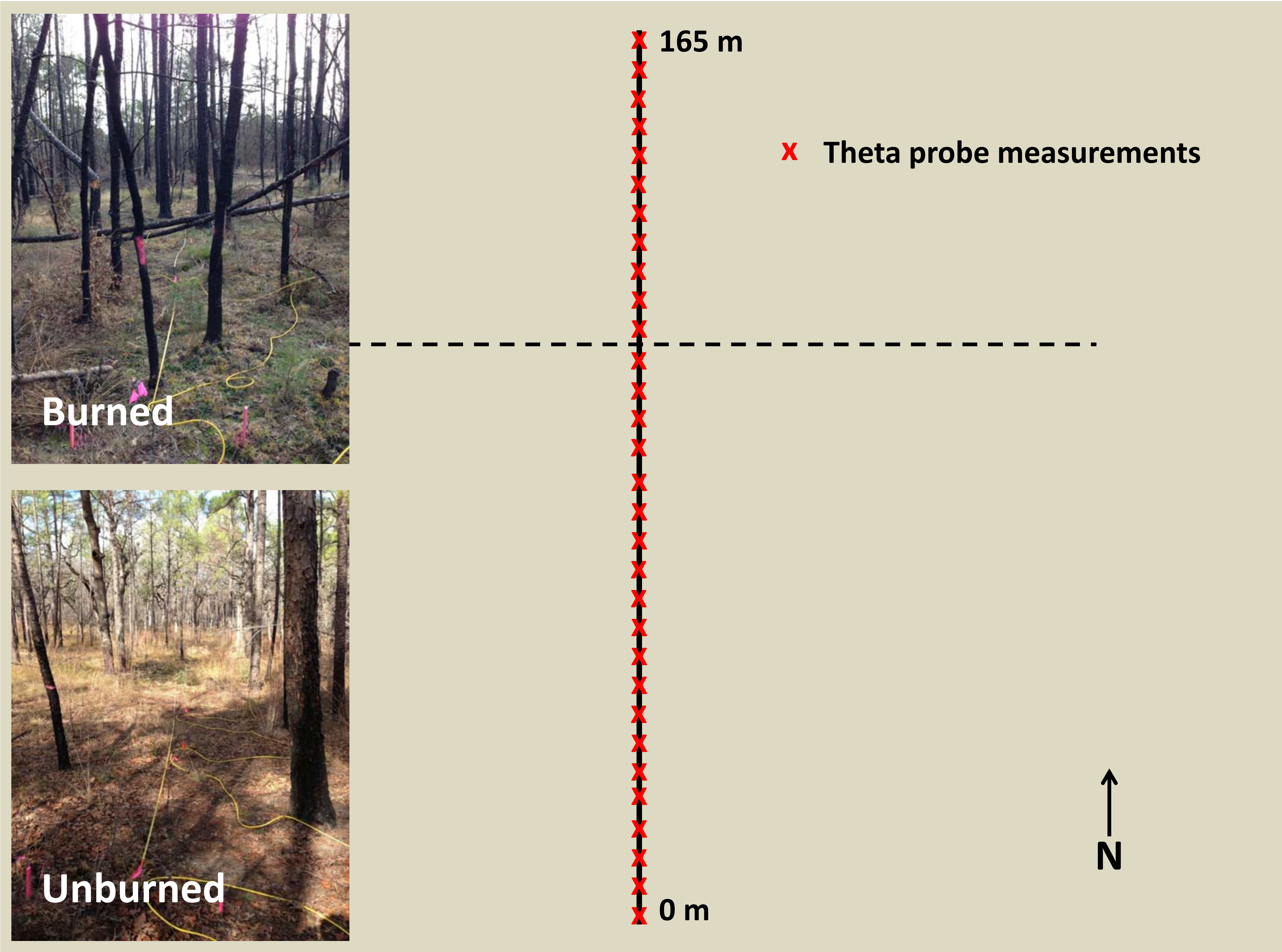




ΔER
Δθ
Unburned
Burned
Nov. - Dec.
Dec. - Jan.
Jan. - Feb.
Feb. - Mar.
Mar. - May
May - Jun.
Relative elevation (m)
Location along ER transect (m)
ΔER (Ω-m)
-5000 -4000 -3000 -2000 -1000 0 1000 2000 3000 4000 5000
Δθ (%)
−15 −10 −5 0 5 10 15

