Mapping pyrophilic percentage across the northeastern United States using witness trees

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Objective

- Convert witness-tree data into maps that reflect the importance of fire in presettlement landscapes.

Why?

- Establish where fire was a major ecological driver (and where it wasn’t) for ecosystem restoration, disturbance-based forestry, and land management planning.

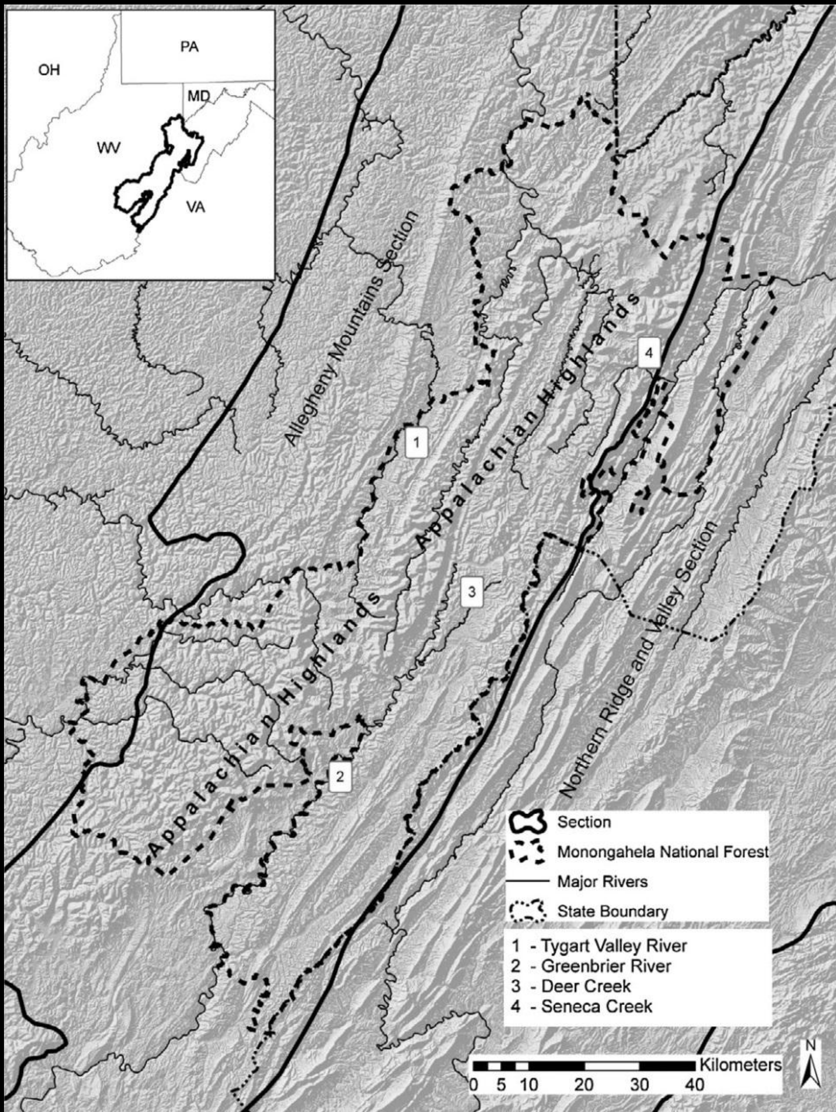
Study Area

- Northeastern United States, with focus on 5 national forests

Methods

- Spatially compile witness-tree data (metes-and bounds)
- Categorize witness trees by pyrogenicity (fire relations)
- Apply kriging to point data to create pyrophilic percentage maps

Technique was developed on the Monongahela National Forest, West Virginia, USA.



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Full length article

The use of witness trees as pyro-indicators for mapping past fire conditions

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ABSTRACT

Understanding and mapping presettlement fire regimes is vitally important for ecosystem restoration, helping ensure the proper placement of fire back into ecosystems that formerly burned. Witness trees can support this endeavor by serving as pyro-indicators of the past. We mapped fire-adapted traits across a landscape by categorizing trees into two classes, pyrophiles and pyrophobes, and applying this classification to a geospatial layer of witness-tree points centered on the Monongahela National Forest, West Virginia. A pyrophilic percentage was calculated for each point and spatially extrapolated via ordinary kriging to form a continuous geospatial cover. Regression analyses showed pyrophilic percentage was significantly related to a number of key environmental factors and changed along an elevation gradient from low, dry valleys (high pyrophilic percentage) to high, wet mountaintops (low pyrophilic percentage). This approach represents a significant advancement through the direct use of witness trees to depict past fire regimes applicable to both Public Land Survey and metes-and-bounds records.

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1. Introduction

Ecosystem restoration is predicated on documenting past compositions, structures, and spatial patterns within and across landscapes (SER, 2004). Even though vegetation characteristics are crucial for establishing reference conditions and restoration goals, the underlining disturbance regimes that profoundly shape ecosystems and vegetation expression are often overlooked. Indeed, re-establishing former disturbance regimes, i.e. returning natural flows/hydrologic pulses back to rivers (Postel and Richter, 2003) or fire back into pyrogenic ecosystems (Nowacki and Abrams, 2008), is vitally important. Since many terrestrial ecosystems are disturbance dependent and have been negatively affected by the disruption/discontinuance of former disturbances (Cowell, 1998; Whitney, 1987; Bond et al., 2004; Bowman et al., 2009), land managers have shifted towards emulating natural disturbance regimes for ecosystem restoration and sustainability (Seymour et al., 2002; North and Keeton, 2008; Long, 2009). By restoring fundamental disturbance processes, the evolutionary environment and basic ecological functions can be re-established, thus leading to the return of historic vegetation conditions.

Direct information for determining presettlement fire regimes in the eastern United States is scarce. Original forests have been greatly modified by European settlement activities, especially through exploitative logging, accidental and deliberate burning, land clearing, and pasturage (Williams, 1990; Whitney, 1994; MacCleery, 1996; Lewis, 1998). This transformation has been so complete that remaining "virgin" forests are few, scattered, and largely unrepresentative of past vegetation types (Nowacki and Trianosky, 1993). Likewise, older trees that may have recorded fire history in their rings are mostly gone. Moreover, even if they did exist, it is questionable whether past fire regimes of low to moderate intensity would be readily detectable through fire scars (McEwan et al., 2007). Vast opportunities exist with paleoecological data (stratigraphic charcoal), however their spatial distribution is geographically unbalanced (skewed to areas with high concentrations of lakes, ponds, and wetlands) with large voids across the east (see Fig. 1 of Hart and Buchanan, 2012). Moreover, charcoal interpretations are imperfect (Higuera et al., 2005) and the high resolution required from the charcoal record for concise fire regime reconstruction is usually not available (Clark, 1988), although there has been marked improvement in these regards (Power et al., 2008). Radiocarbon-dating of soil and cave-alluvial charcoal looks promising for reconstructing past fire regimes, but research is only in its infancy with few studies to date (Talon et al., 2005; Hart et al., 2008; Fesenmyer and Christensen, 2010; Springer et al., 2010). In the absence of such direct evidence, inferences from indirect information sources may be best for scientists and land managers seeking to understand past disturbance regimes.

The recognition that disturbance played a key role in determining past vegetation compositions, structures, and patterns has

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Witness-tree categorization

Pyrophilic

Traits: Thick bark, sprouters, xerophytic, fire-encouraging leaves, early seral

Carya	Hickory
Castanea	Chestnut
Cornus	Dogwood
Juniperus	Red cedar, cedar
Nyssa	Blackgum, gum
Pinus	Pine
Populus	Aspen, cottonwood
Quercus	Oak
Robinia	Locust
Sassafras	Sassafras

Pyrophobic

Traits: Thin bark, shallow roots, mesophytic, fire-discouraging leaves, late seral

Abies	Balsam fir, fir, balsam
Acer	Maple
Betula	Birch
Carpinus/Ostrya	Hornbeam, ironwood
Fagus	American beech
Fraxinus	Ash
Juglans	Butternut, walnut
Liriodendron	Yellow-poplar, tulip tree
Magnolia	Magnolia, cucumber
Picea	Red spruce, spruce, yew pine
Plantanus	Sycamore
Prunus	Black or wild cherry
Salix	Willow
Taxus	Yew
Tilia	Basswood, white lynn, lin
Tsuga	Hemlock, hemlock-spruce
Ulmus	Elm

