Ecological Restoration in a GIS Setting:

The Integration of Domain Knowledge into Spatial Analysis for Restoration Projects

Robert Roth | rereth@wisc.edu
Jesse Papez | jjpapez@wisc.edu

THE UNIVERSITY *of* WISCONSIN
MADISON

The Problem

- The Ecological Root:

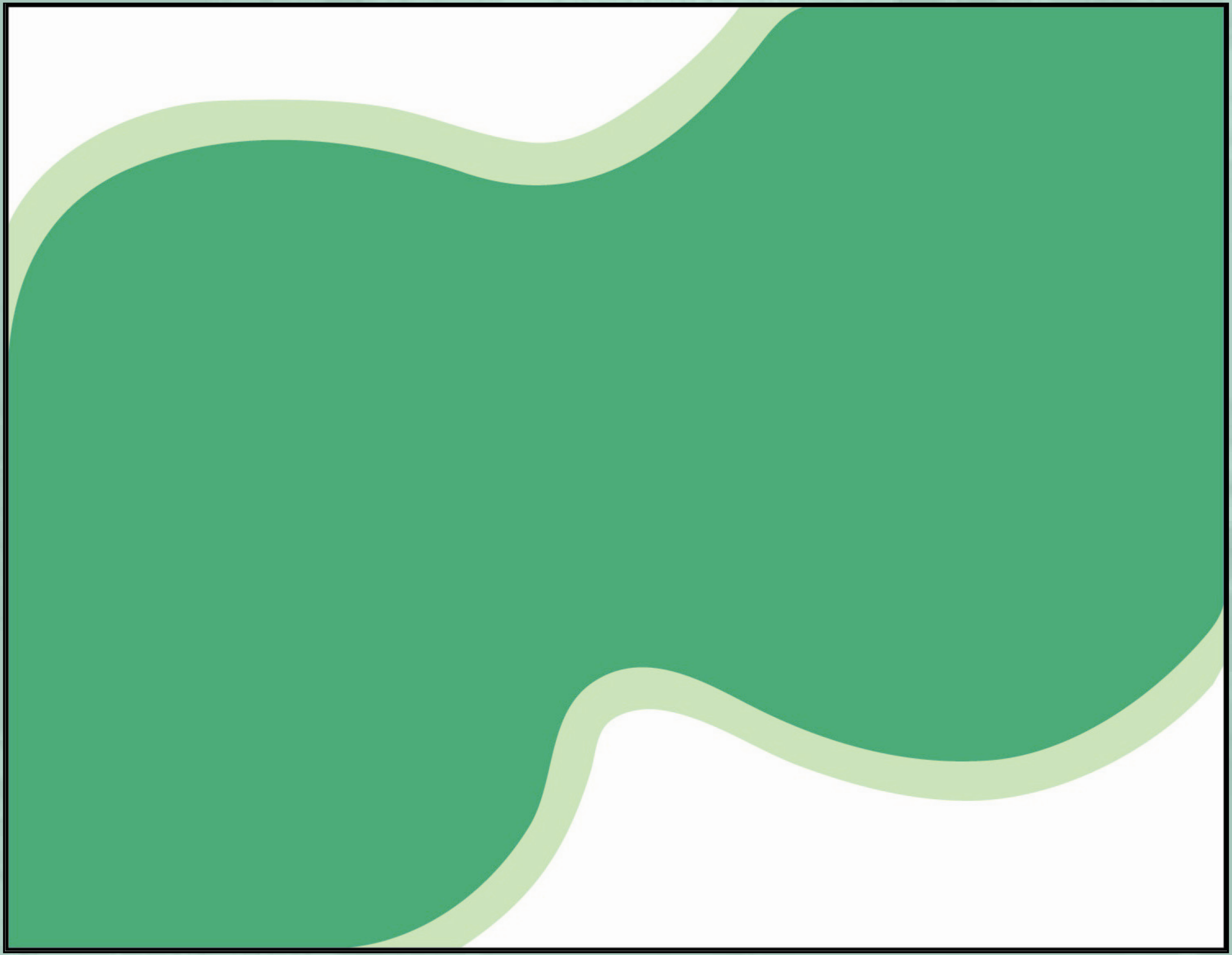
* ***Habitat fragmentation*** – the process of dividing a discrete, homogenous habitat into smaller, isolated patches

* ***Interior Area*** – lands far enough within a patch to eliminate the edge effects of increased predation and parasitism (200m from edge)