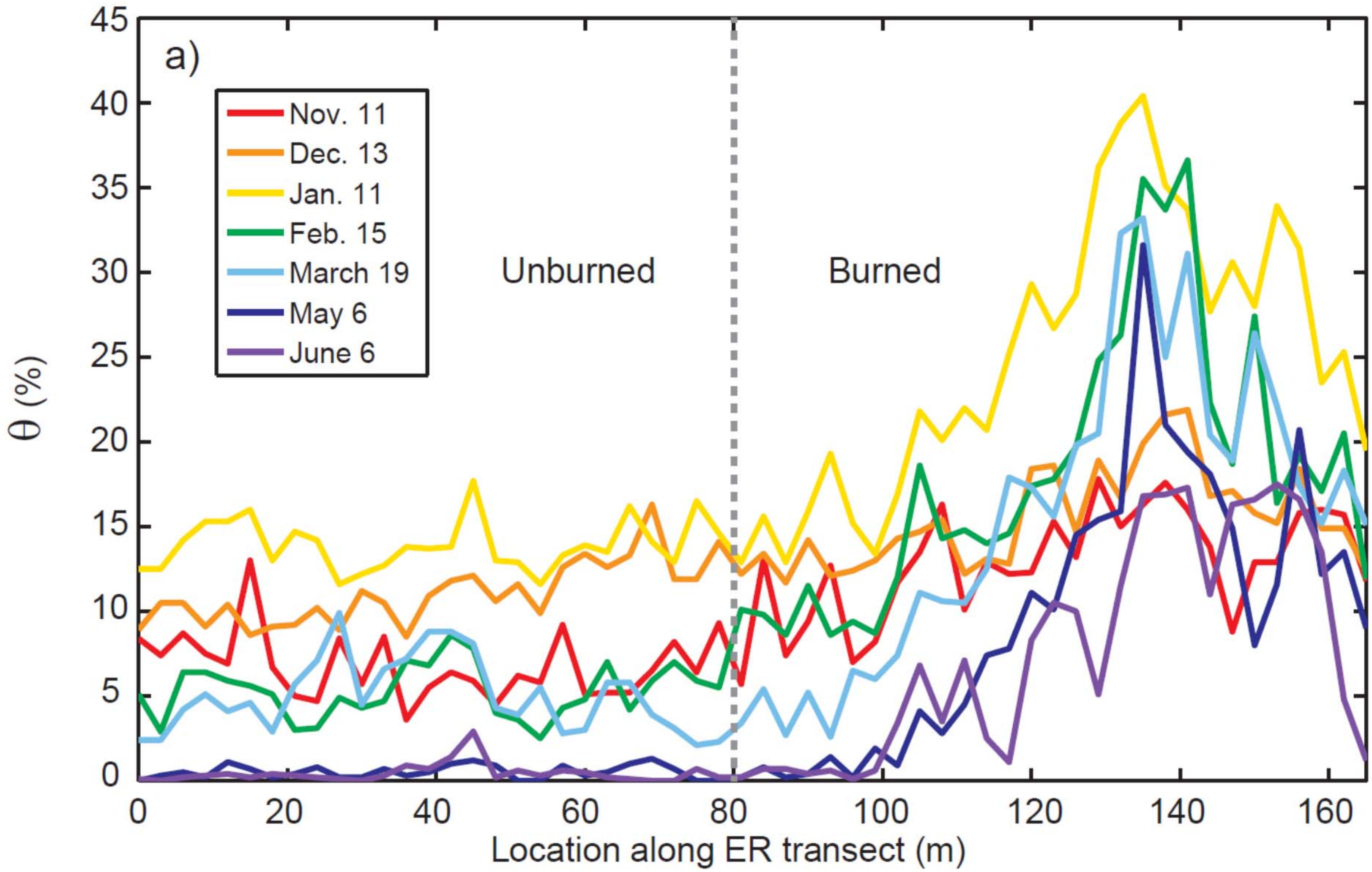
Delta-T Devices Theta probe ML2x

- Measurements taken at each electrode along the transect
- Senses dielectric constant of the soil, which is converted to soil moisture
- Essentially point measurements of soil moisture at the surface