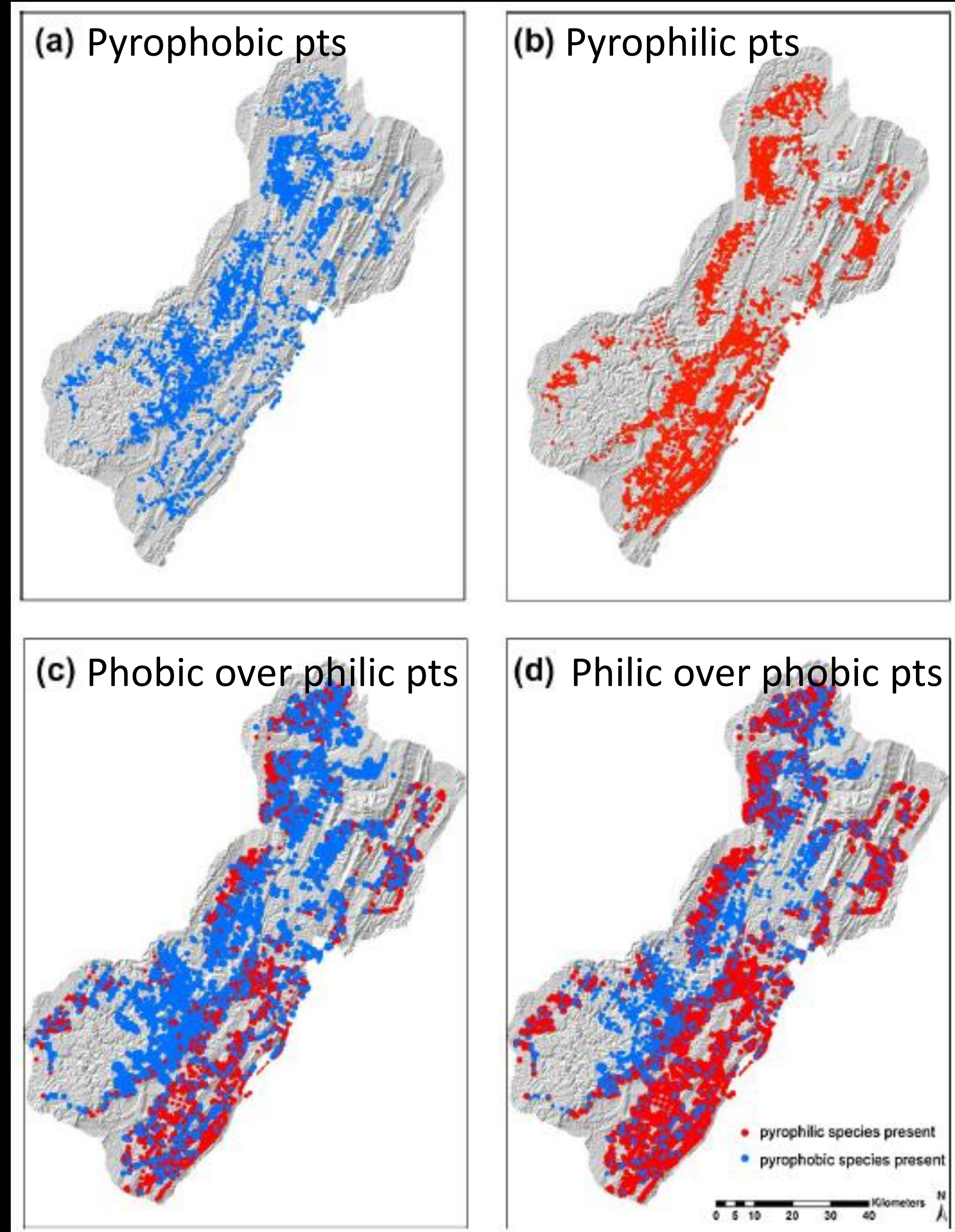
Witness-tree data

(1752-1899 surveys)

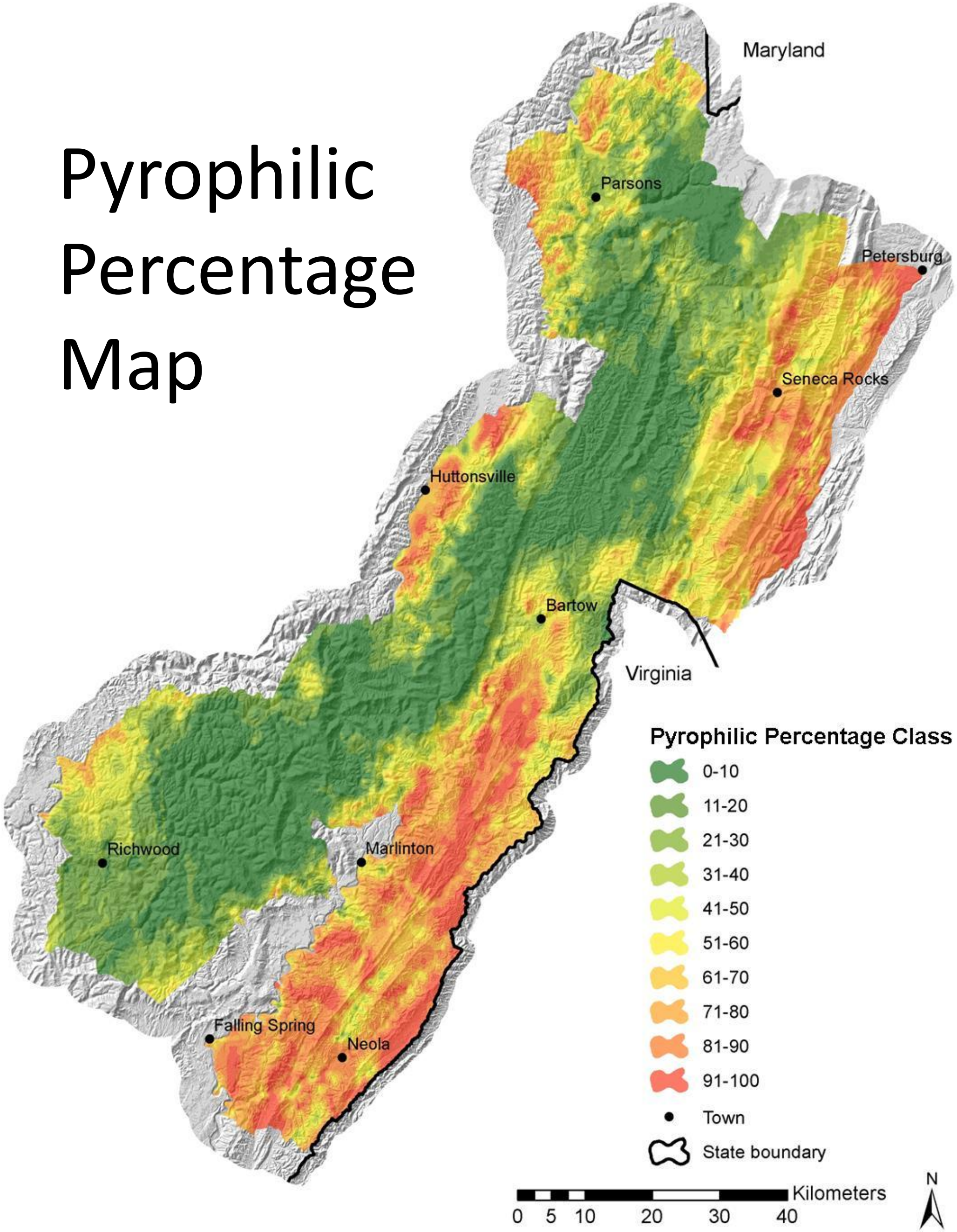
Pyrophilic percentage =

$$\frac{\text{\# of pyrophilic trees}}{\text{total \# of trees}} * 100$$

Category of witness tree point	No. in study area
No. of 1-tree points	7,710
No. of 2-tree points	5,451
No. of 3-tree points	1,016
No. of 4-tree points	131
No. of 5-tree points	24
No. of 6-tree points	4
Total no. of points	14,336
No. of exclusively pyrophilic points	6,329
No. of mixed points	2,109
No. of exclusively pyrophobic points	5,898
Total no. of points	14,336