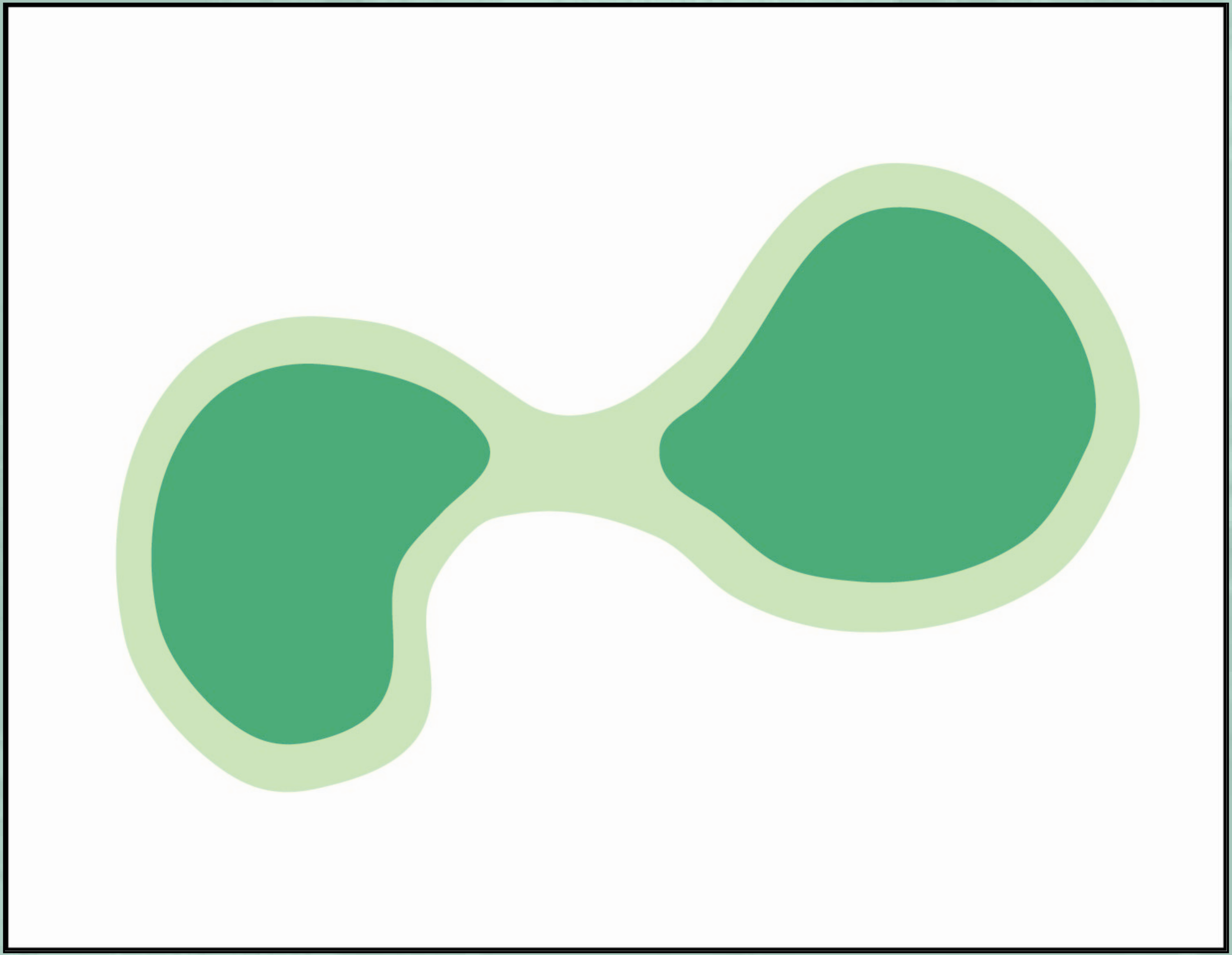
- It is the aim of a restoration project to decrease habitat fragmentation and increase interior area.

The Problem

The Problem



The Problem



The Problem

- **The problem becomes <u>where</u> to restore in order to get the an optimal improvement of fragmentation and interior area**

  *complicated further by context specific requirements

- **The AutoPASS method:**

  * *Auto*mated *P*atch *A*nalysis for *S*ite *S*election

  * AutoPASS integrates domain knowledge into an objective, geometric analysis of the spatial characteristics of patches to prioritize the importance of selecting particular sites for restoration

The AutoPASS method

Compactness as a foundation

- **To reduce fragmentation, the shape of the patch must be reduced in complexity**

  * The idea is that we want to reduce the perimeter where edge effects occur, while increasing the interior area for habitation.