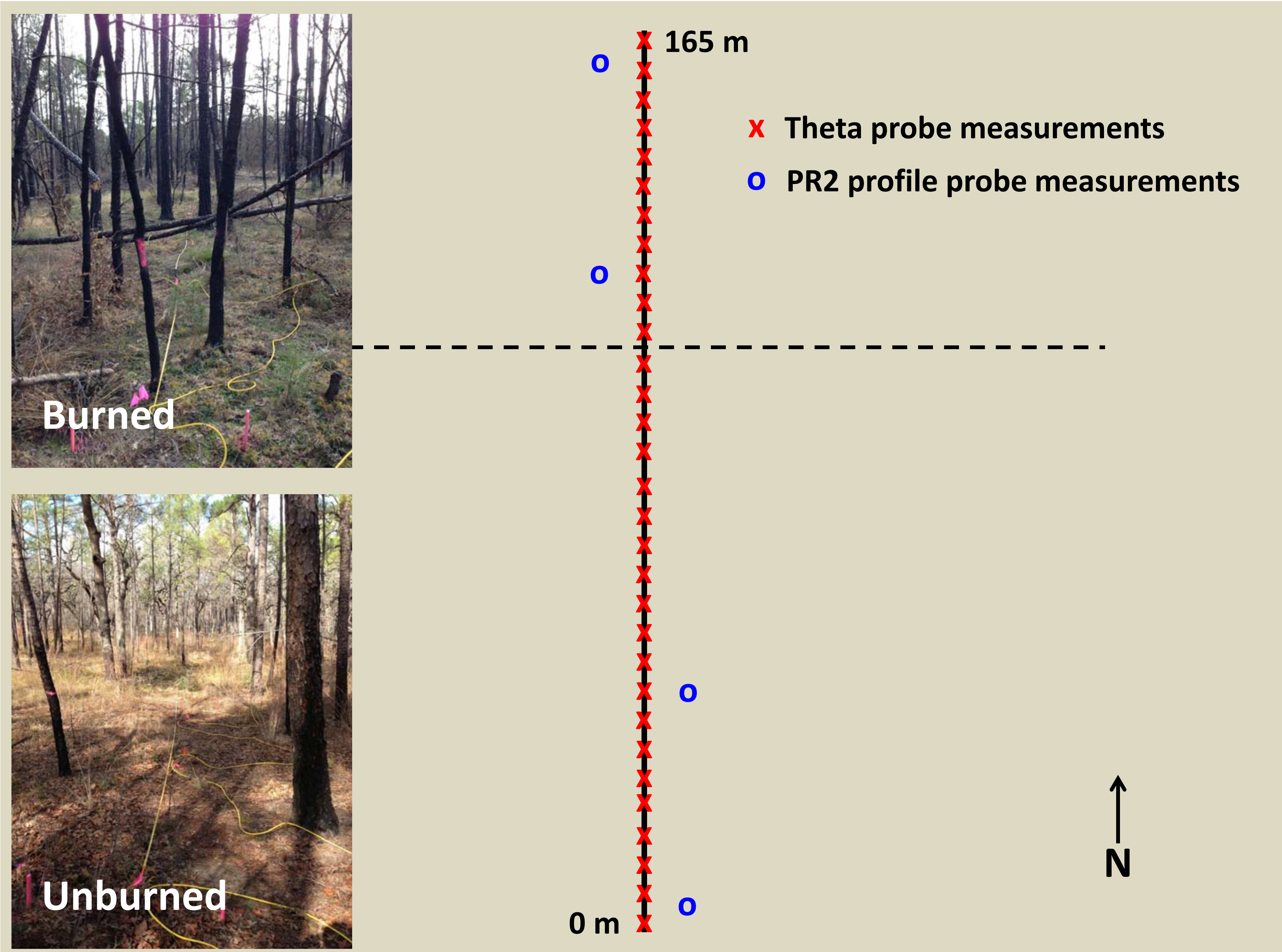
Burned
Unburned
165 m
0 m
x Theta probe measurements
N