Pyrophilic Percentage Map

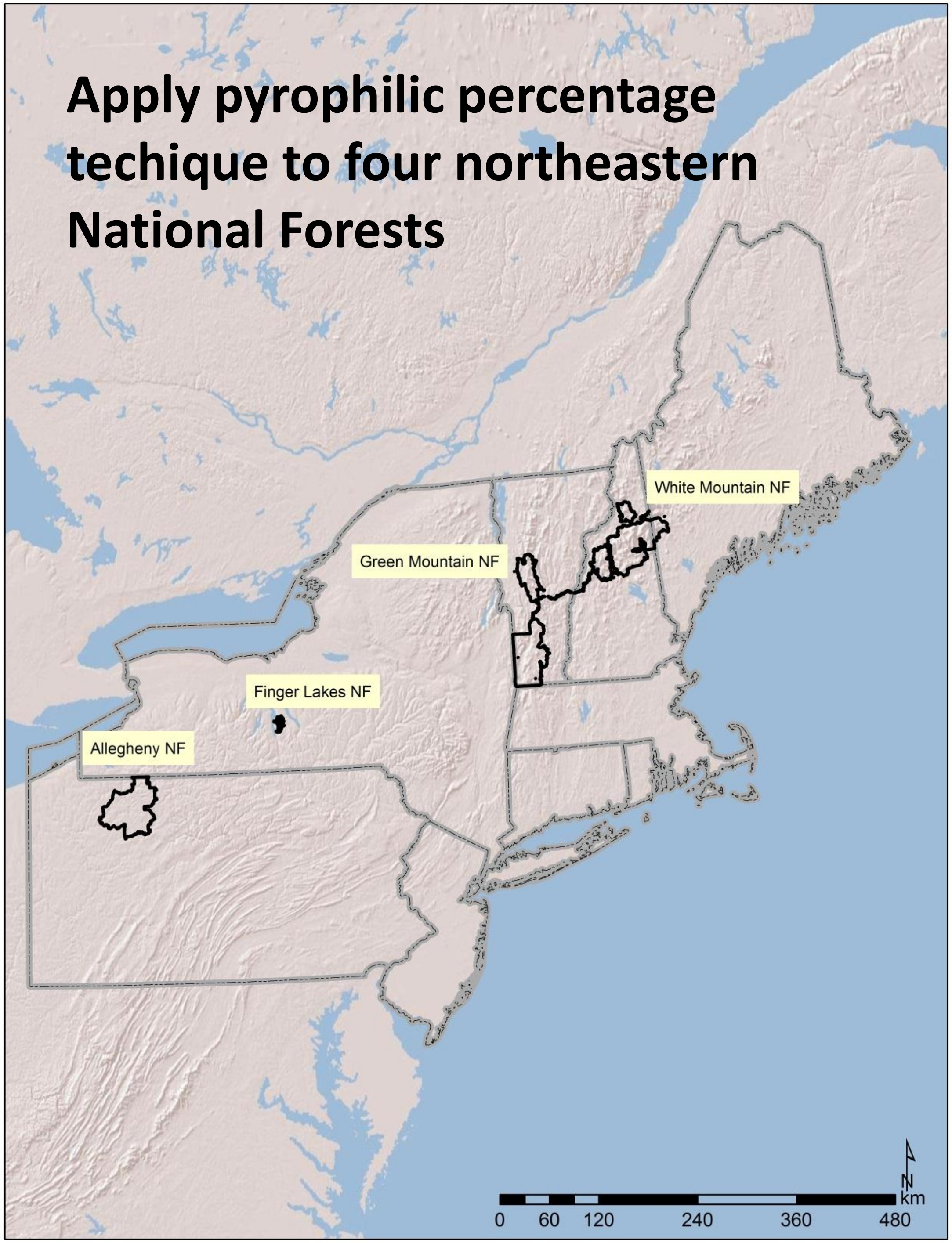


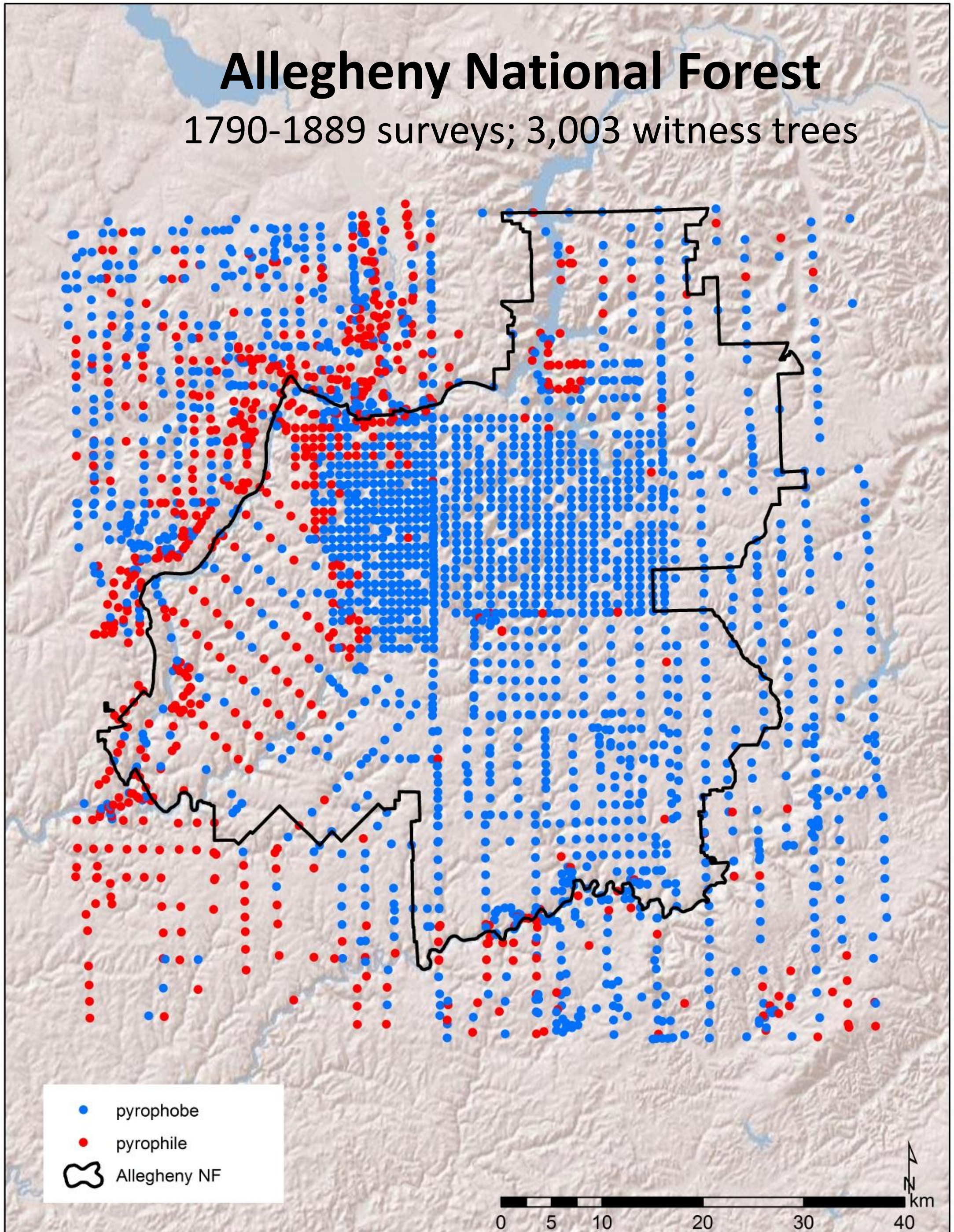
Pyrophilic %age corresponded to a climo-elevational gradient.

PP% ↓ with:

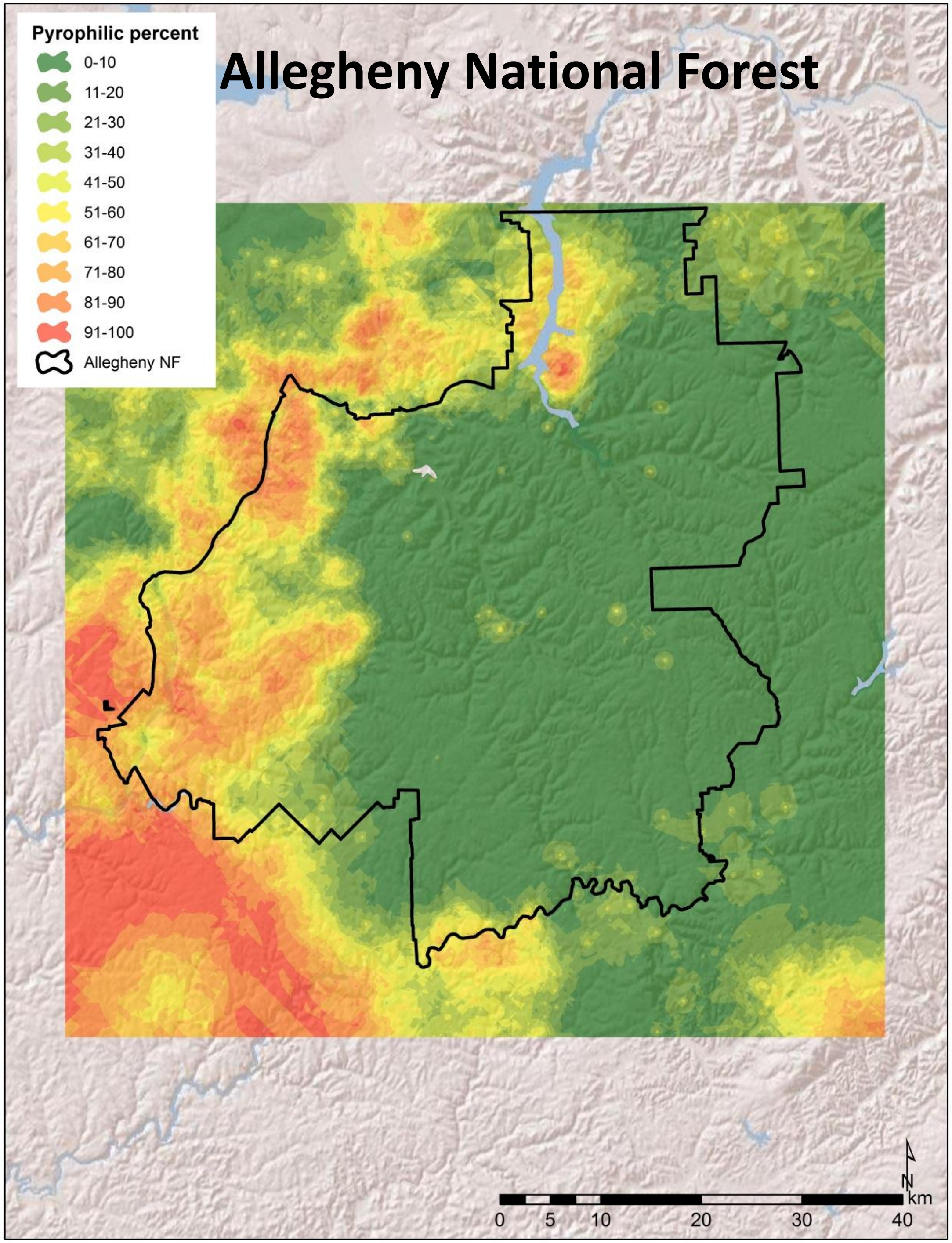
- ↑ elevation
- ↑ precipitation
- ↑ frost days
- ↓ temperature
- ↓ growing days