- **To do so, shape must be quantified**

  * ***Compactness Ratio*** – a ratio of the area of a shape to its perimeter

$$C = \frac{\sqrt{Area}}{.282 * Perimeter}$$

Where:
0 = a line
1 = a circle

The AutoPASS method

Compactness as a foundation

- However, the compactness ratio alone is not enough

Problem #1.

*The compactness ratio is solely a summary statistic, and will only show if a change is for better or worse (never where to actually make the change)

- Leads us to an impractical and time-consuming "trial and error" approach to selecting sites

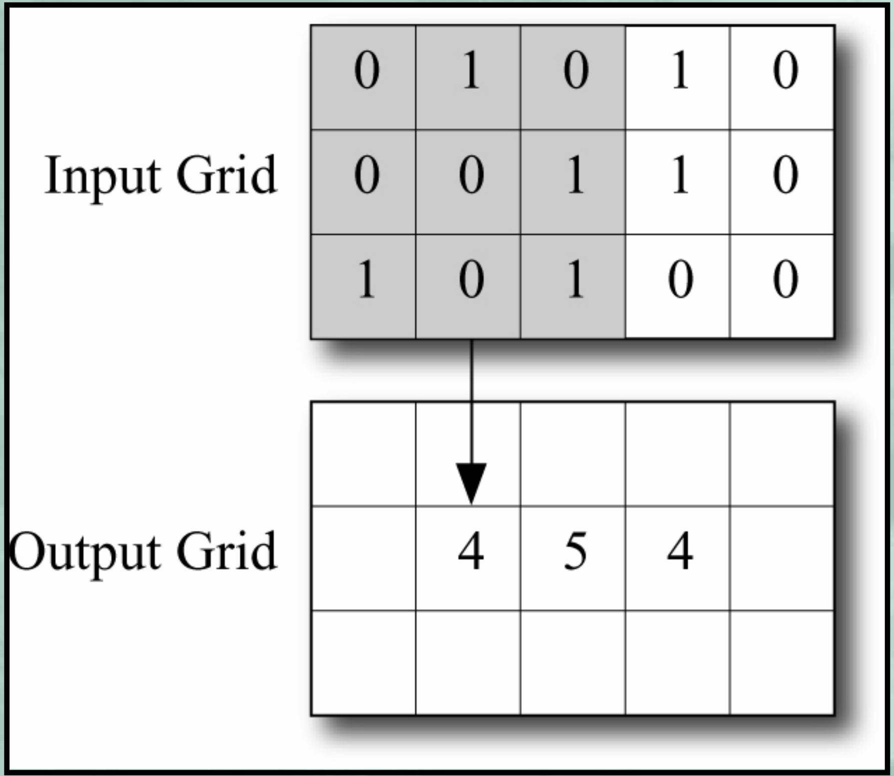
Problem #2

*There is no way to integrate domain knowledge into the shape analysis

The AutoPASS method

Shape prioritization using convolution

- **To analyze shape locally, we developed a convolution strategy to produce a shape prioritization grid**



* The patch boundaries are first rasterized and the pixels codified as follows:

0 = pixels not within the patch
1 = pixels within the patch

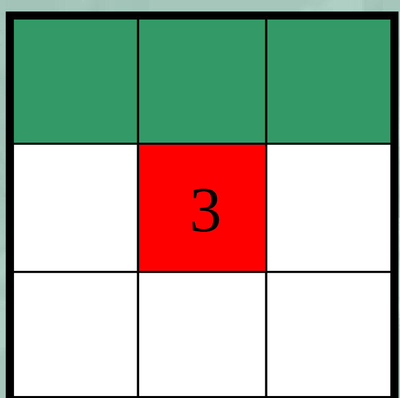
* A 3x3 kernel is then convoluted throughout the binary grid with the sum of the nearest neighbors placed in the center pixel