Surface soil moisture distribution

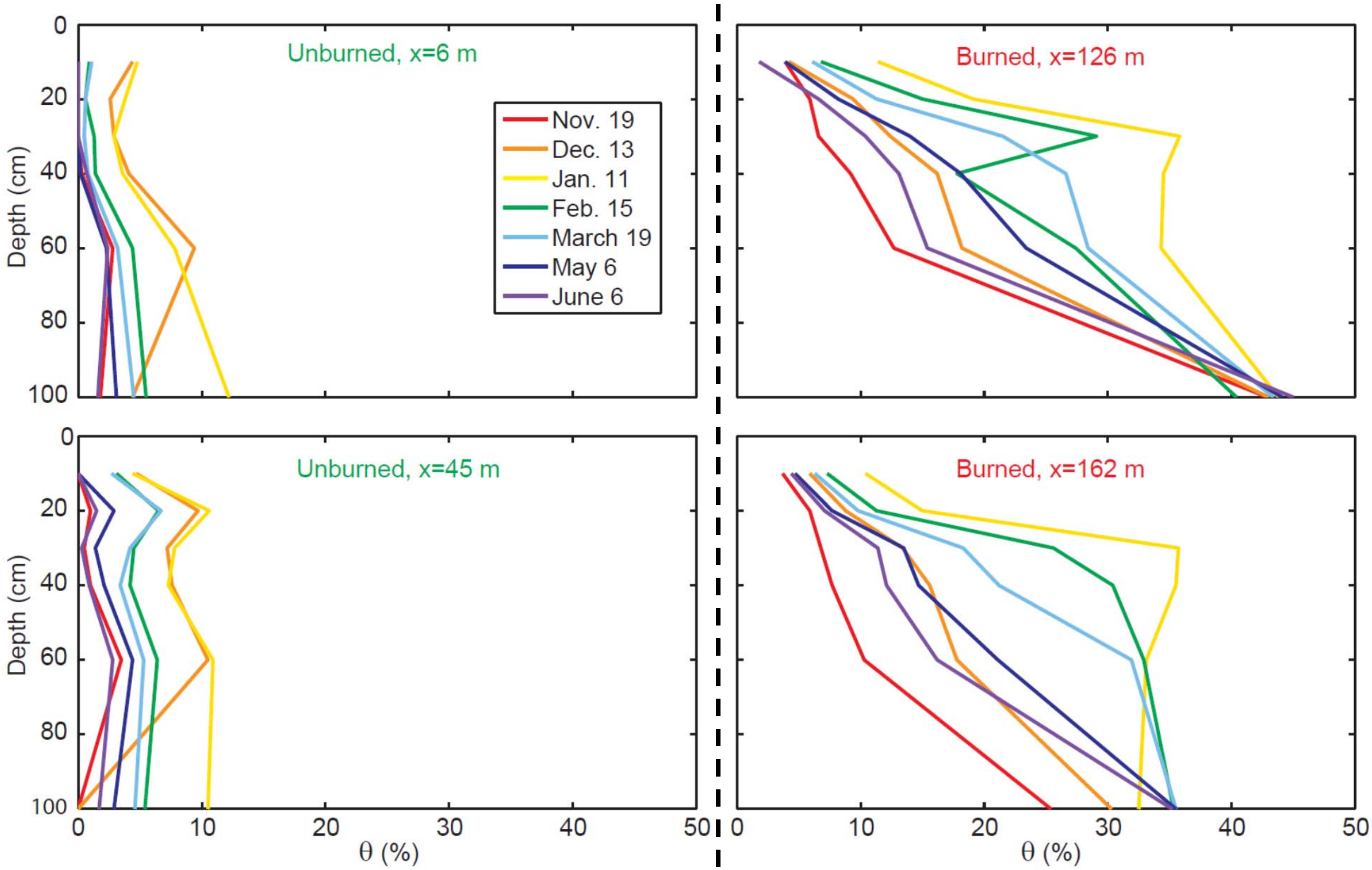


Delta-T Devices PR2 profile probe

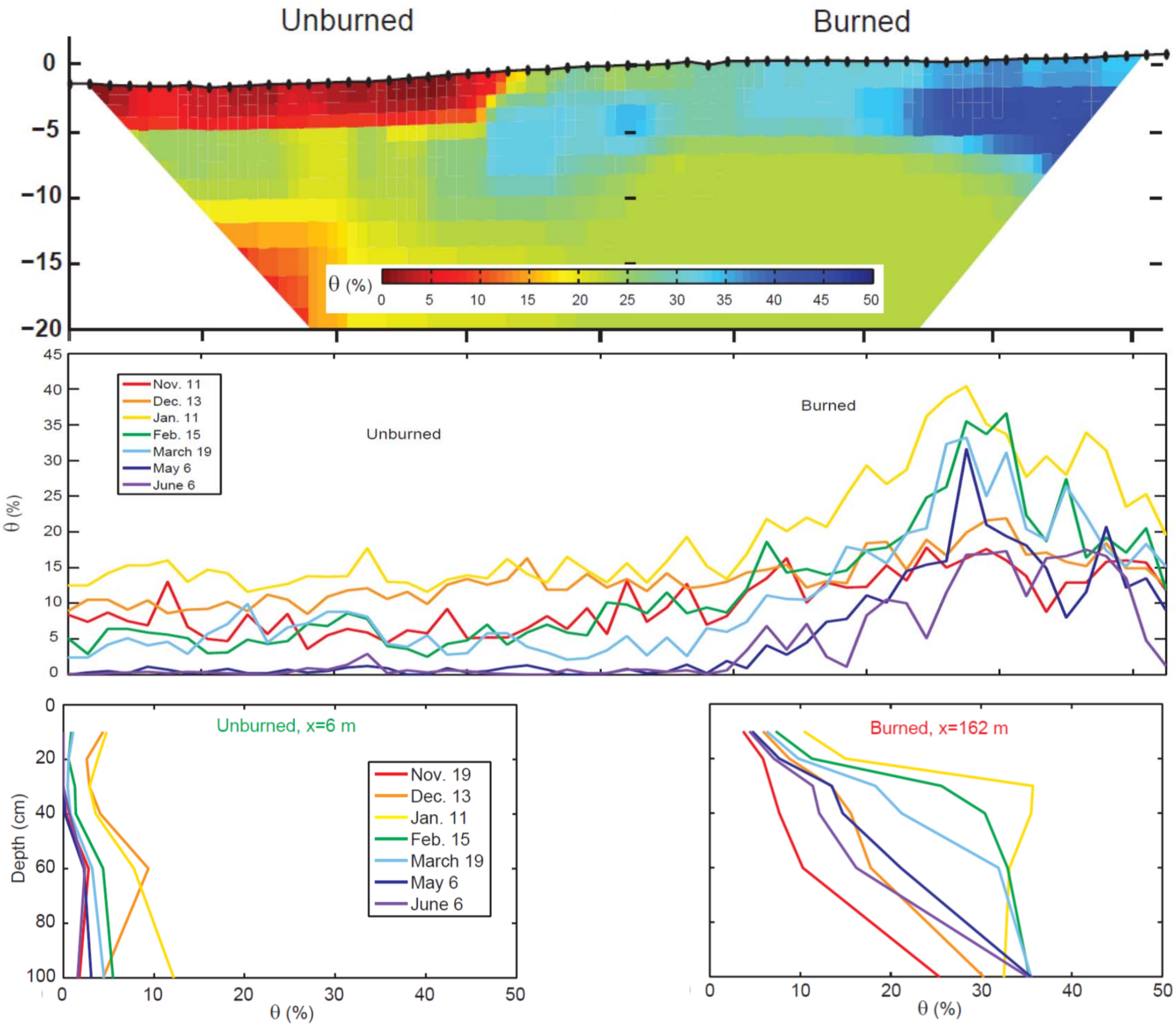
- Monthly measurements taken at 4 points along study transect
- Measures a vertical moisture profile at 6 depths, up to 1 m
- Uses EM fields to measure permittivity, which is converted to soil moisture


Burned
Unburned
165 m
0 m
x Theta probe measurements
o PR2 profile probe measurements
N