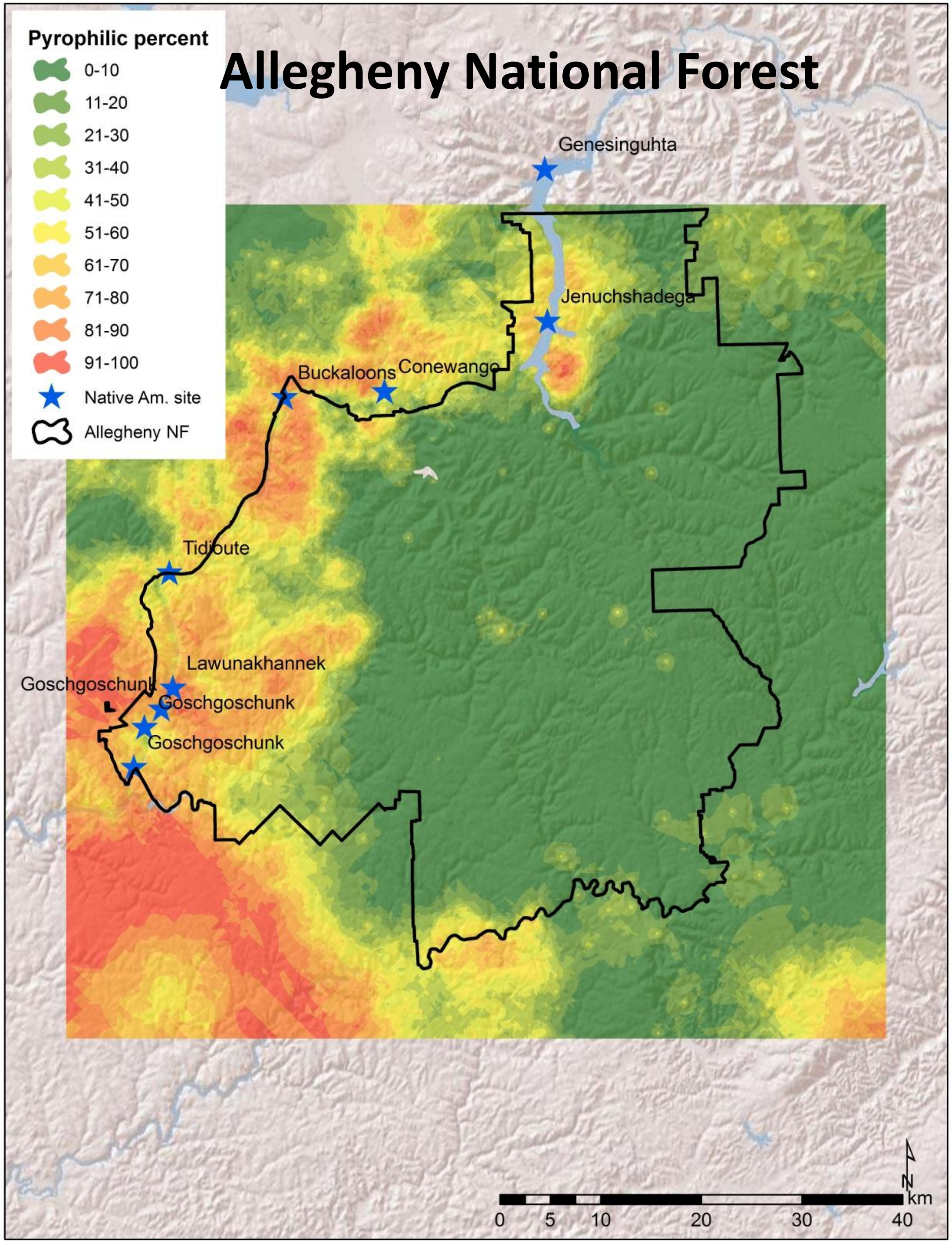
Apply pyrophilic percentage techique to four northeastern National Forests




Allegheny National Forest
1790-1889 surveys; 3,003 witness trees
pyrophobe
pyrophile
Allegheny NF
km
0
5
10
20
30
40
N

Allegheny National Forest

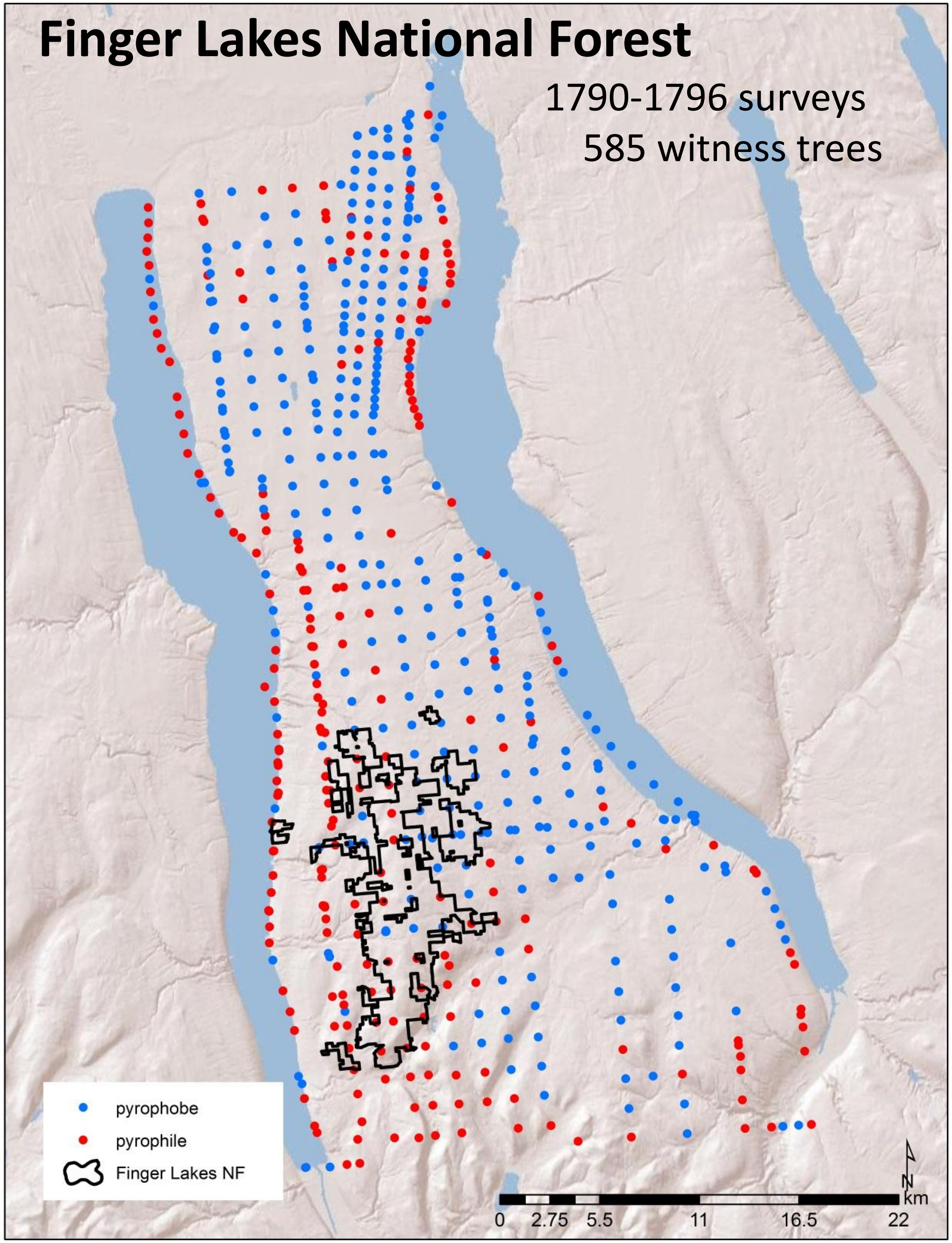




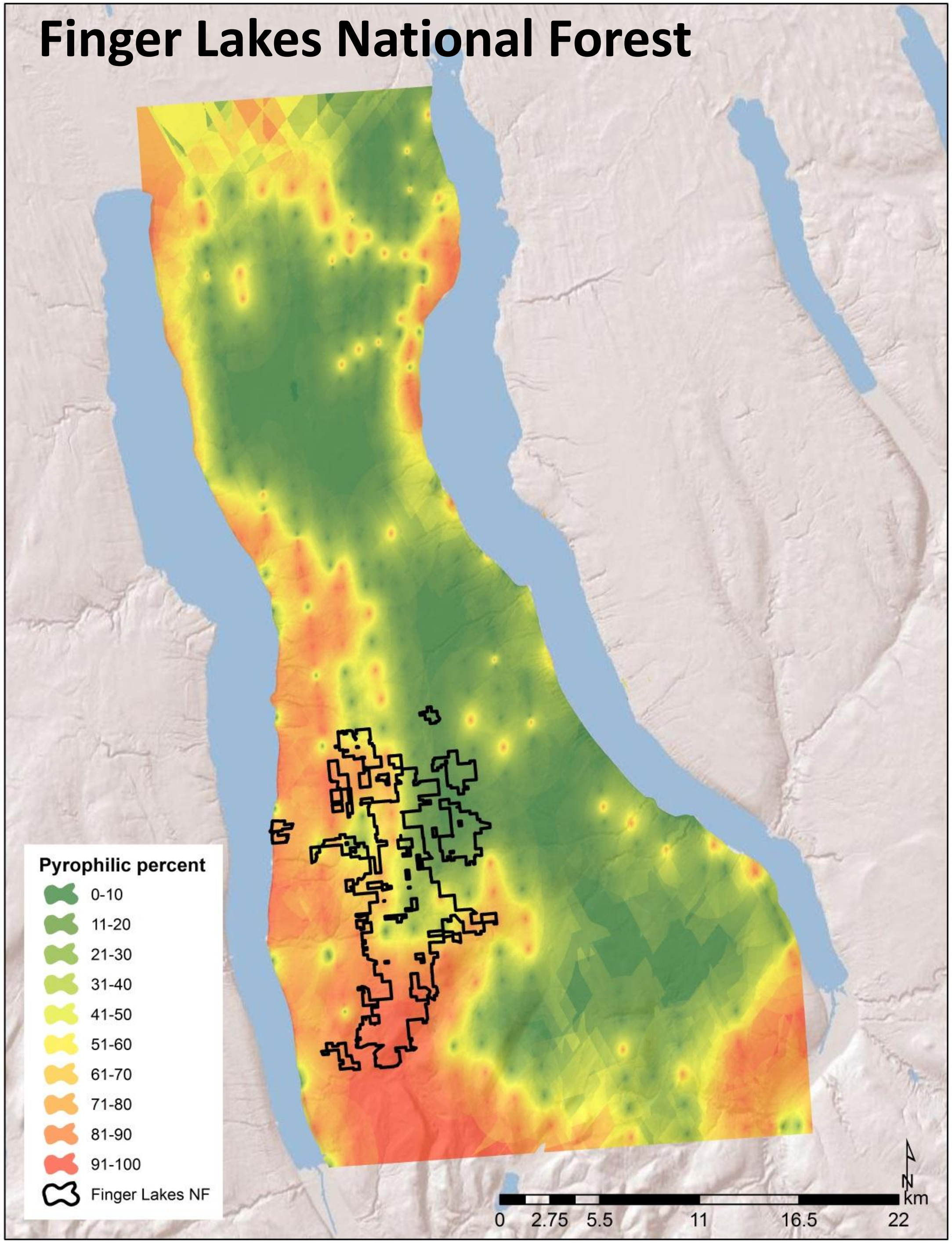
Allegheny National Forest
Pyrophilic percent
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
Native Am. site
Allegheny NF
Genesinguhta
Jenuchshadega
Buckaloons
Conewango
Tidioute
Lawunakhannek
Goschgoschunk
Goschgoschunk
Goschgoschunk
N
0
5
10
20
30
40
km

