Expanding the Uses of Convolution in GIS:

A Moving Window Analysis as the Basis for a Reforestation Priority Index

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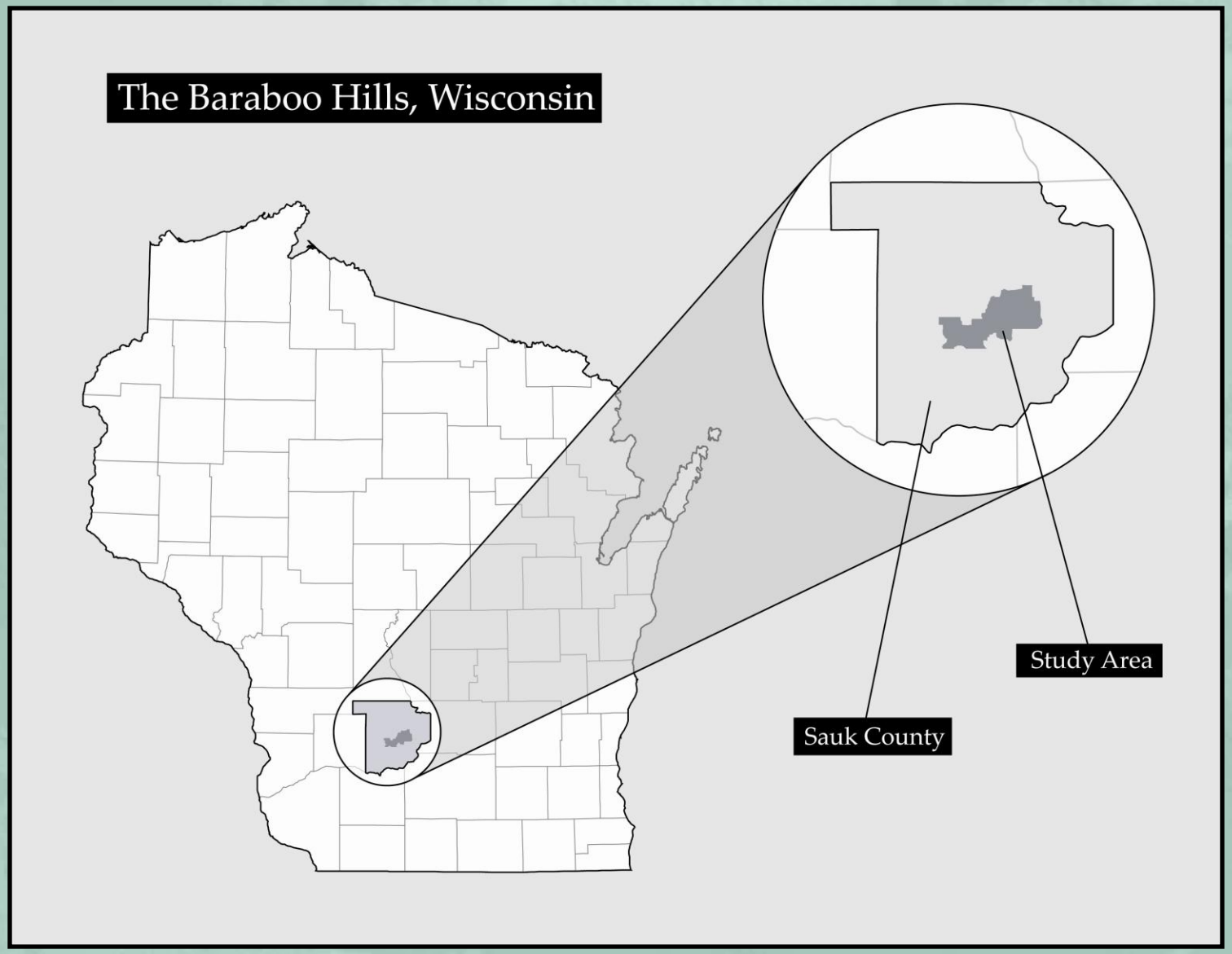
Introduction



Introduction

- Why is this natural area so important?

* One of oldest rock formations in North America

* Largest remaining forest block in Southern Wisconsin

* Home to 1,800 species of flora and fauna, many of which are not found elsewhere in the Midwest

* Rapidly deforested in the first half of the century

Introduction

- This is where the Nature Conservancy comes into the picture:

* Since the 1960s, the Conservancy has acquired 7,841 acres of land in the hills

* Early years spent slowing the deforestation, but now the focus has turned towards active reforestation in the area

Analysis Criteria

- The Conservancy has developed several criteria, borrowing from multiple disciplines, for choosing optimal lands for reforestation

- These criteria break nicely into three categories:

1. Characteristics that improve lands for reforestation
2. Characteristics that exclude lands for reforestation
3. Characteristics that increase the amount of interior forest

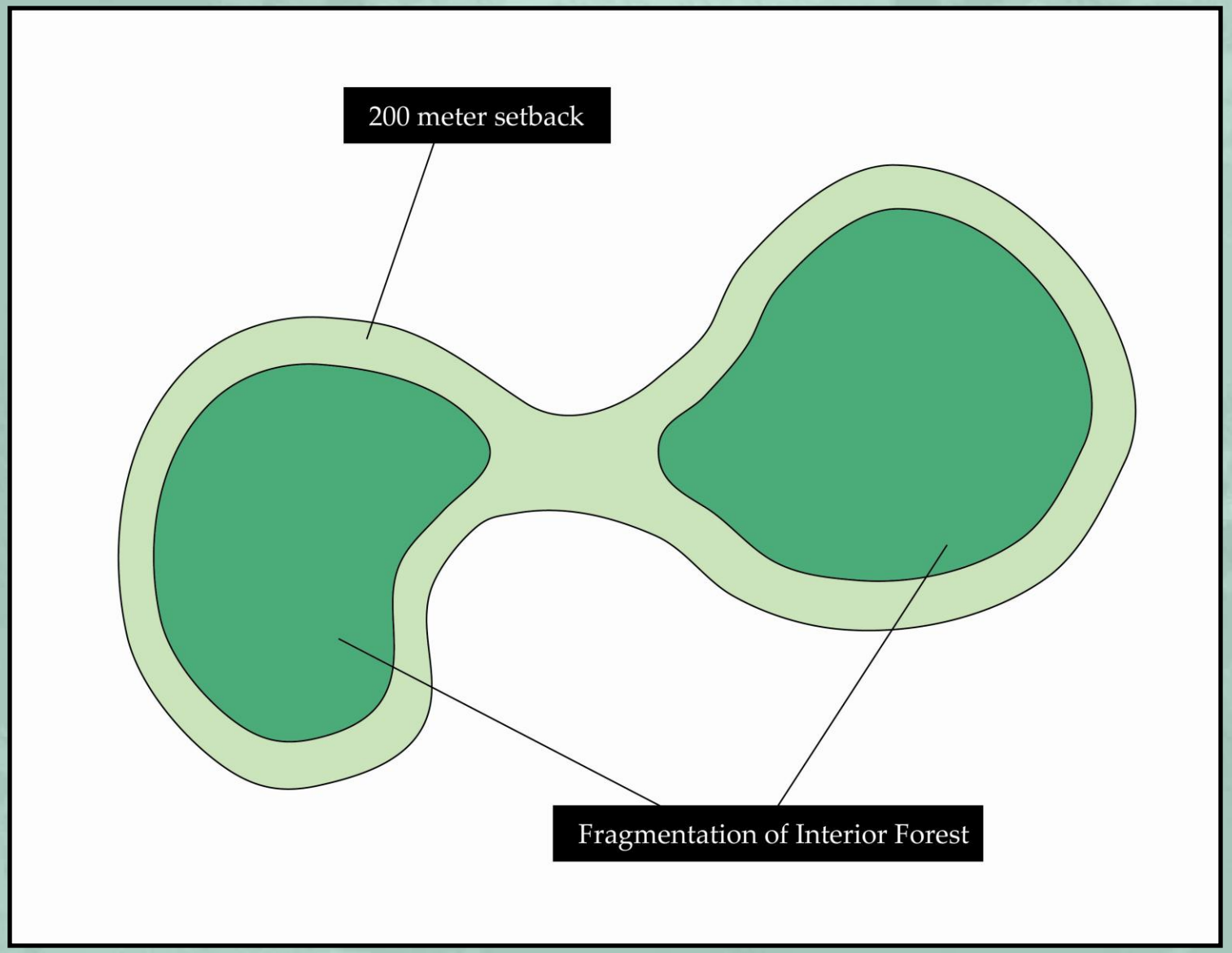
Analysis Criteria

- By habitat fragmentation, deforestation provides exotic species easier access into the forest

* The Nature Conservancy has established that the exotic species in Baraboo Hills can penetrate up to 200 meters into the forest

- *Interior Forest* – forest beyond this 200 meters that acts as a sanctuary for native species

Analysis Criteria



Analysis Criteria

- The idea is that we want to reduce this perimeter in which the evasive species can penetrate, while increasing the interior forest area.

* Want to add more than one acre of interior forest for every acre we reforest

* So we need to somehow analyze the shape of the forest polygons

- *Compactness* – a commonly measured characteristic of shape

$$\text{Compactness} = \frac{\text{Perimeter}}{\text{Area}}$$

Analysis Criteria

- Why will the concept of compactness not help us analyze where to reforest?

1. The most compact shape is a circle
   - It is not plausible to simply convert all of our polygons into large circles

2. There is no way to incorporate the other analysis criteria

3. Because multiple different sizes and shapes can yield the same compactness ratio, it can only be used to compare changes that are made, not actually suggest what changes to be made
   - Puts us right back to where we started

Convolution

- In response, I propose to expand the uses of convolution in a novel way

- *Convolution* – a spatial processing technique that takes a kernel of coefficients or weights and moves it throughout the entirety of the image

* At each pixel, the neighbors included in the kernel are calculated given the particular expression and the resulting value is set as the digital number for that pixel

* Also called a *Moving Window Analysis*

Convolution

- The values in each cell, the kernel size, and the calculation placed in the center are parameters that are set at the start of the convolution

1	1	1
1	1	1
1	1	1

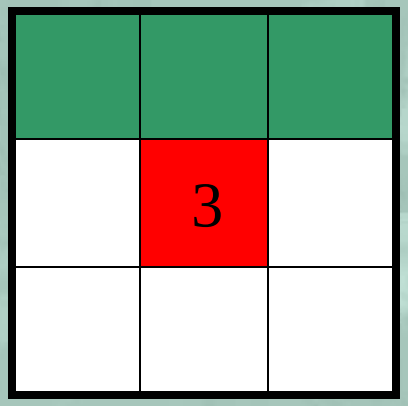
- For our analysis:

1. The cell value is 1 for each
2. The kernel size is 3x3
3. The center pixel will get the sum of the nine values in the window

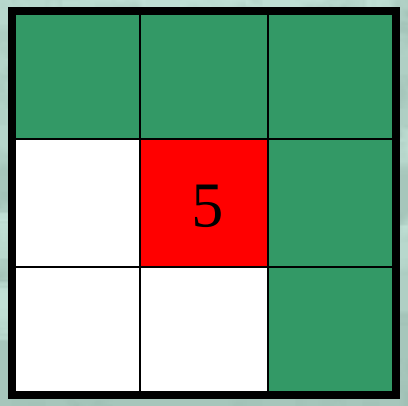
Convolution

- How will this analysis solve our problem?