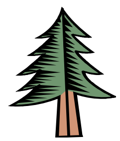
Vertical soil moisture profiles



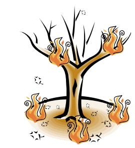
Bringing everything together



Key observations

Unburned end 

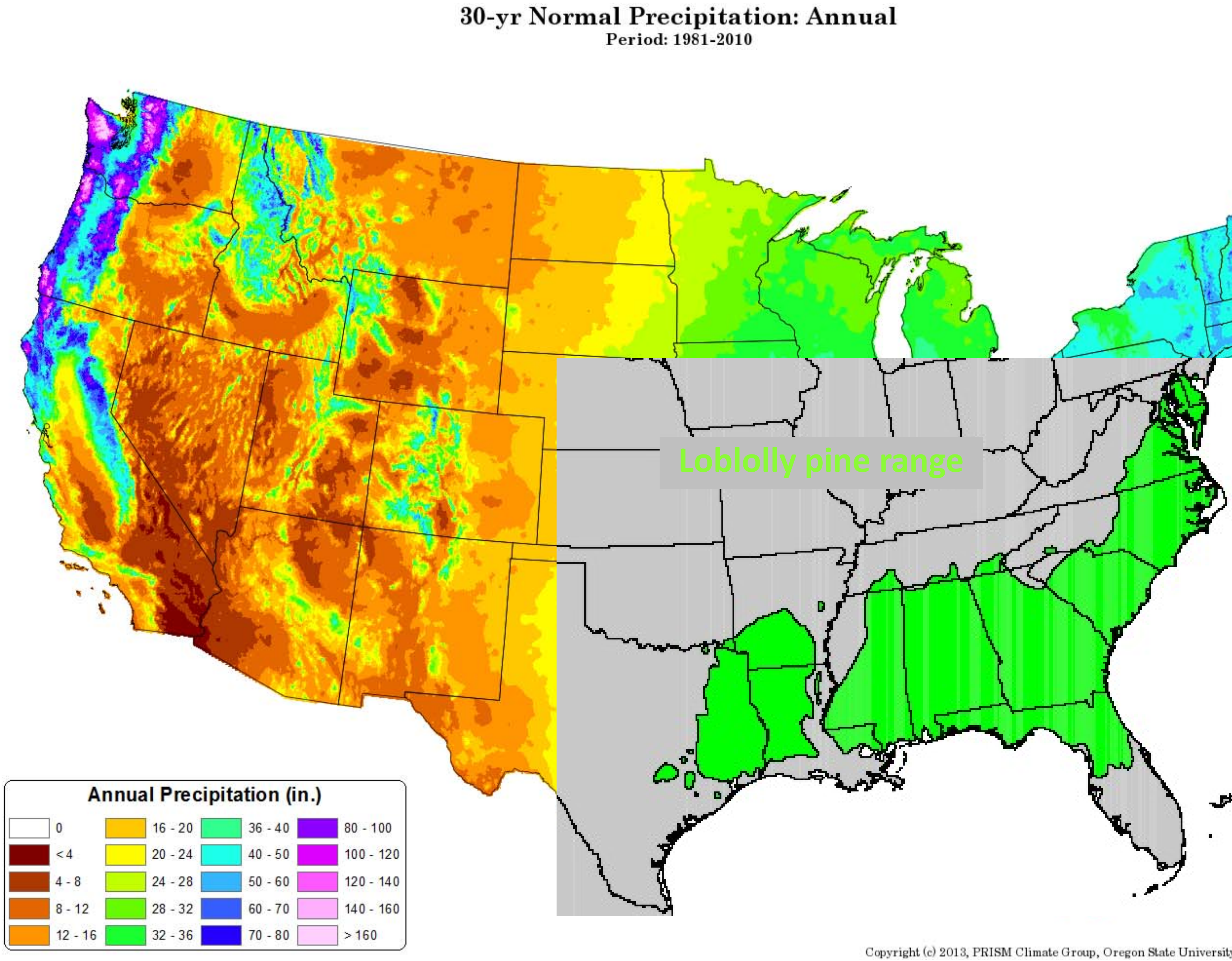
- Drier soil
- Less wetting response due to infiltration from rainfall
- Vertically uniform moisture profile, with minimum ~20-40 cm, even during wetting

Burned end 

- Wetter soil
- More wetting response due to infiltration from rainfall
- Generally drier at the top, wettest at the bottom, including during wetting

Loblolly pine (*Pinus taeda*)

- Favor extensive shallow lateral root systems (lateral roots typically shallower than 50 cm)
- Roots typically spread farther than tree crowns
- Rooting depth varies, but usually found no deeper than ~50 cm in mature trees; tap root usually less than 1 m
- Gets water from the upper 40 cm when it is available


30-yr Normal Precipitation: Annual
Period: 1981-2010
Loblolly pine range
Annual Precipitation (in.)
0
< 4
4 - 8
8 - 12
12 - 16
16 - 20
20 - 24
24 - 28
28 - 32
32 - 36
36 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 100
100 - 120
120 - 140
140 - 160
> 160
Copyright (c) 2013, PRISM Climate Group, Oregon State University

Some climate indices for the site

Mean annual precipitation = 96 cm/yr
Actual evapotranspiration = 70-80 cm/yr (Selnick and Sanford [2013])
Potential evapotranspiration = 146 cm/yr (texaset.tamu.edu)

The trees and vegetation are thirsty because the atmosphere is thirsty!

Throughfall and canopy interception

From Soto and Diaz-Fierros [1997]

Unburned area: 88% throughfall   Burned area: 58% throughfall

From Stogsdill et al. [1989, 1992]

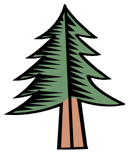
Decreasing loblolly pine stand density increases throughfall

Macropores

From Beven and Germann [2013]

Dead roots are one of the most common macropores

Key observations

Unburned end 

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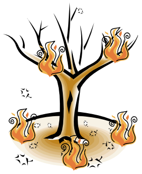
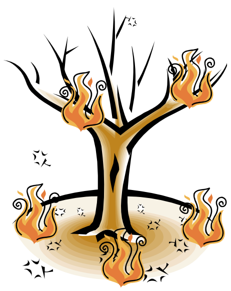
Burned end 