Finger Lakes National Forest

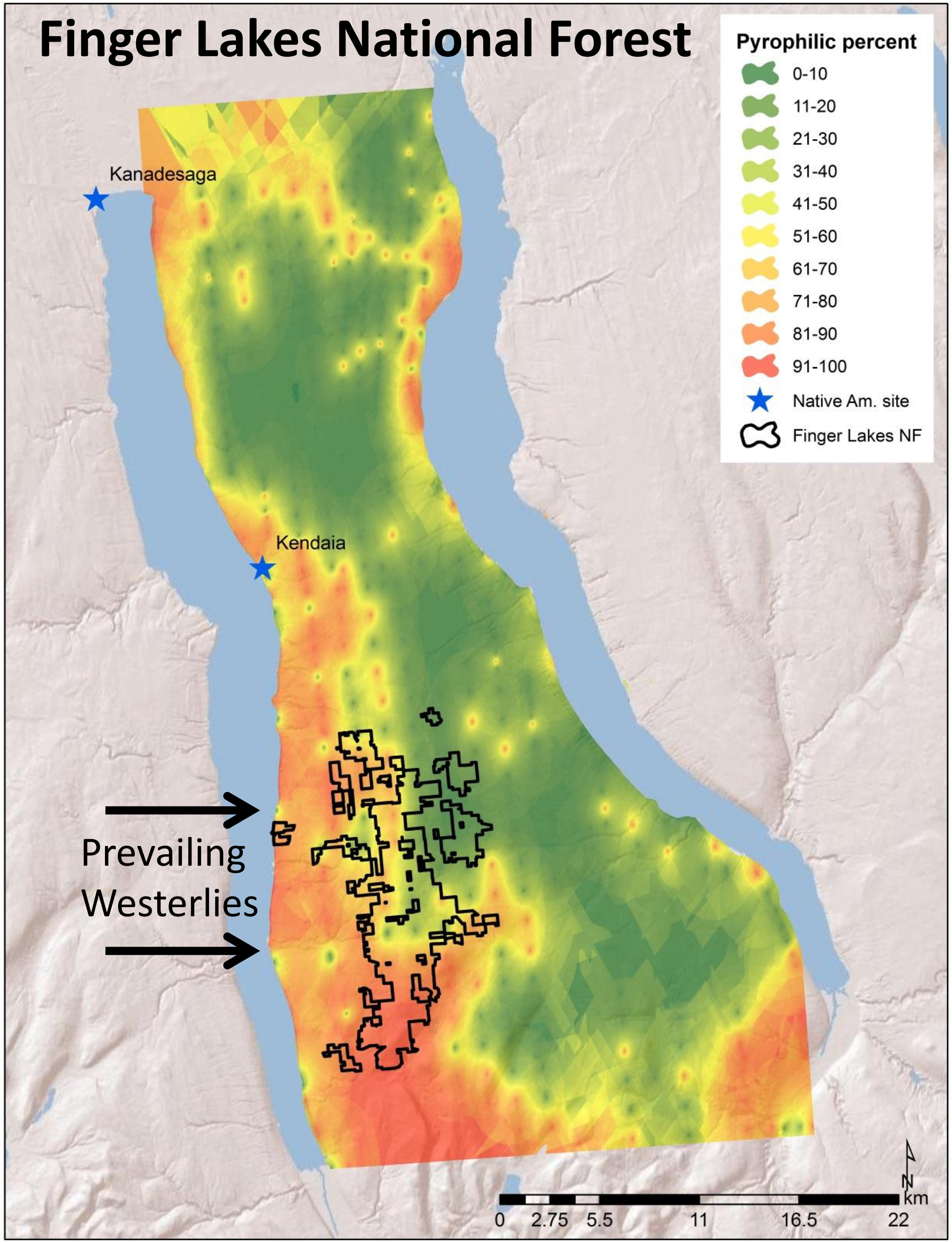
1790-1796 surveys
585 witness trees



Finger Lakes National Forest

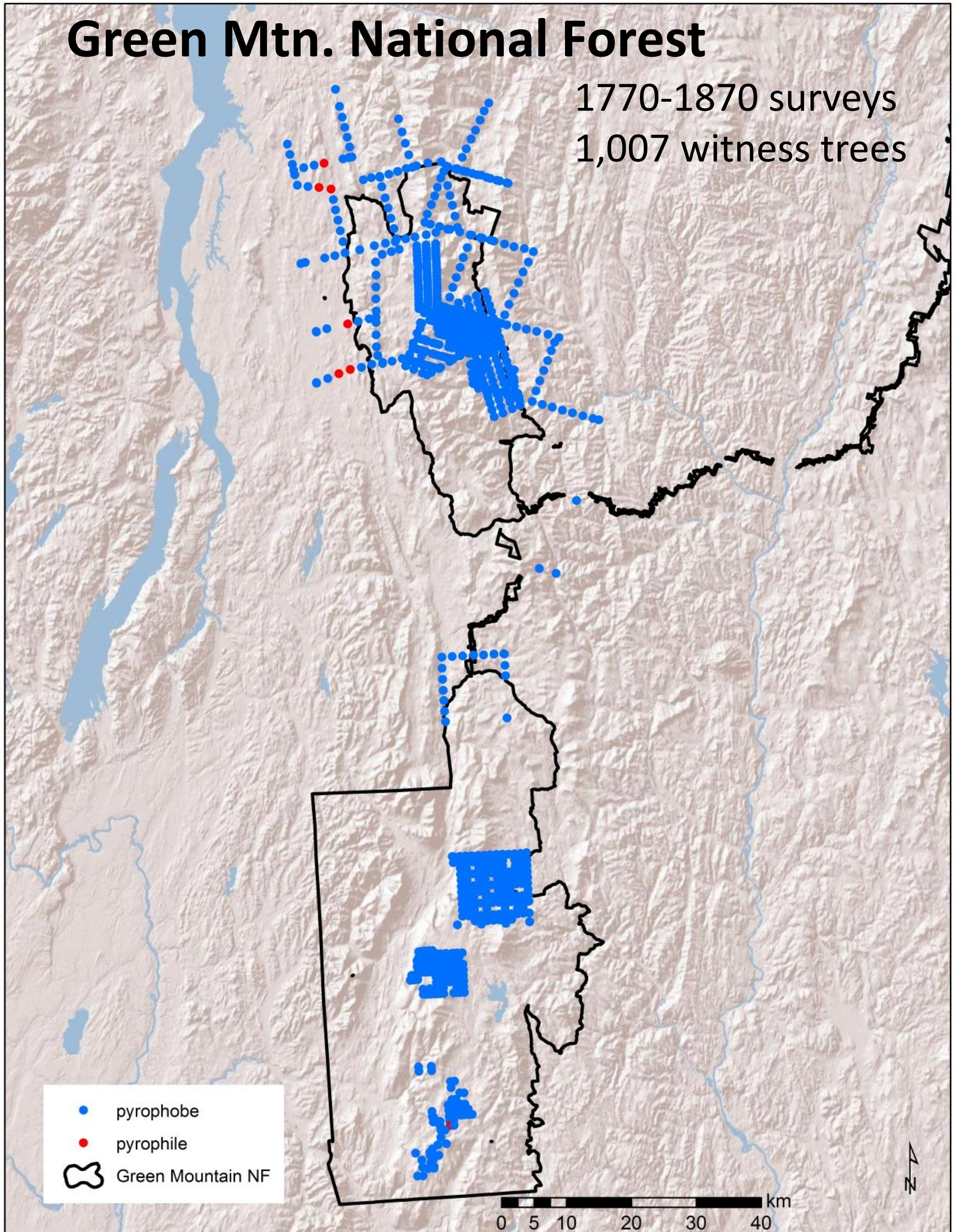


Finger Lakes National Forest

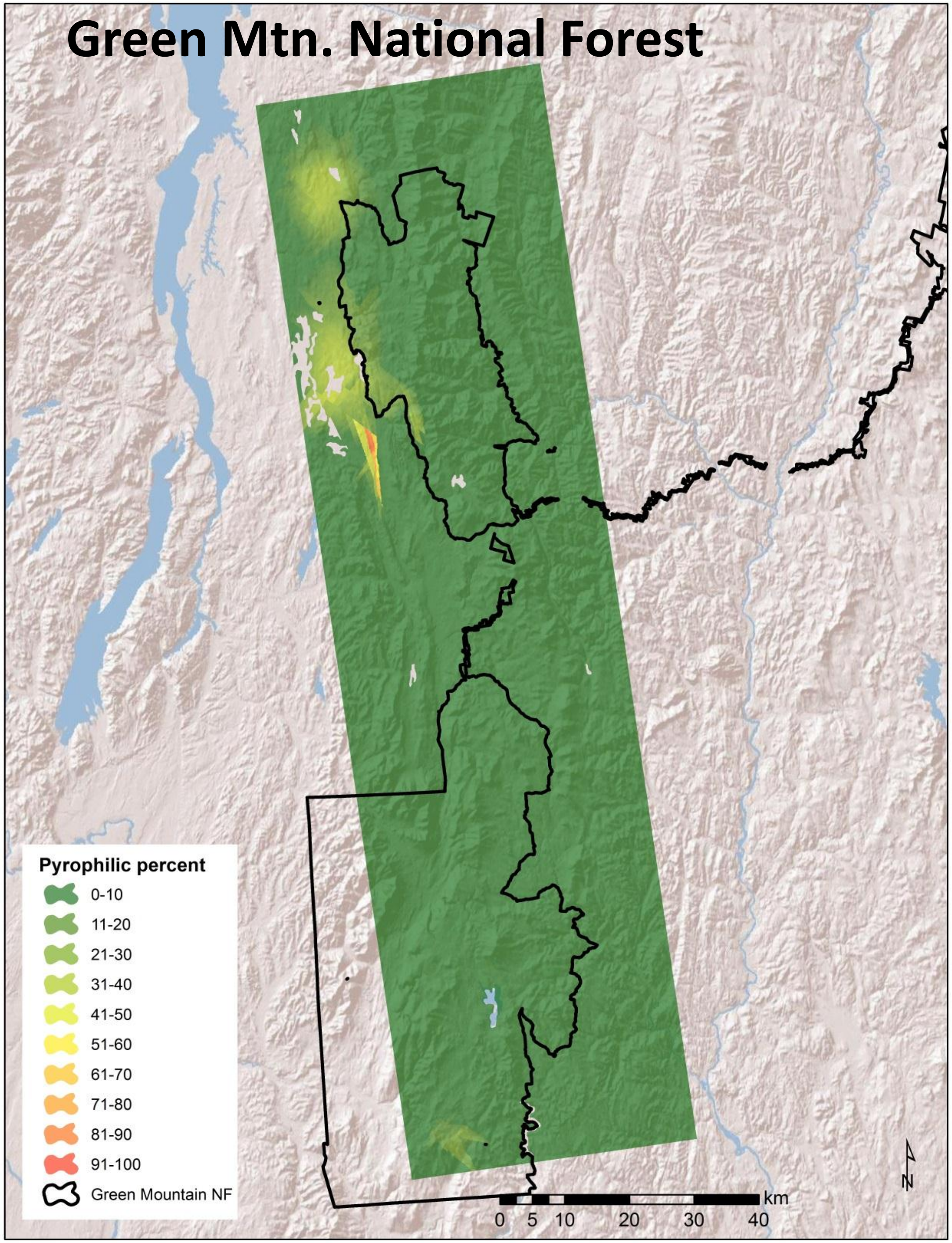