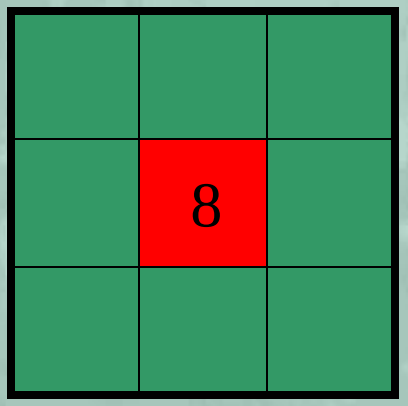
* There is a direct relationship to the sum placed in the center and the compactness value



EX1. The addition of the center pixel adds two sides of perimeter by only adding one pixel of area



EX2. The addition of the center pixel adds one pixel of area, but does not add any perimeter



EX3. The addition of the center actually removes four sides of perimeter while still adding one pixel of area

Implementation

- The first necessary step is to rasterize the original forest distribution

- The image must then be codified properly before the convolution is applied:

* 0 = nonforested areas

* 1 = forested areas

1	1	1
0	0	0
0	0	0

Rasterized, coded forest distribution

*

1	1	1
1	1	1
1	1	1

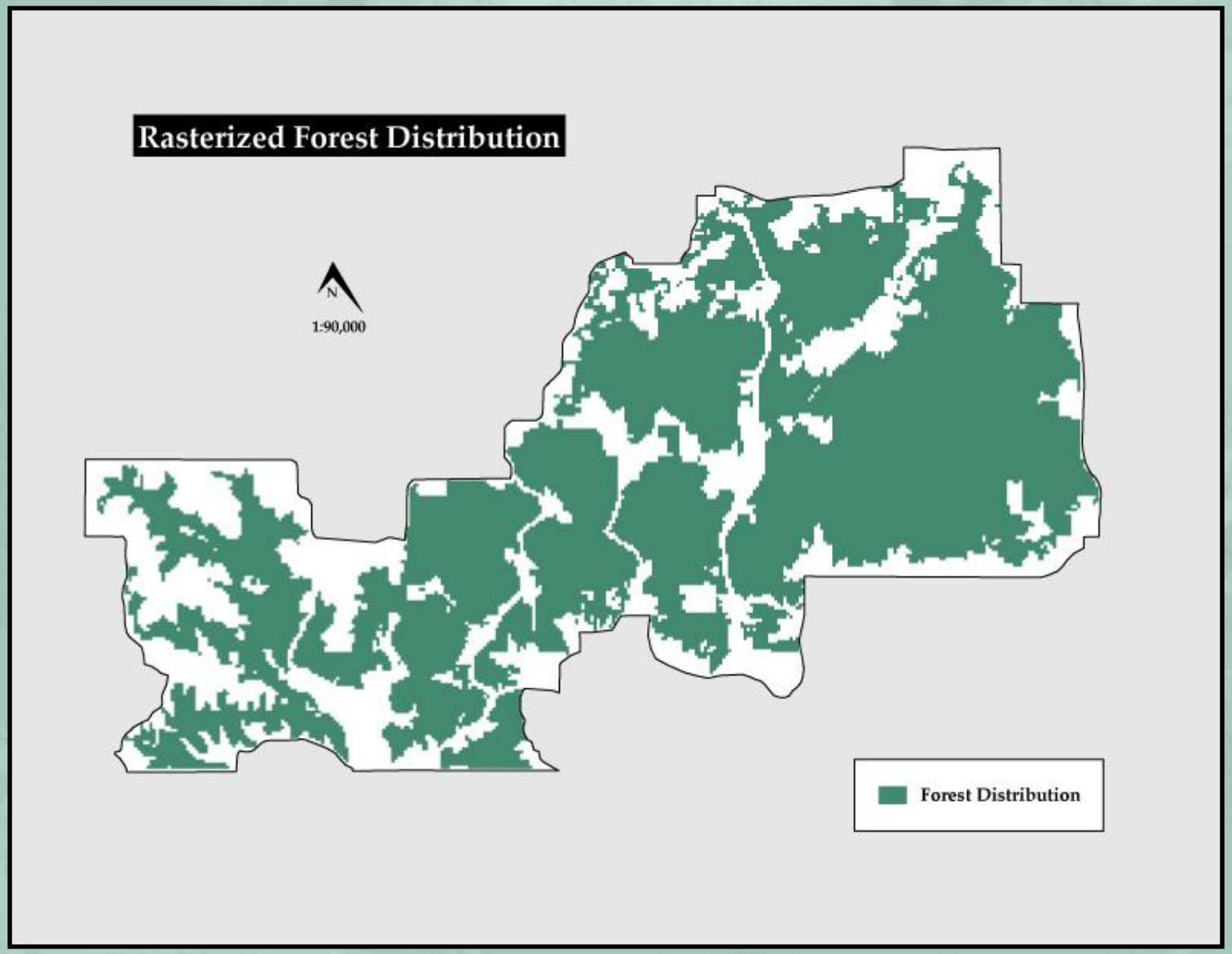
Kernel values

=

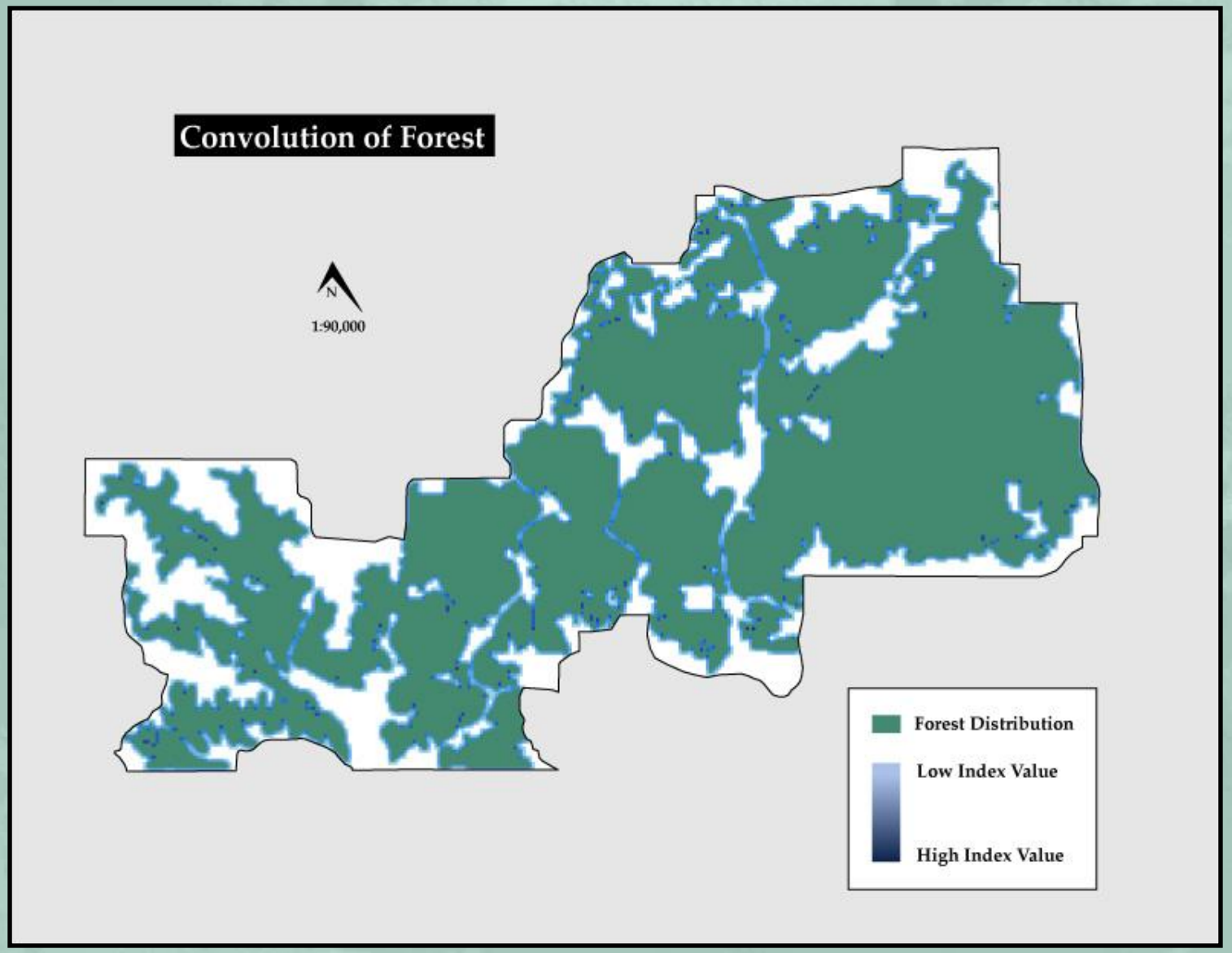
	3	

Resulting index value

Implementation



Implementation



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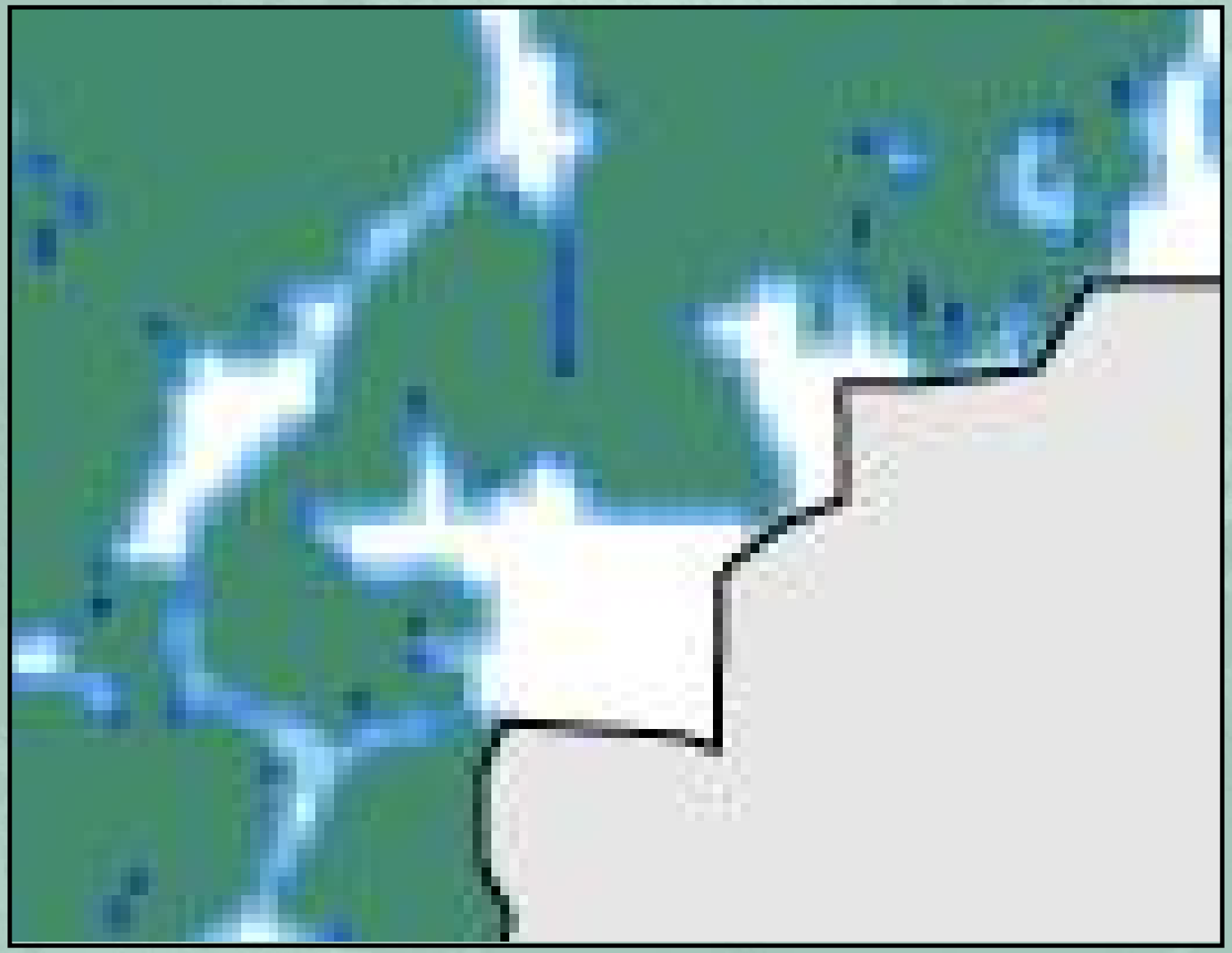


Implementation

- We then integrate the other analysis criteria outlined by the Nature Conservancy

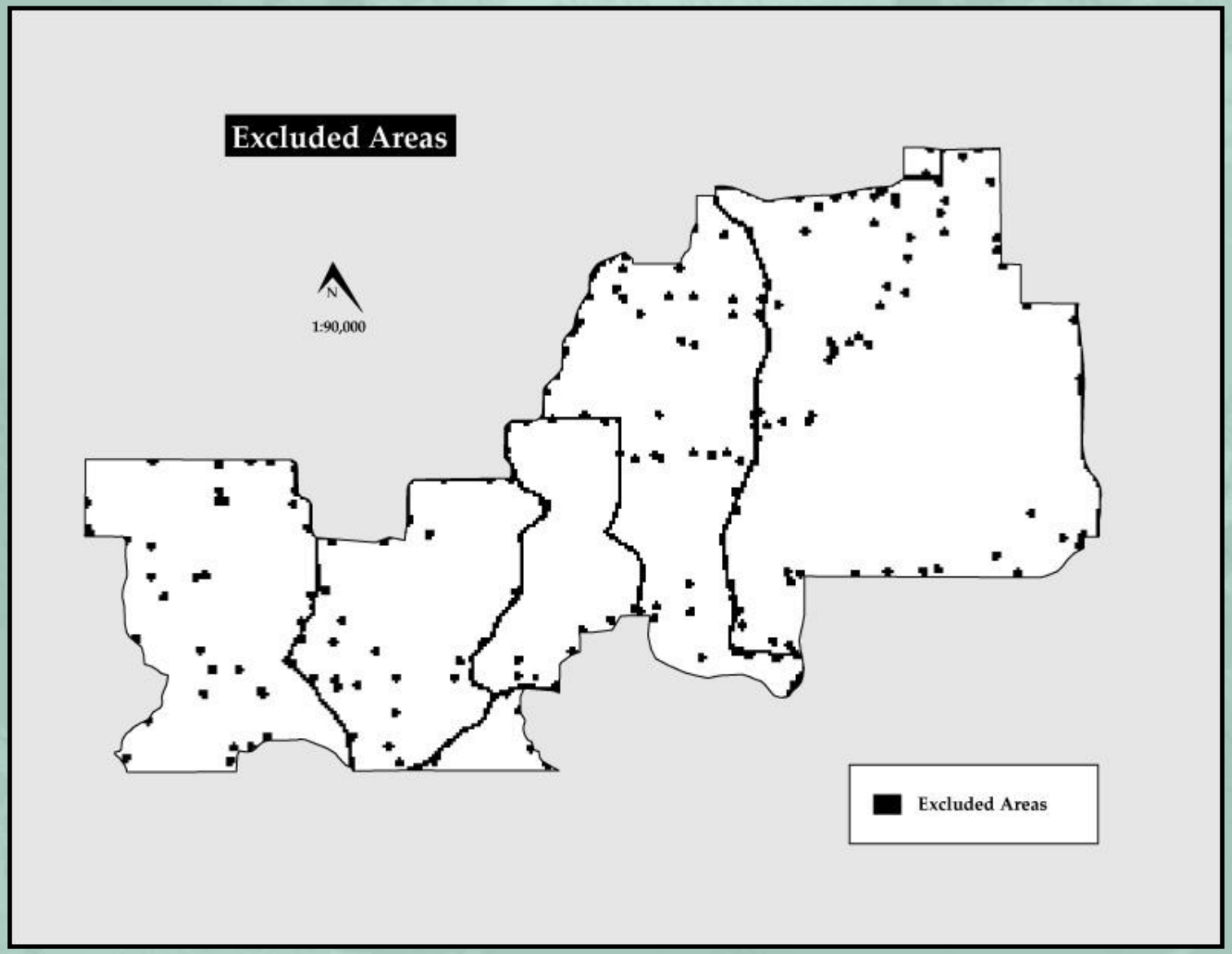
- These layers must also be rasterized and codified:

* 0 = excluded areas

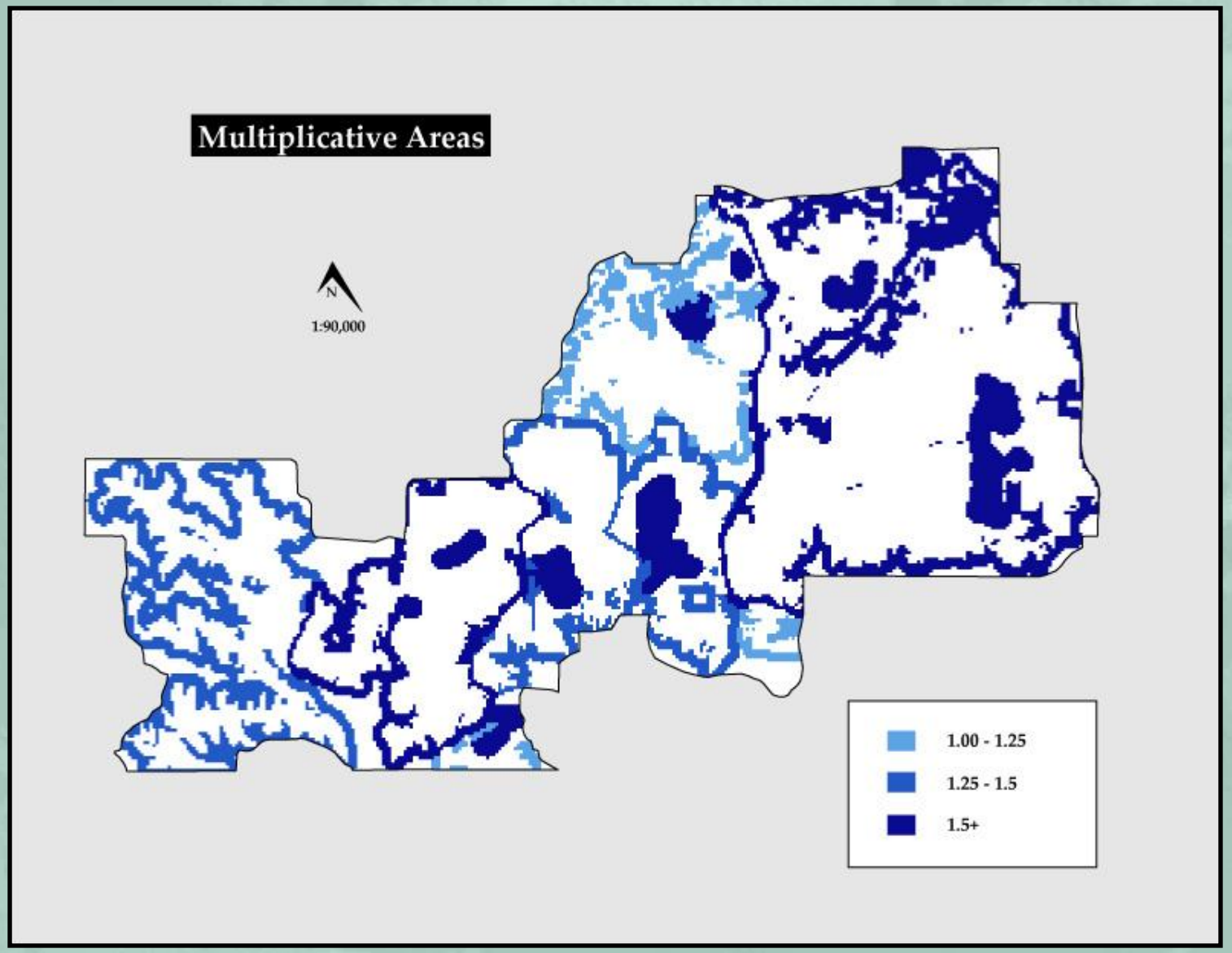
* >1 = multiplicative areas

  - Different values can be attributed as weight, allowing incorporation of even more information