- Wetter soil
- More wetting response due to infiltration from rainfall
- Generally drier at the top, wettest at the bottom, including during wetting

Likely causes

- Tree transpiration
- Canopy interception of rainfall
- Root water uptake

- No transpiration, just evaporation
- Mostly throughfall of rain
- Dead roots serve as macropores



Implications

- Burned areas will store and transmit more water, at least in the near term
- The increased soil moisture in the burned areas are ideal for vegetation recovery
- Groundwater recharge might be enhanced
- Leaching or displacement of ‘zone of illuviation’, aka B horizon

Acknowledgments

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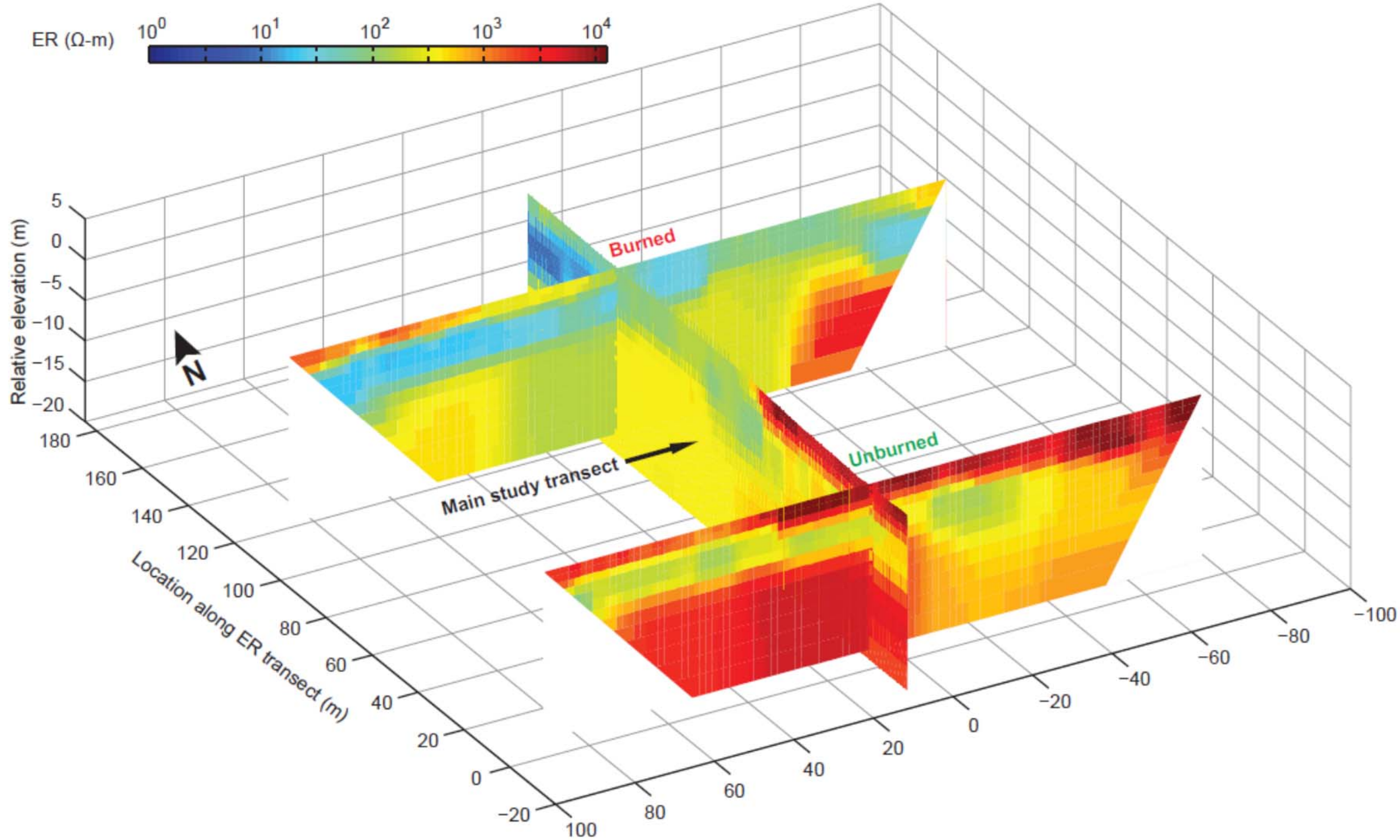
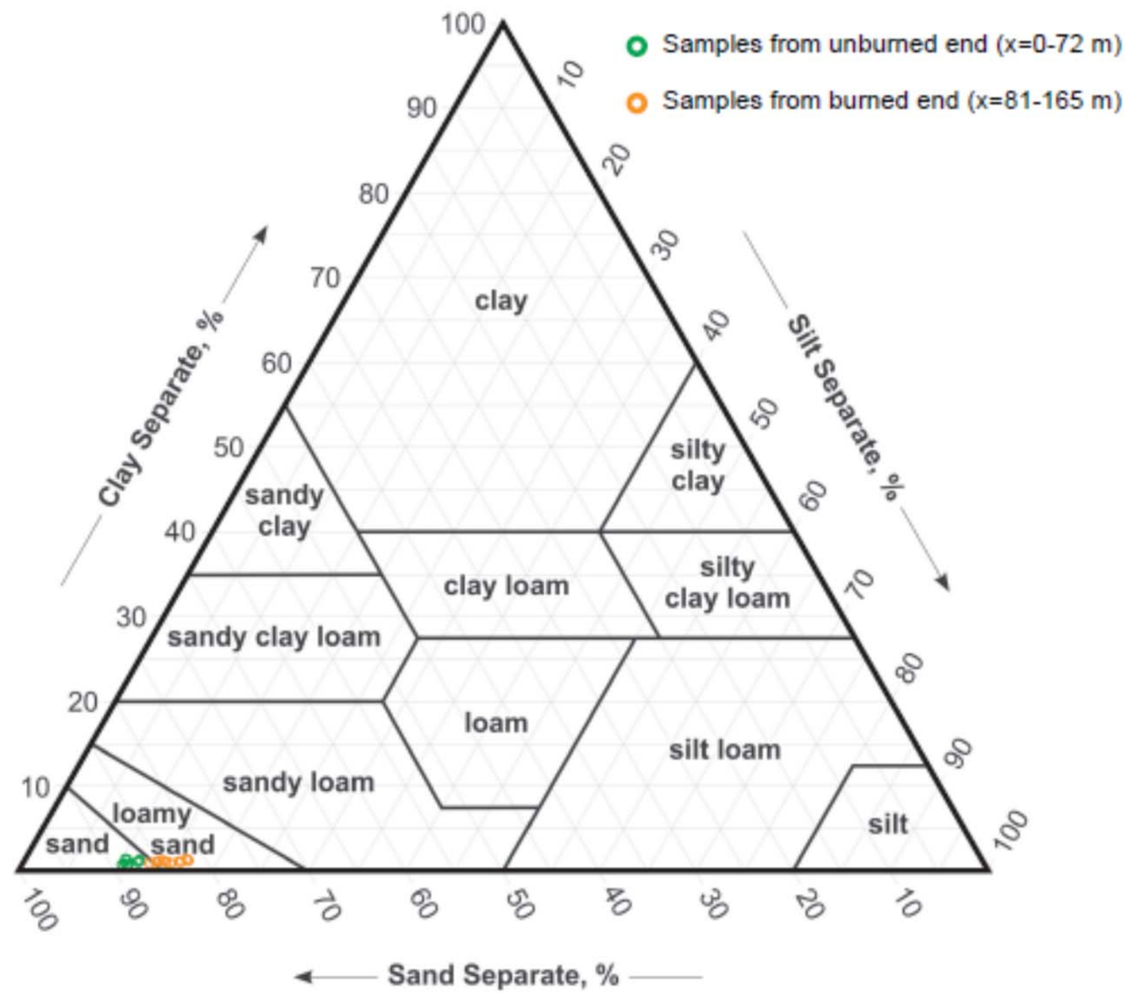
Ram Sanchez, <u>Greg Creacy</u>

Any burning questions?



ER (Ω-m)
10^0
10^1
10^2
10^3
10^4
Relative elevation (m)
5
0
−5
−10
−15
−20
Burned
Unburned
N
Main study transect
Location along ER transect (m)
180
160
140
120
100
80
60
40
20
0
−20
100
80
60
40
20
0
−20
−40
−60
−80
−100



Samples from unburned end (x=0-72 m)
Samples from burned end (x=81-165 m)
Clay Separate, %
Silt Separate, %
Sand Separate, %
clay
sandy clay
silty clay
clay loam
silty clay loam
sandy clay loam
loam
sandy loam
silt loam
loamy sand
sand
silt
100
90
80
70
60
50
40
30
20
10