Green Mtn. National Forest

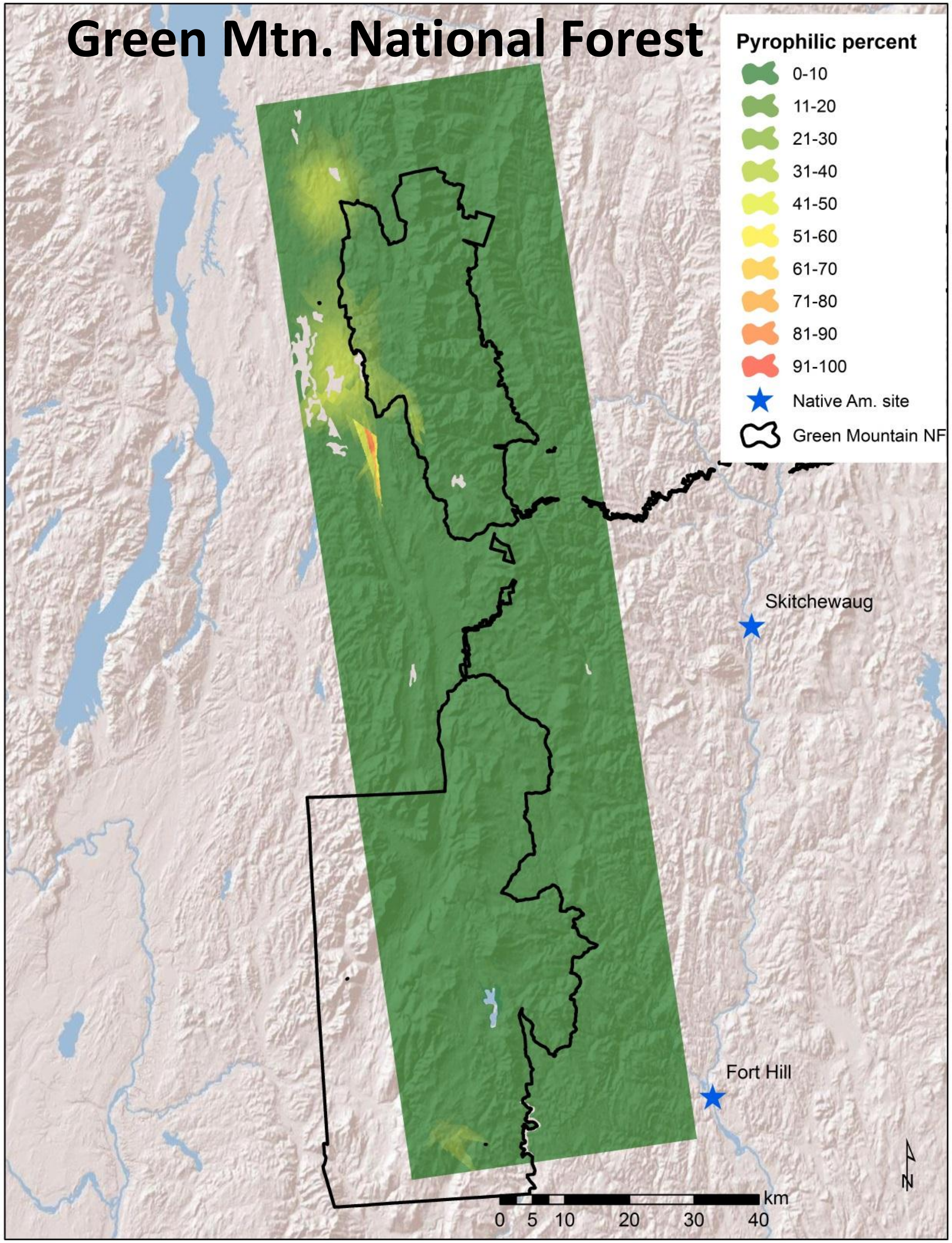
1770-1870 surveys
1,007 witness trees

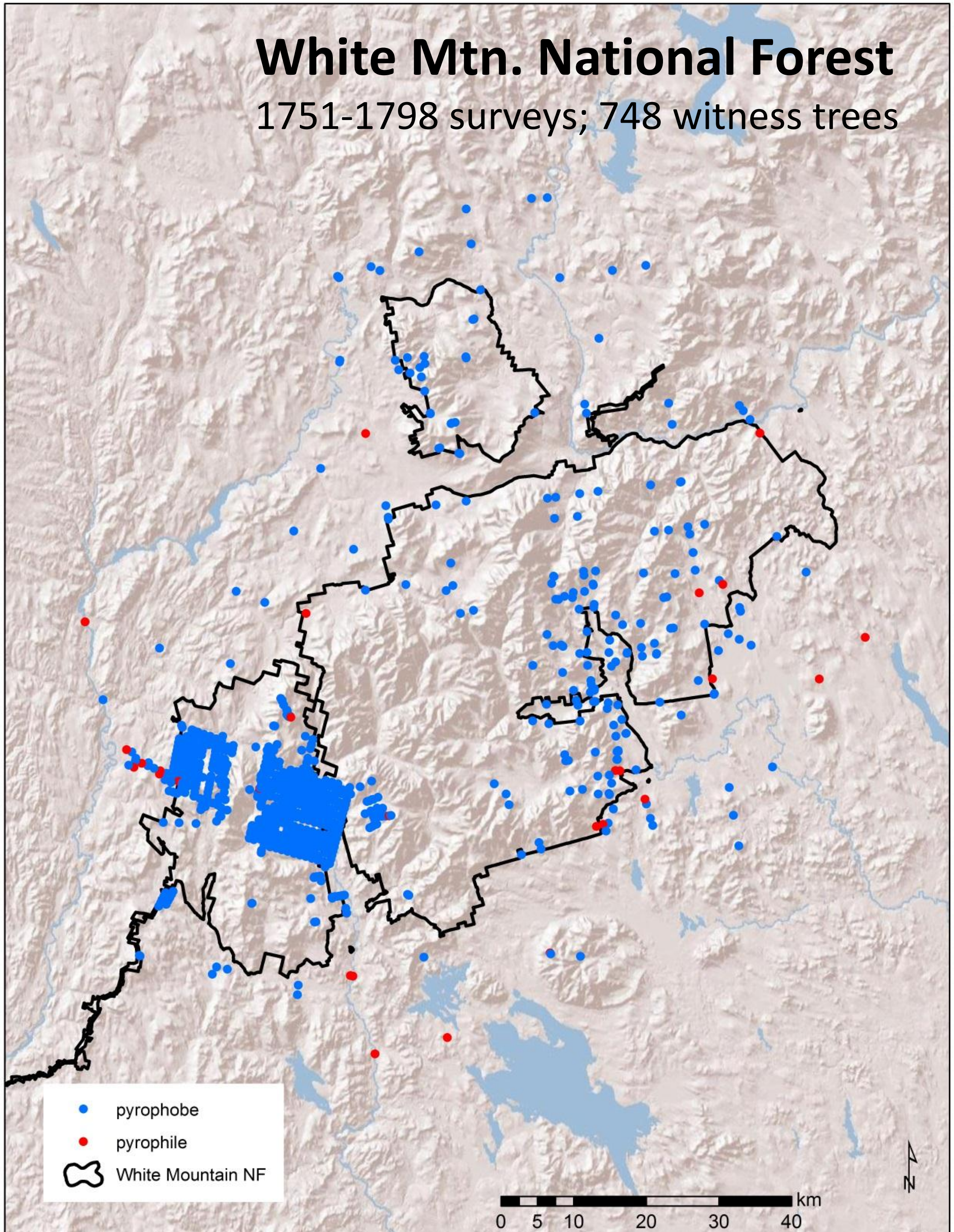


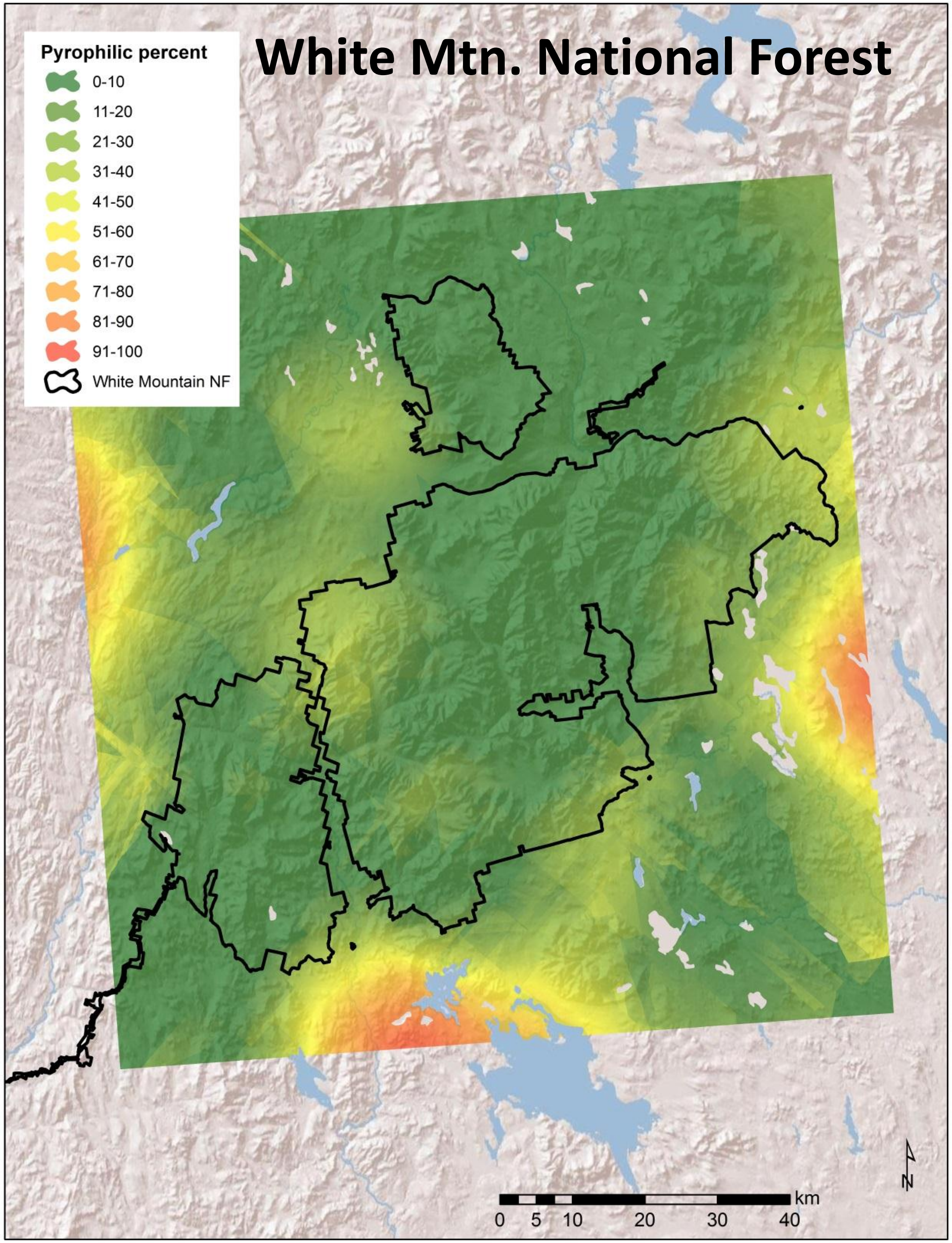
Green Mtn. National Forest