Implementation



Implementation



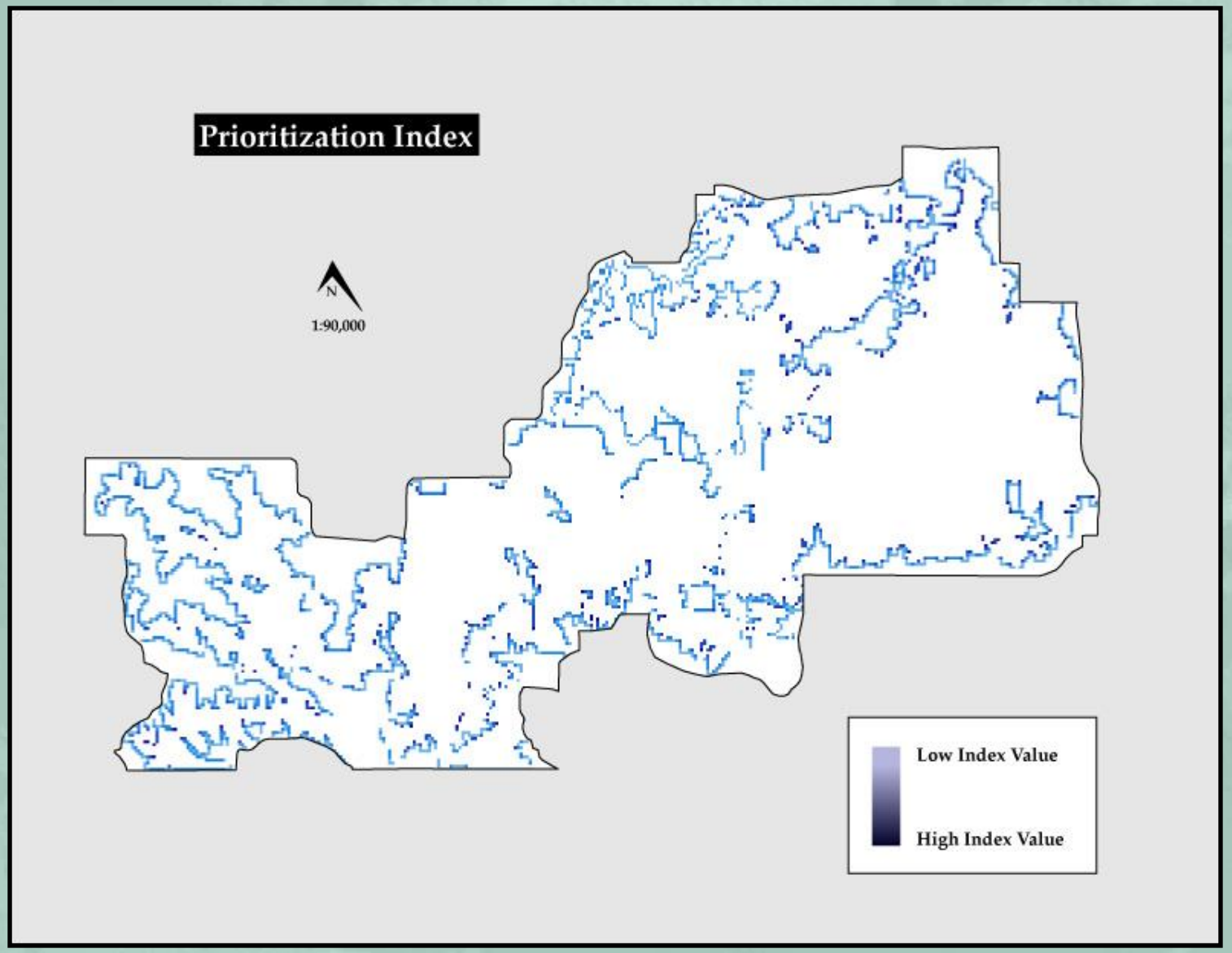
Implementation

- These other raster layers will then be multiplied with the convoluted image by a raster calculator

* The output will be a grid containing a single value that has all three types of information desired by the Nature Conservancy imbedded within it

* Difficult to say such a complex phenomenon can be quantified by a single value, but here the resulting index has great significance

Implementation



Implementation

- Perhaps the most important aspect to this analysis is determining the critical value

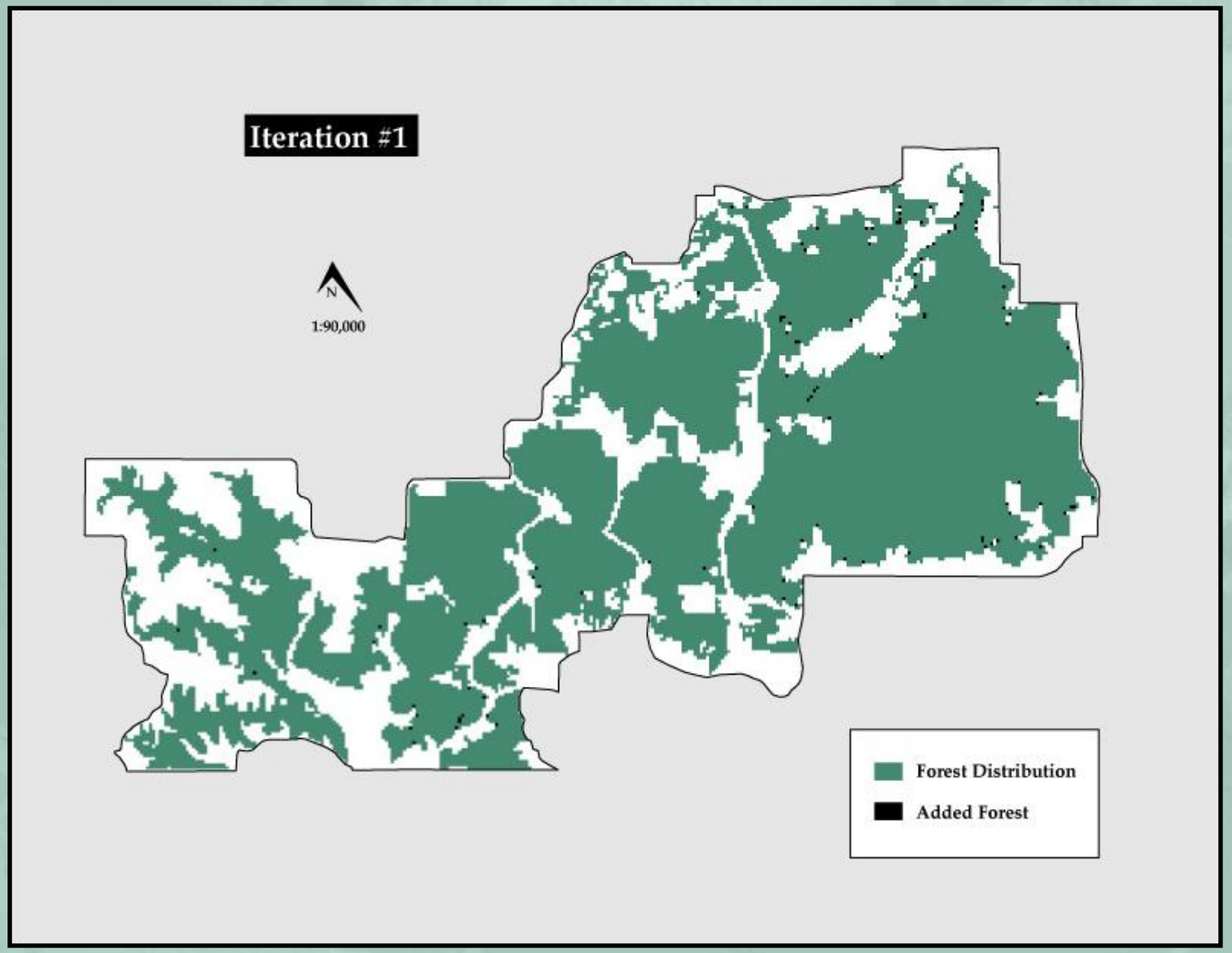
* What do the index values mean?

* Found a natural break between 6 and 6.25

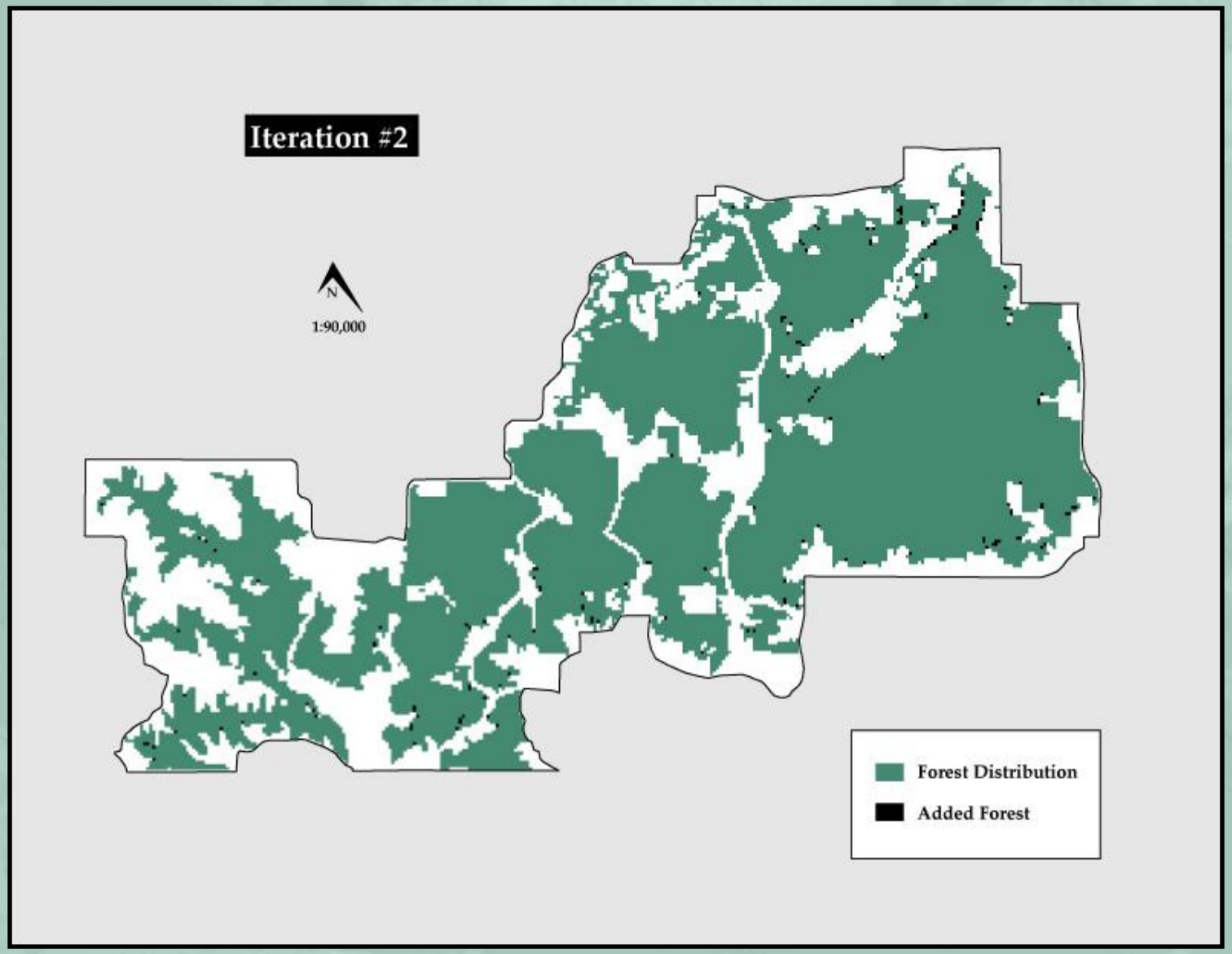
- Once the critical value is determined, we run as many iterations necessary to gather the desired amount of acreage for reforestation

* The Nature Conservancy has budgeted for 800 acres in the next 10 years.