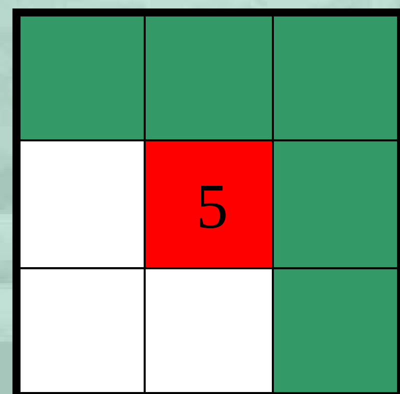
The AutoPASS method

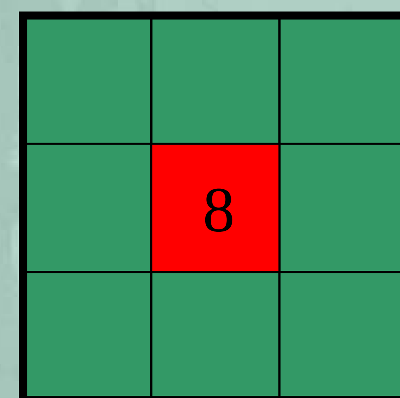
Shape prioritization using convolution

- There is a direct relationship of the focal sum to the compactness ratio

* Solution to problem #1







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

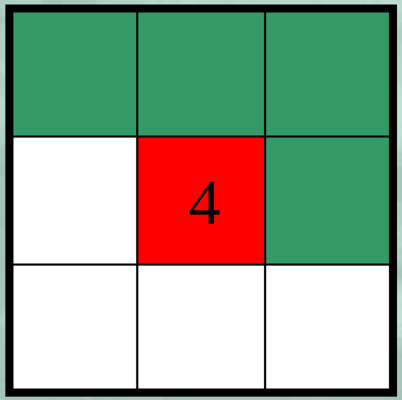
EX3. The addition of the center actually removes four sides of perimeter while still adding one pixel of area

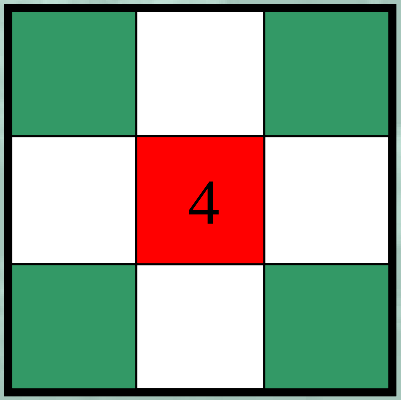
The AutoPASS method

Shape prioritization using convolution

- Problem of ambiguous focal sums

* Reason a 3x3 window is preferred





EX4. The addition of the center pixel adds one pixel of area, but does not add any perimeter

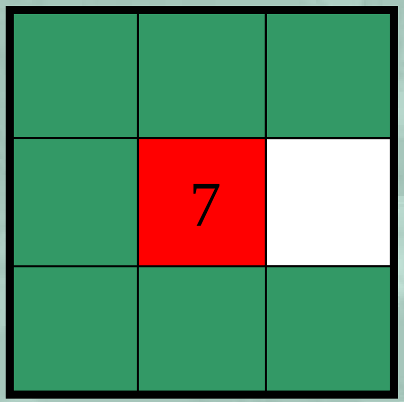
EX5. The addition of the center pixel adds one pixel of area as well as four new sides of perimeter

The AutoPASS method

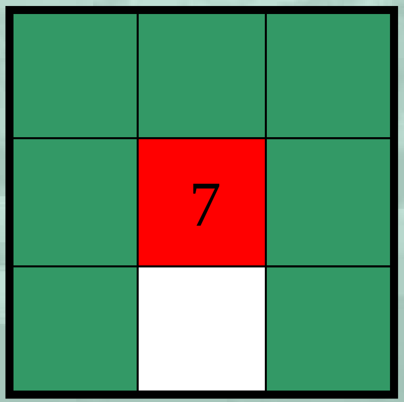
Shape prioritization using convolution

- Need to have a critical value that ensures an improvement in compactness

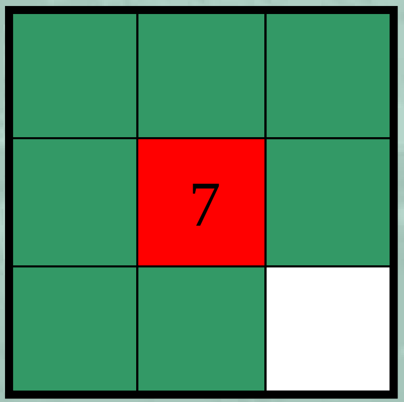
* Focal sums of 7 or more guarantee this
* Because of such a high value, the method is iterative, allowing recommended pixels to aggregate



EX6. The addition of the center pixel removes two sides of perimeter by only adding one pixel of area



EX7. The addition of the center pixel removes two sides of perimeter by only adding one pixel of area



EX8. The addition of the center actually removes four sides of perimeter while still adding one pixel of area