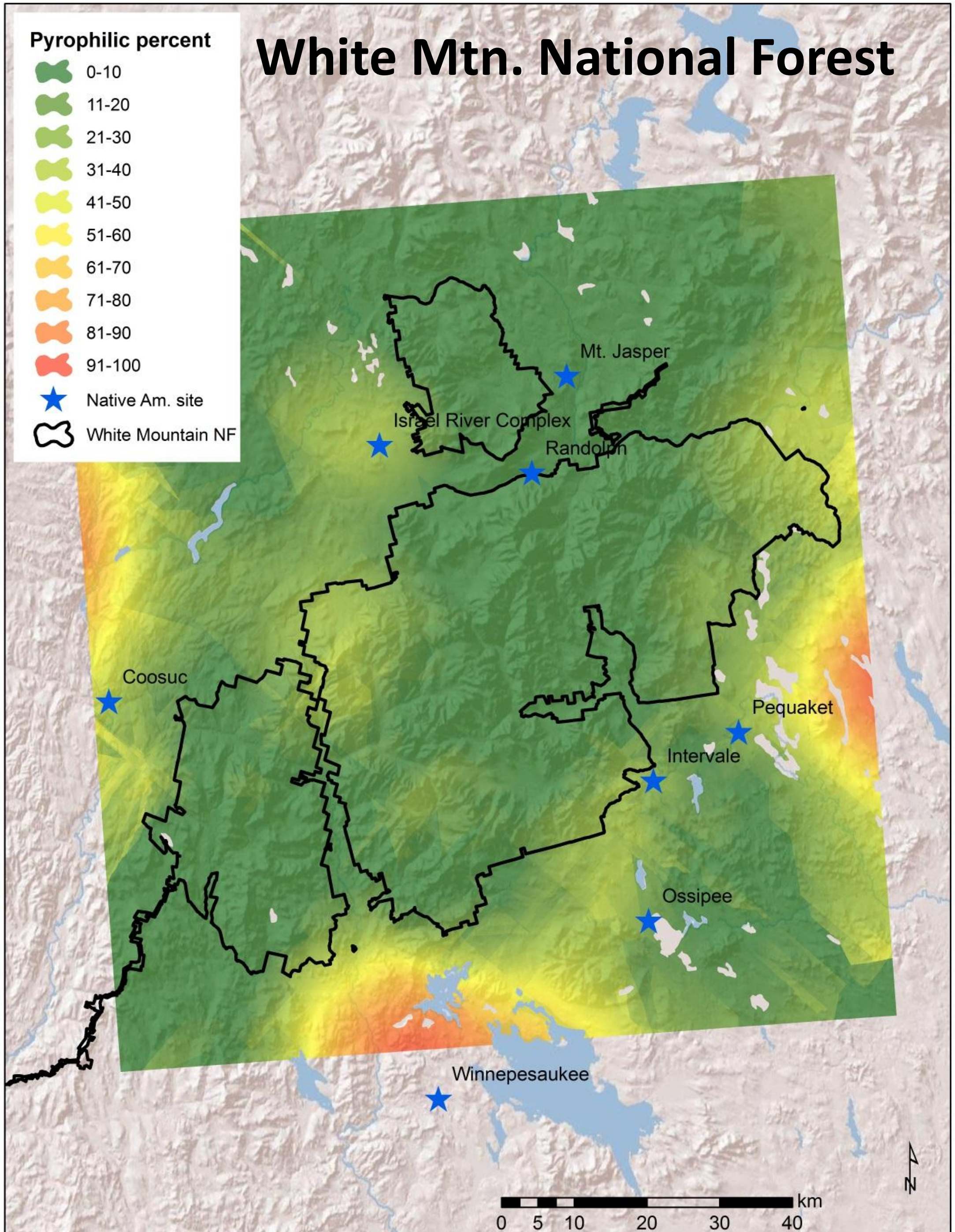
Green Mtn. National Forest

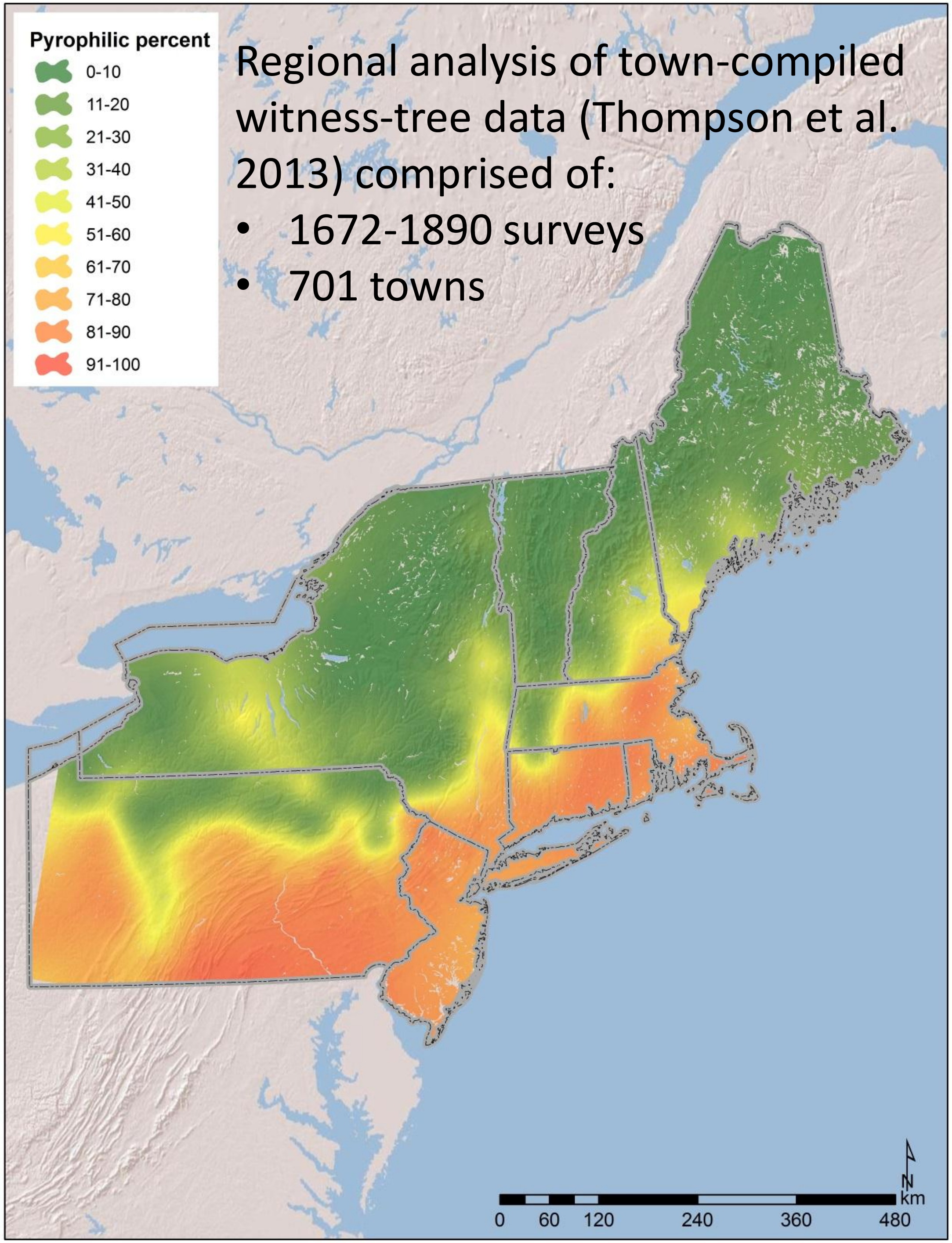



White Mtn. National Forest
1751-1798 surveys; 748 witness trees
pyrophobe
pyrophile
White Mountain NF
km
0 5 10 20 30 40
N