Implementation



Implementation



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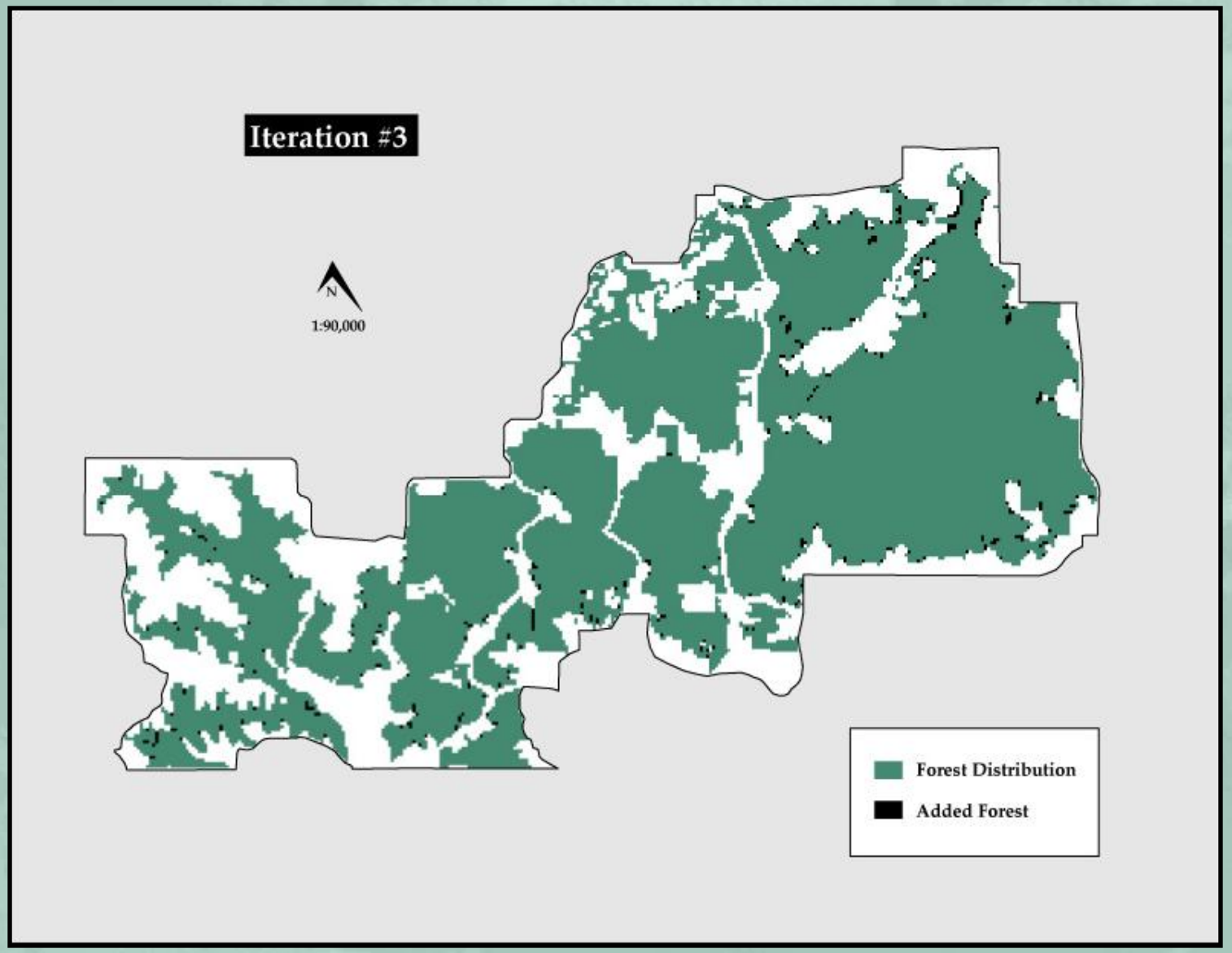

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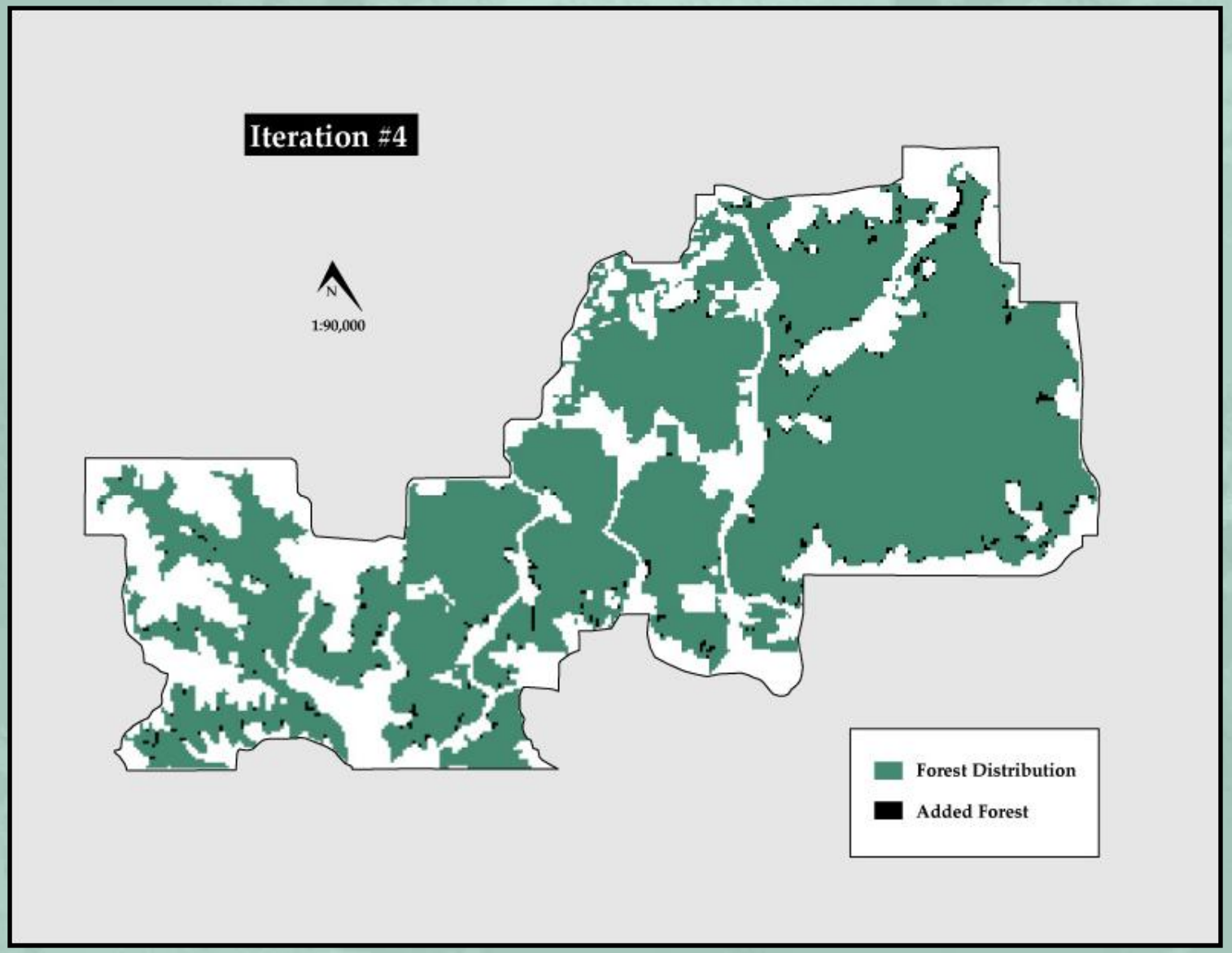

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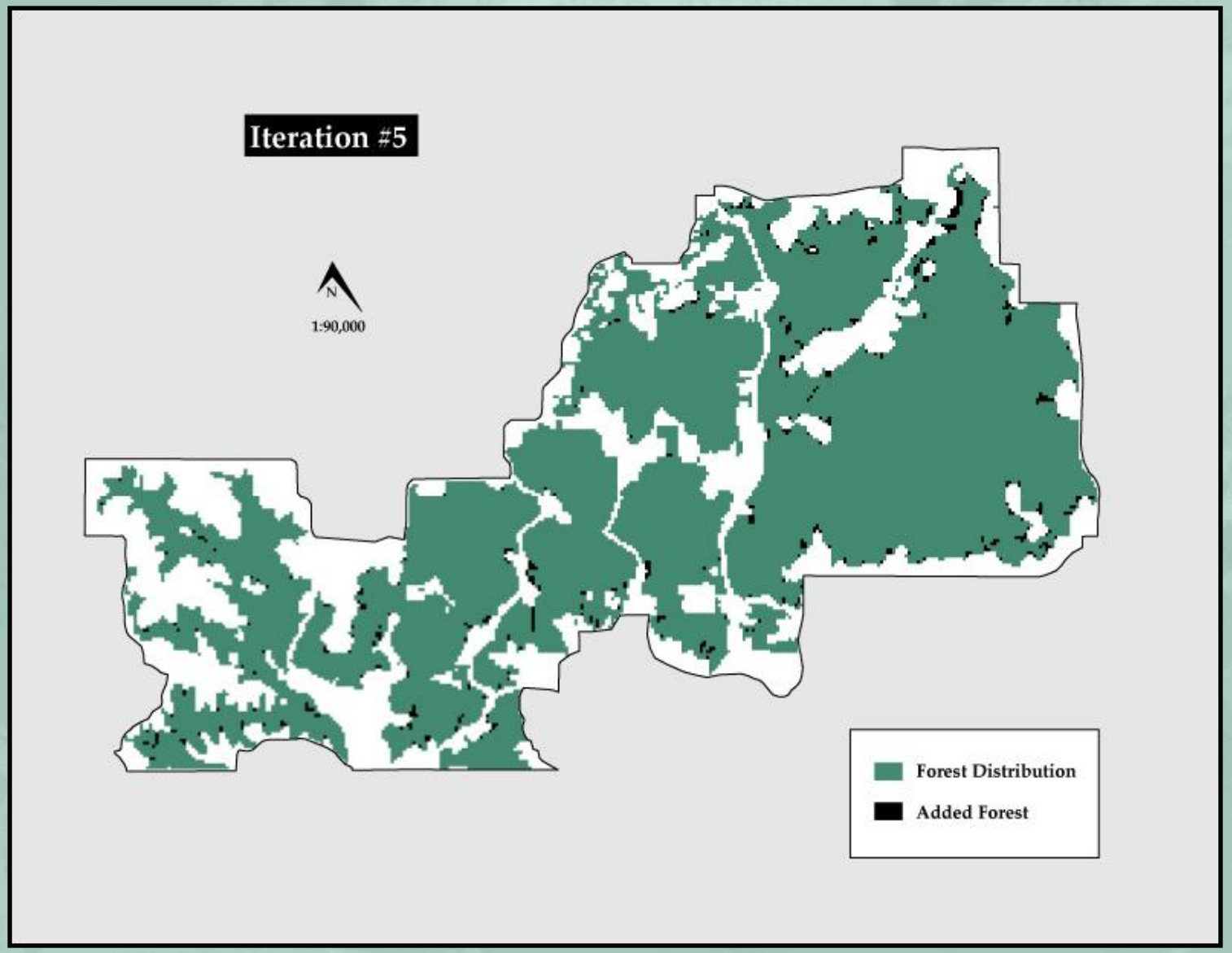

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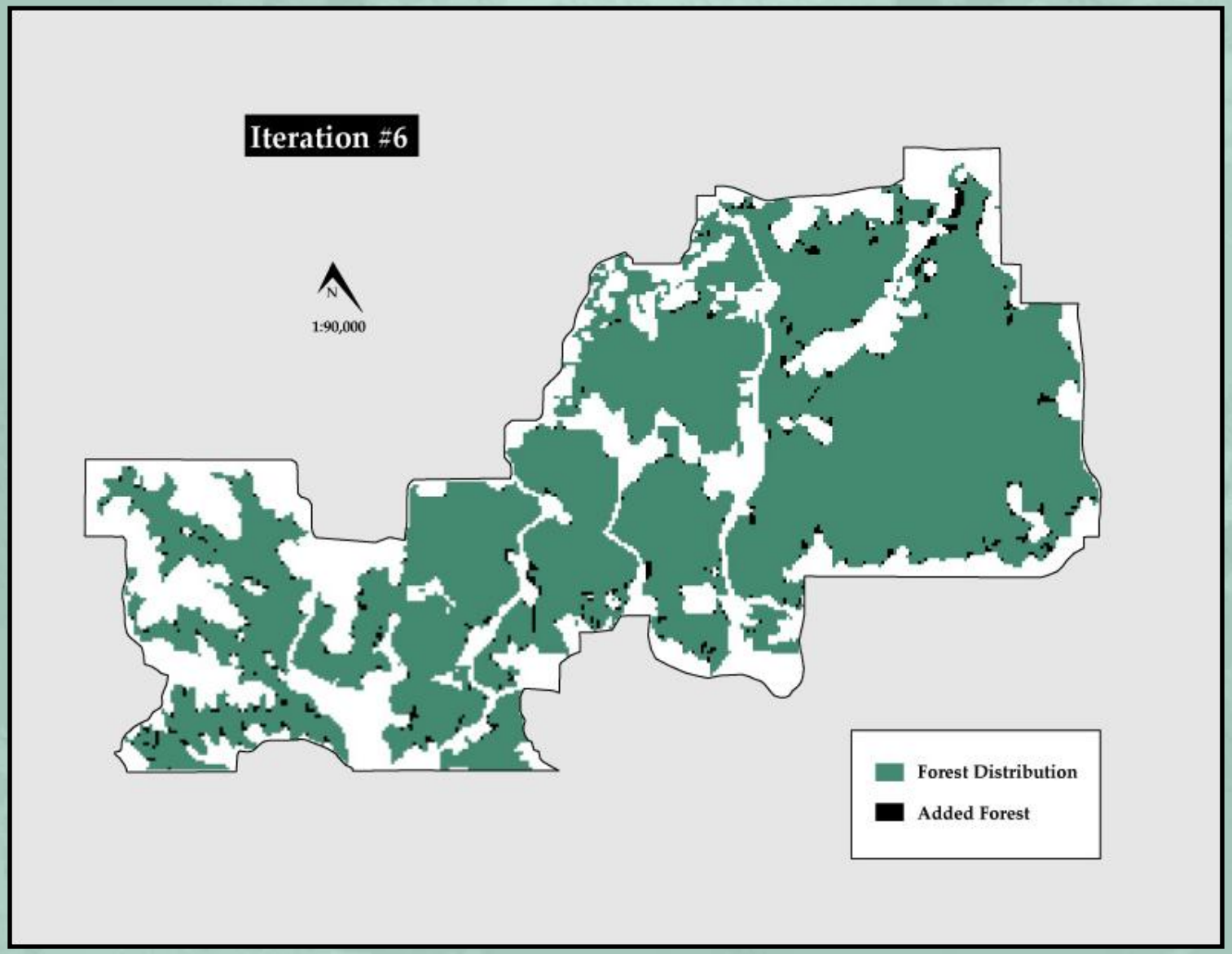

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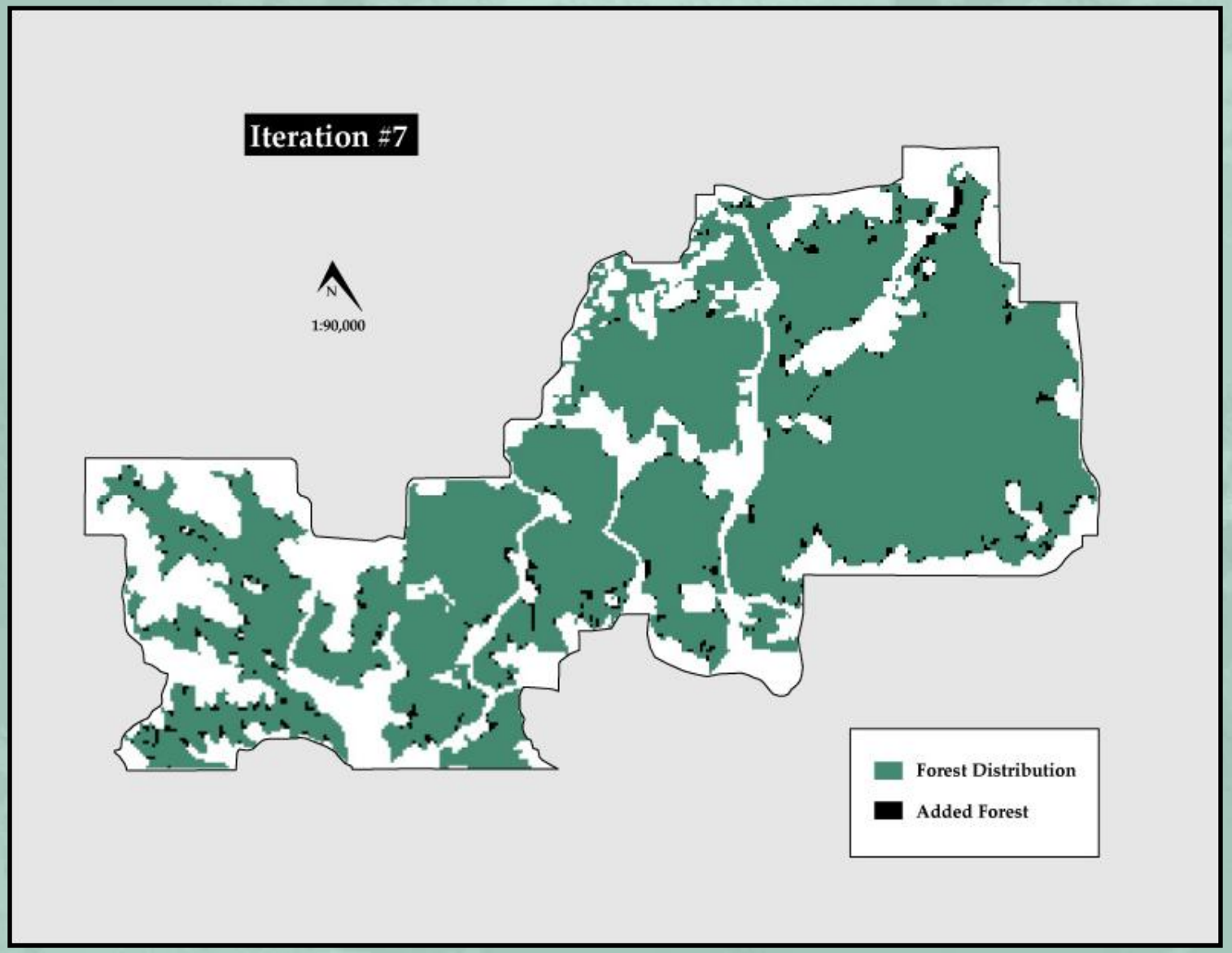

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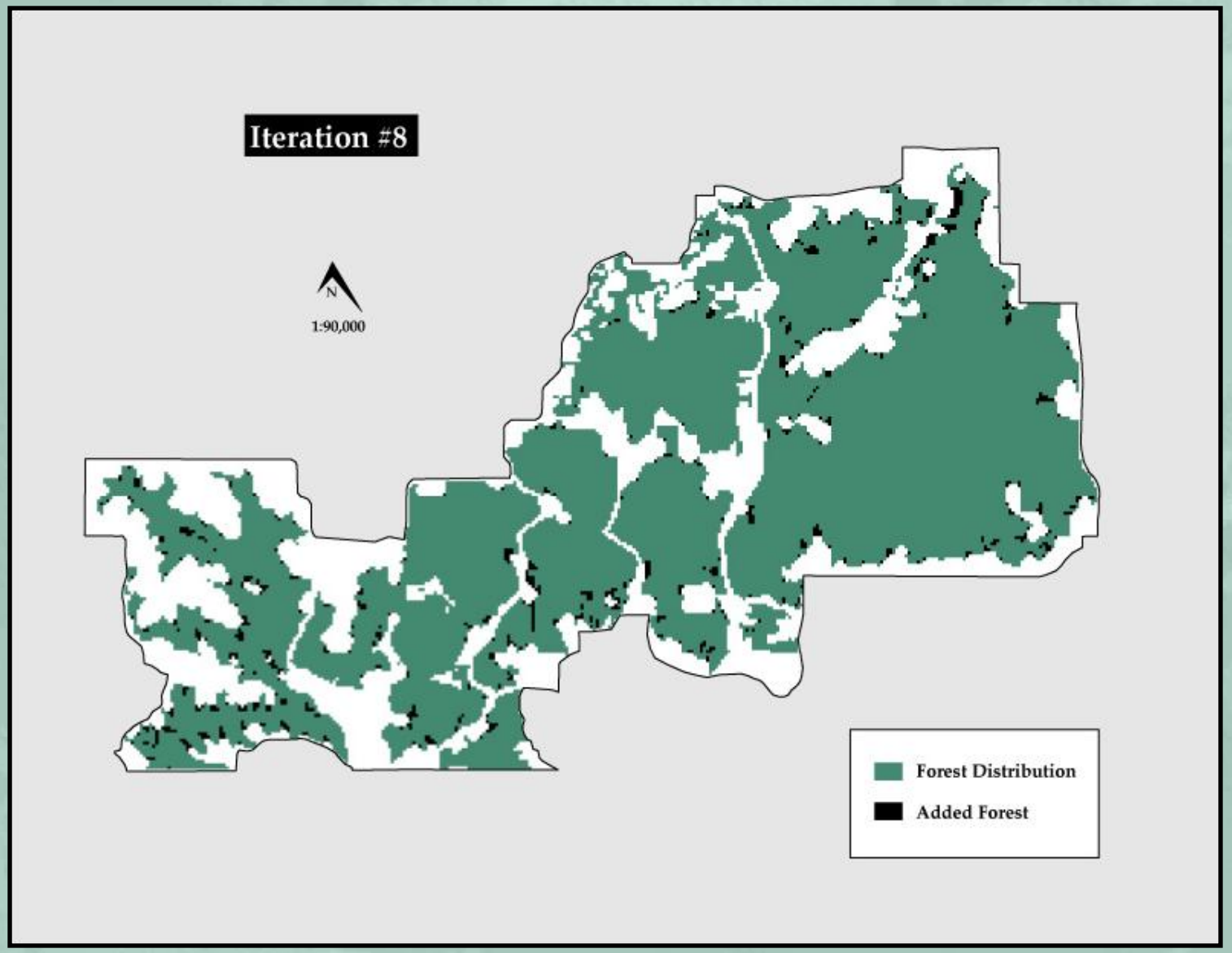