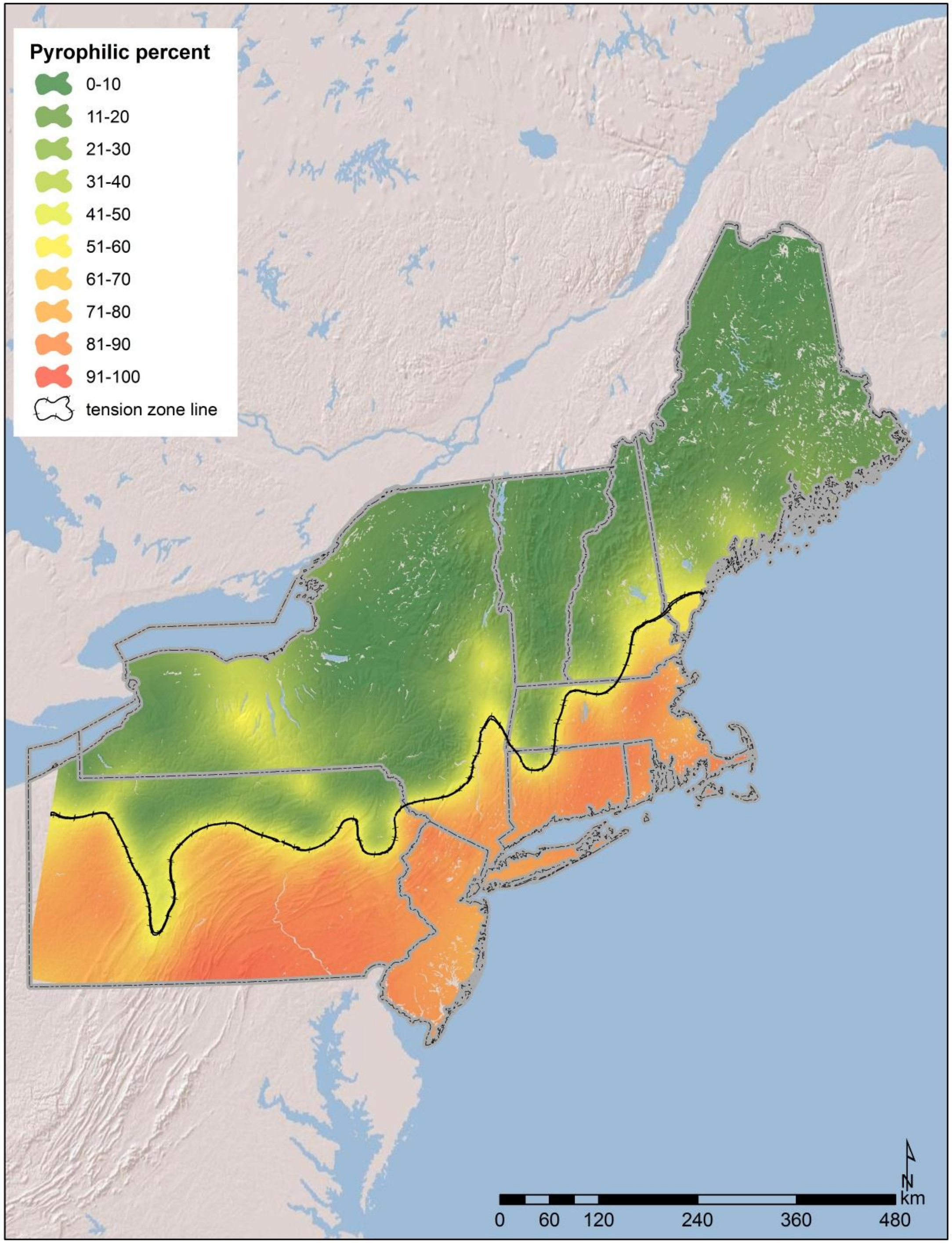


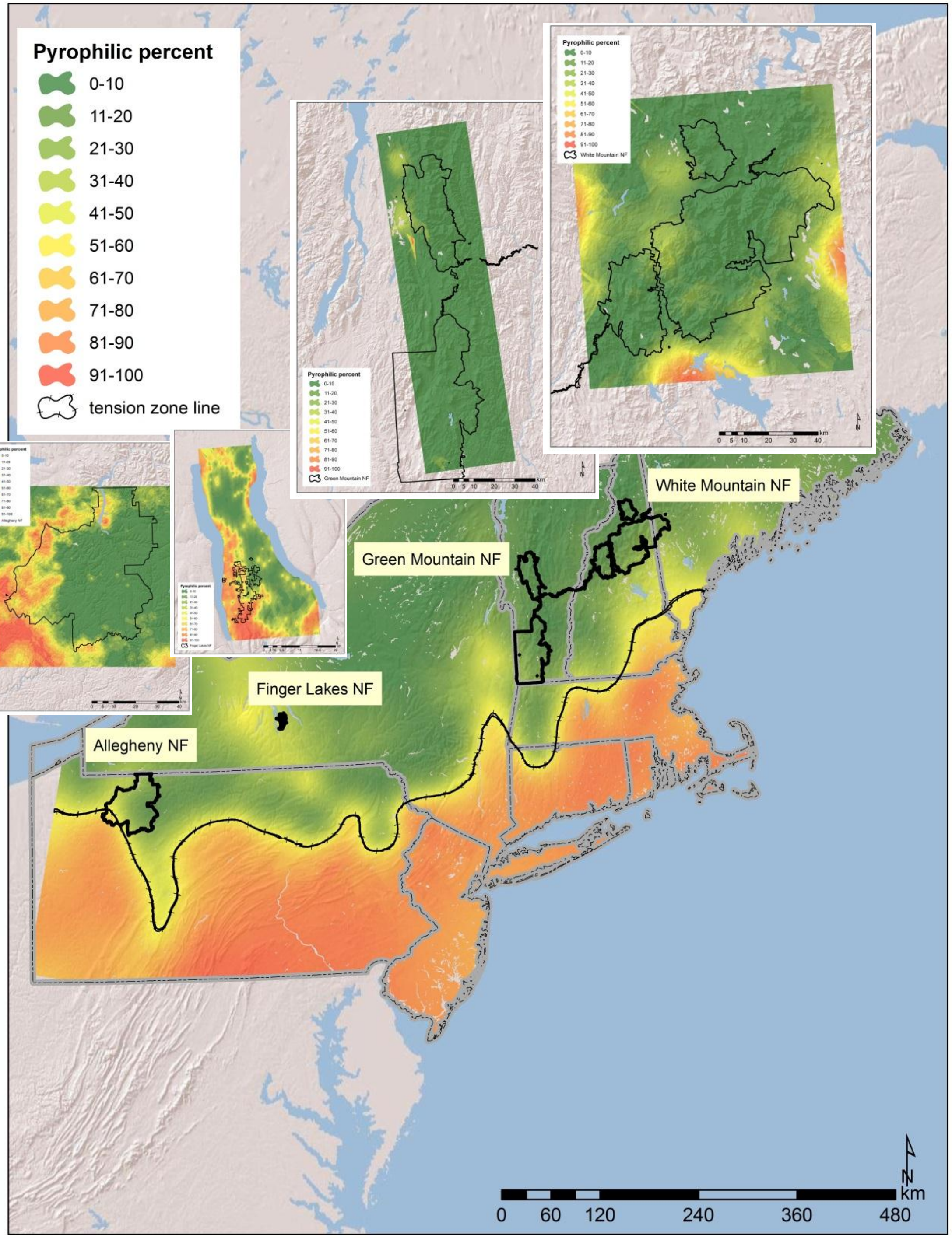
White Mtn. National Forest
Pyrophilic percent
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
White Mountain NF
km
0 5 10 20 30 40
N


White Mtn. National Forest
Pyrophilic percent
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
Native Am. site
White Mountain NF
Mt. Jasper
Israel River Complex
Randolph
Coosuc
Pequaket
Intervale
Ossipee
Winnepesaukee
km
0 5 10 20 30 40
N



Pyrophilic percent
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
Regional analysis of town-compiled witness-tree data (Thompson et al. 2013) comprised of:
• 1672-1890 surveys
• 701 towns
N
km
0 60 120 240 360 480


Pyrophilic percent
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
tension zone line
N
0 60 120 240 360 480
km


Pyrophilic percent
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
tension zone line
White Mountain NF
Green Mountain NF
Finger Lakes NF
Allegheny NF
km
0
60
120
240
360
480

Conclusions

- Kriging proved effective in converting witness-tree point data into spatial covers depicting fire importance.
- Fire was formerly most important in the western-most National Forest (Allegheny) and decreased eastward.
- Fire regimes were closely associated with Native American settlements and travel corridors on the Allegheny and Finger Lakes national forests. No association on National Forests farther east (Green Mtn. and White Mtn.).
- Two distinct fire regimes occur in the Northeast divided by the "Tension Zone Line"
  - Pyrophobic conifer-northern hardwood system (north)
  - Pyrophilic oak-pine system (south)


? Questions ?