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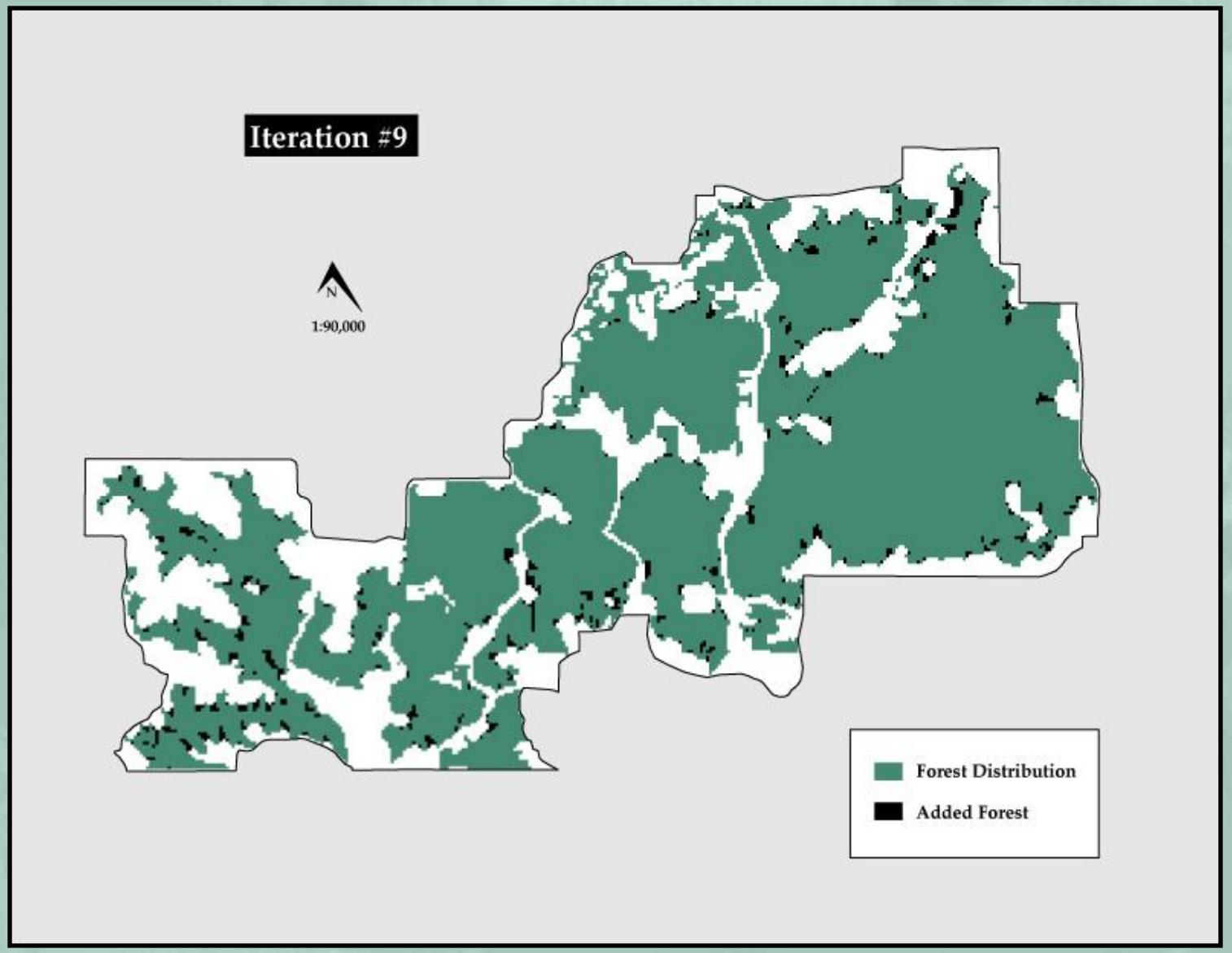

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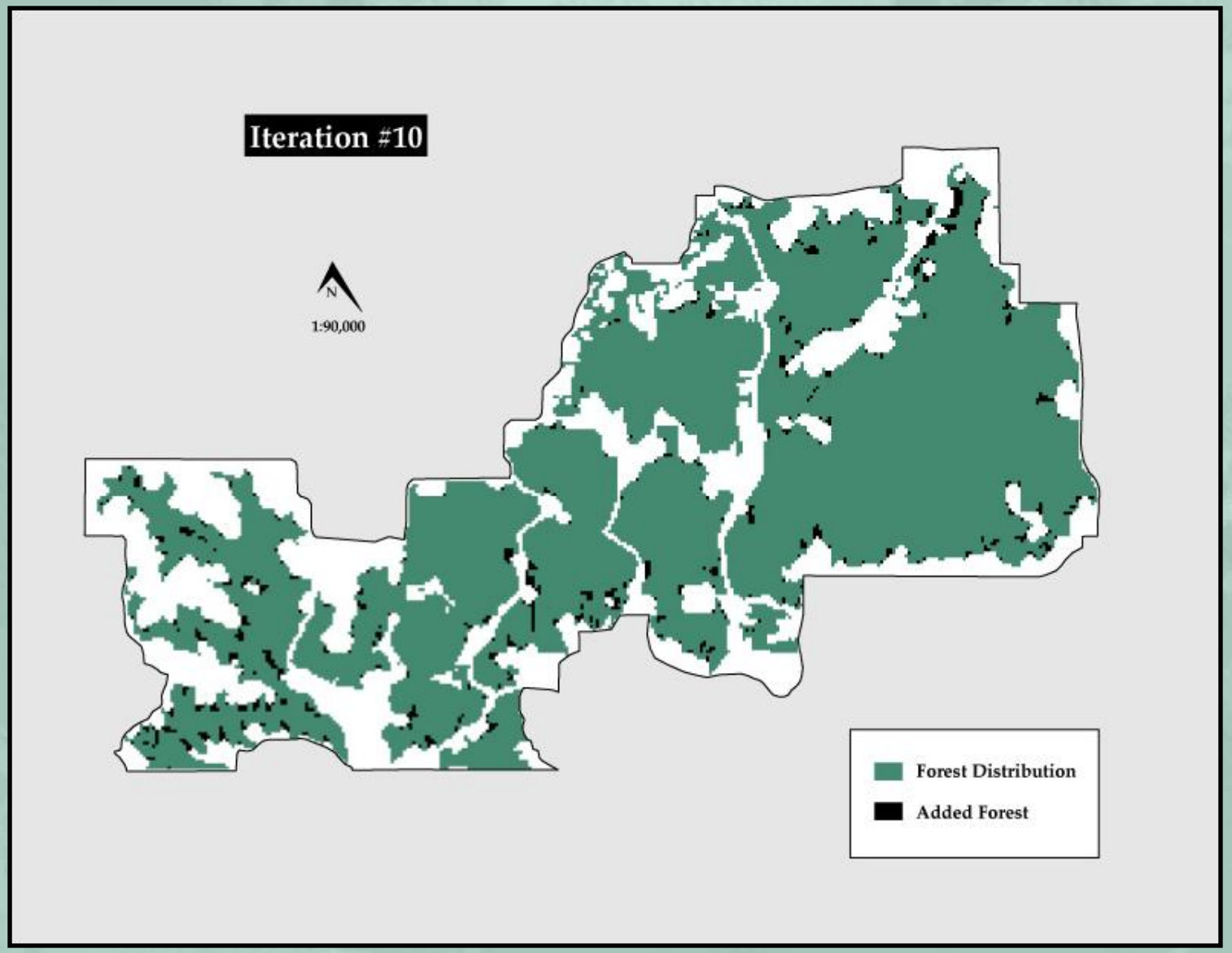


Results

- The analysis suggests 950 acres total

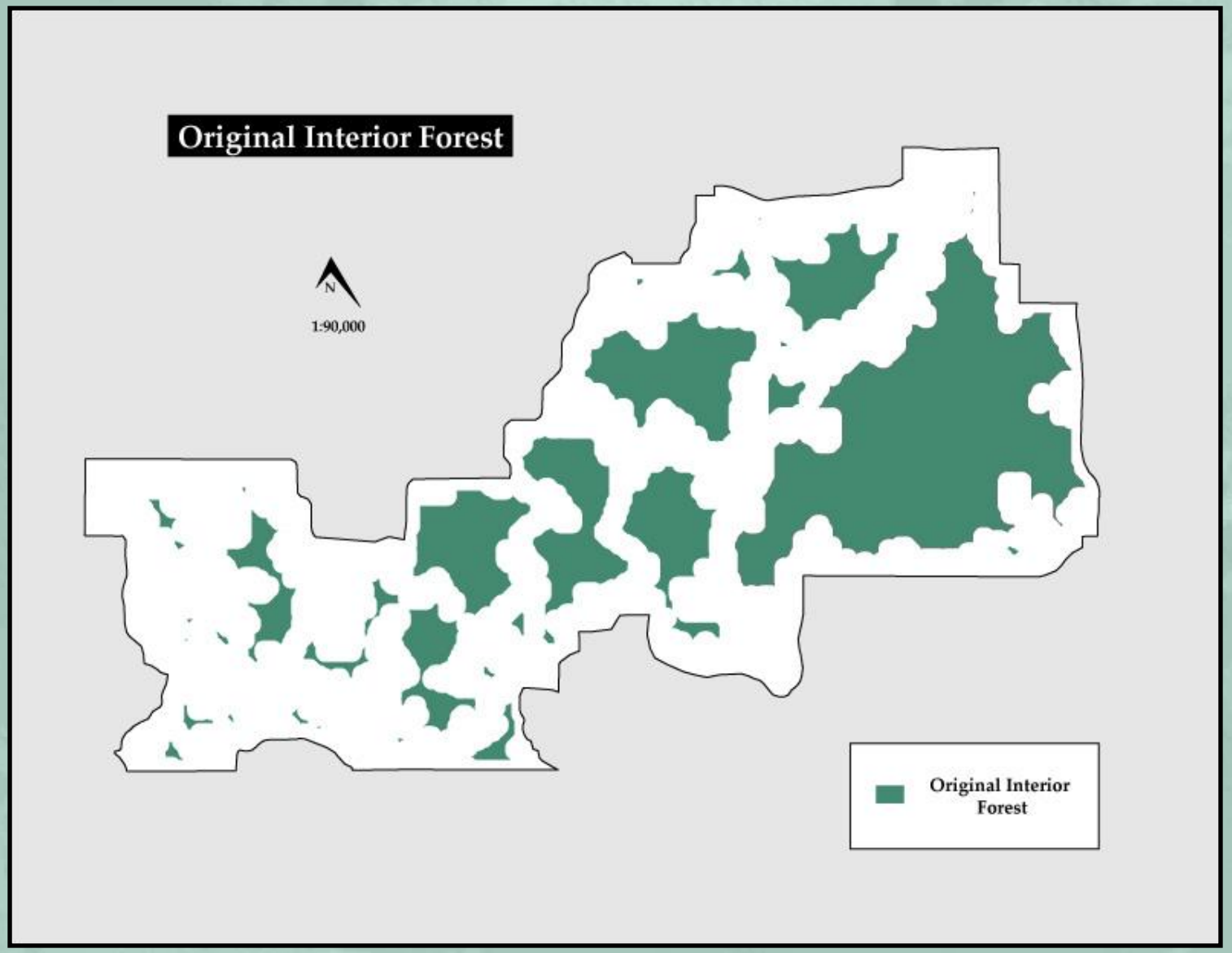
* The Nature Conservancy will use ground-truthing to further reduce this amount to the allocated 800 acres

- So does this approach work?

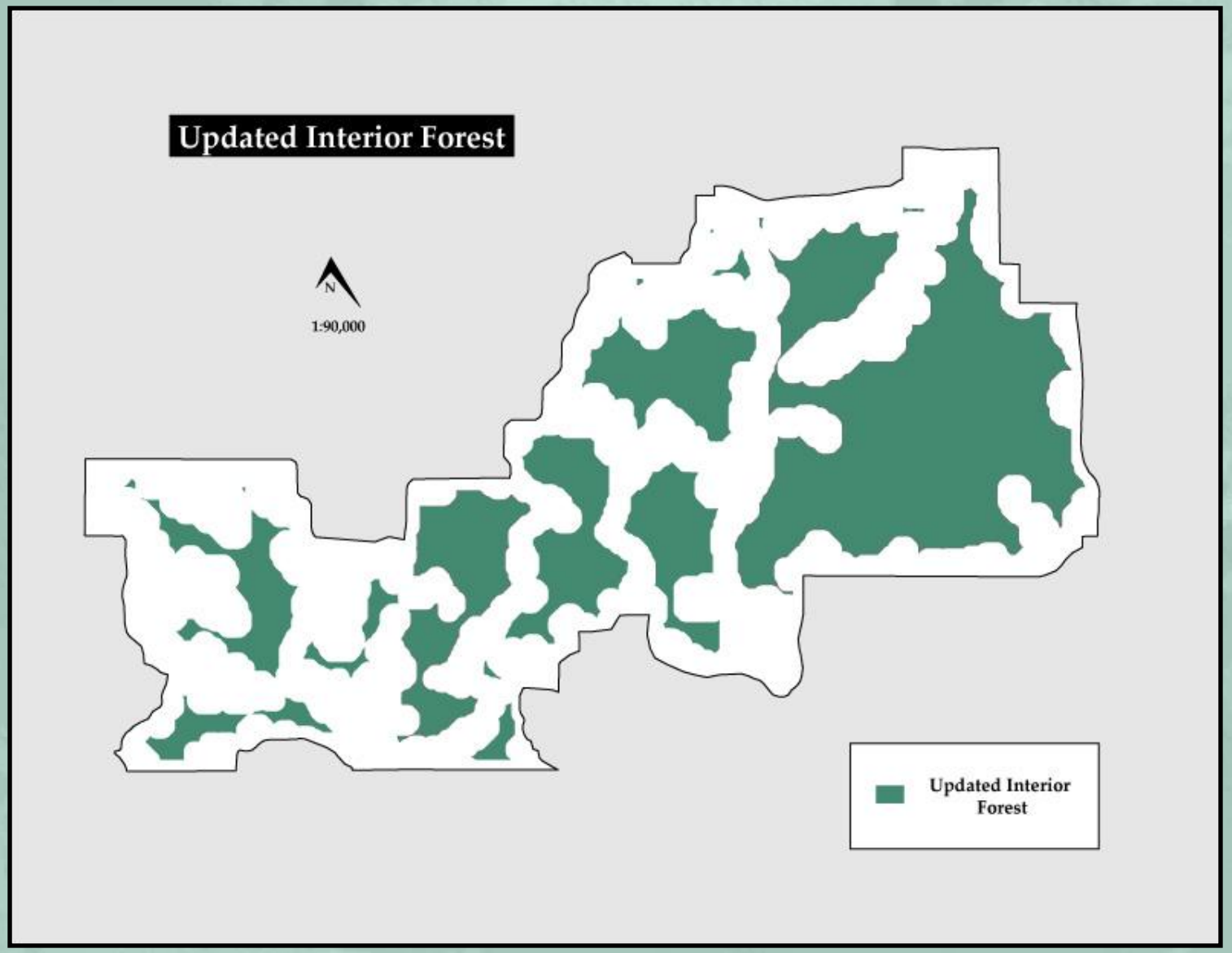
* We cannot just look at the exterior forest edge

* Compare the amount of interior forest we originally had to the amount of interior forest we added through our analysis

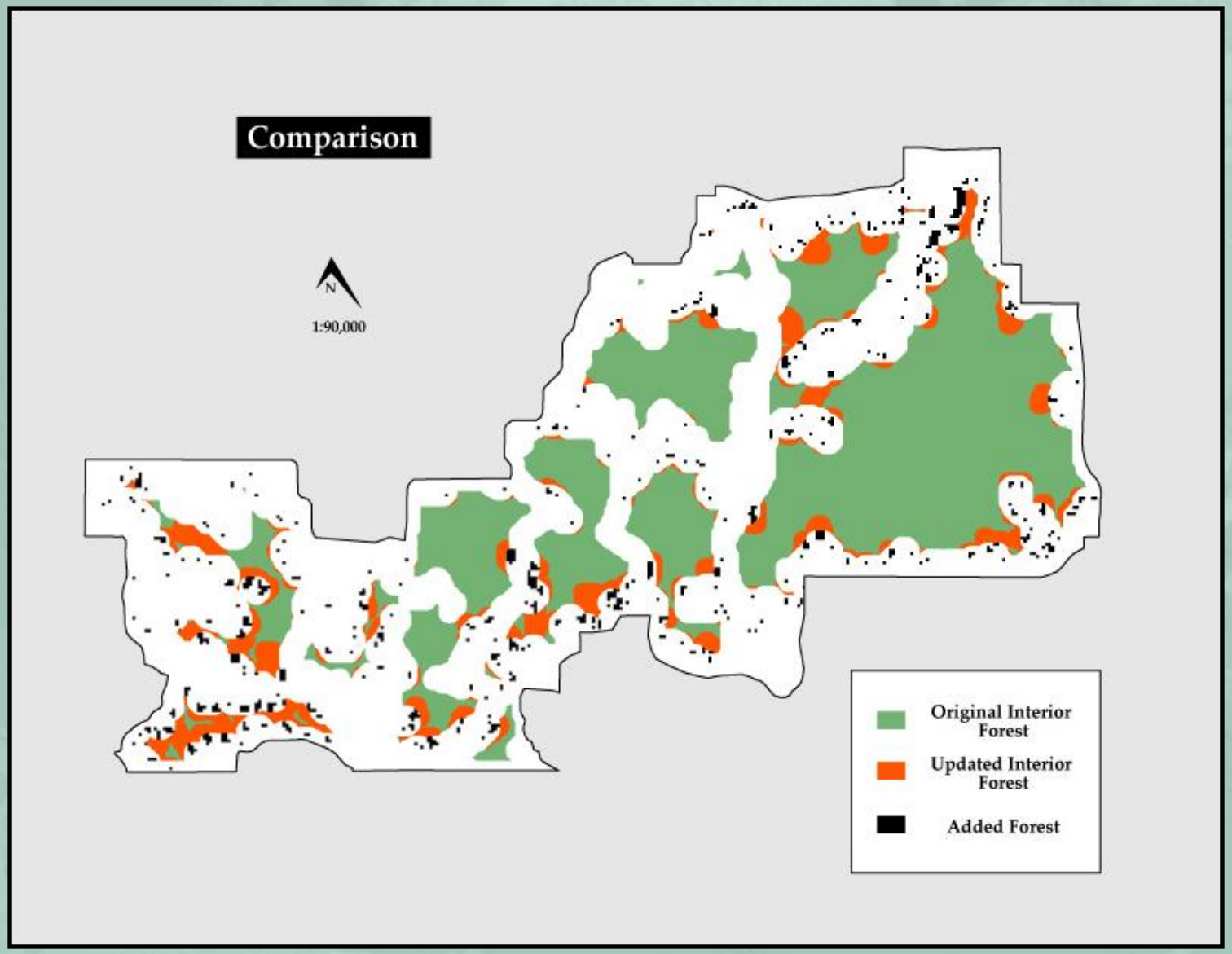
Results


Original Interior Forest
N
1:90,000
Original Interior Forest

Results



Results


Comparison
N
1:90,000
Original Interior Forest
Updated Interior Forest
Added Forest

Results

- Findings:

*Original Interior Forest: 11,186.81 acres

*Updated Interior Forest: 13,413.89 acres

*Difference: 2,227.08 acres

- Thus, because we added 950 acres total, we got a 235% return on our reforestation

Questions?

~ Thank you for your time,
Robert