The AutoPASS method

Integration of domain knowledge

- **Using a raster calculator, the shape prioritization grid can then be adjusted based on quantified domain knowledge**

  * Solution to problem #2

  * ***Multiplicative Criteria*** – non-shape attributes that increase the importance of selecting the site for restoration

  * ***Exclusionary Criteria*** – non-shape attributes that decrease the importance of selecting the site for restoration

The AutoPASS method

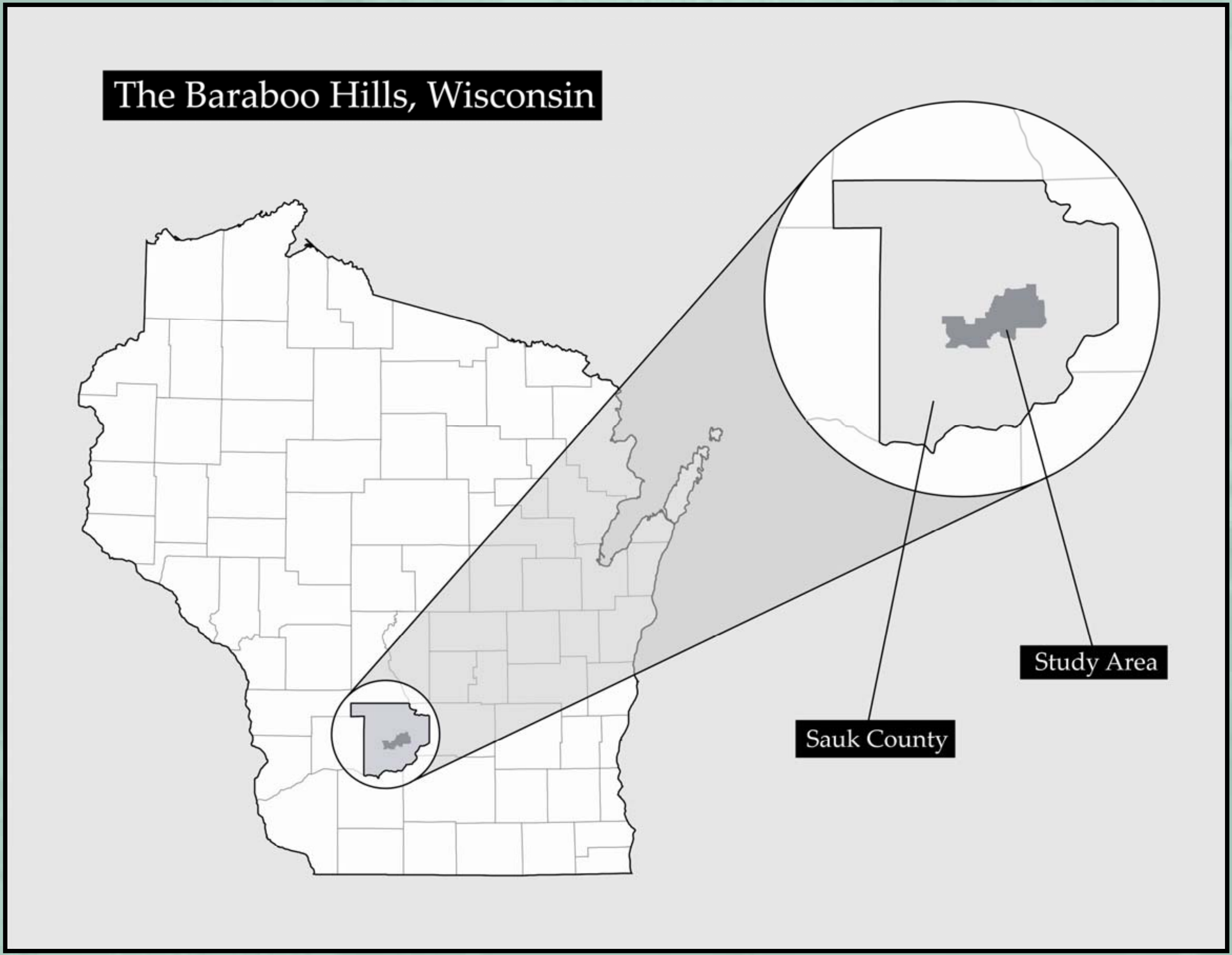
Integration of domain knowledge

- The final step is to select the appropriate critical value based on the multiplicative values used

- Continue iterations to allow for pixel aggregation until:

1. The desired amount of area to be restored is reached
2. There are no longer any pixels above t ecritical value threshold

The Case Study



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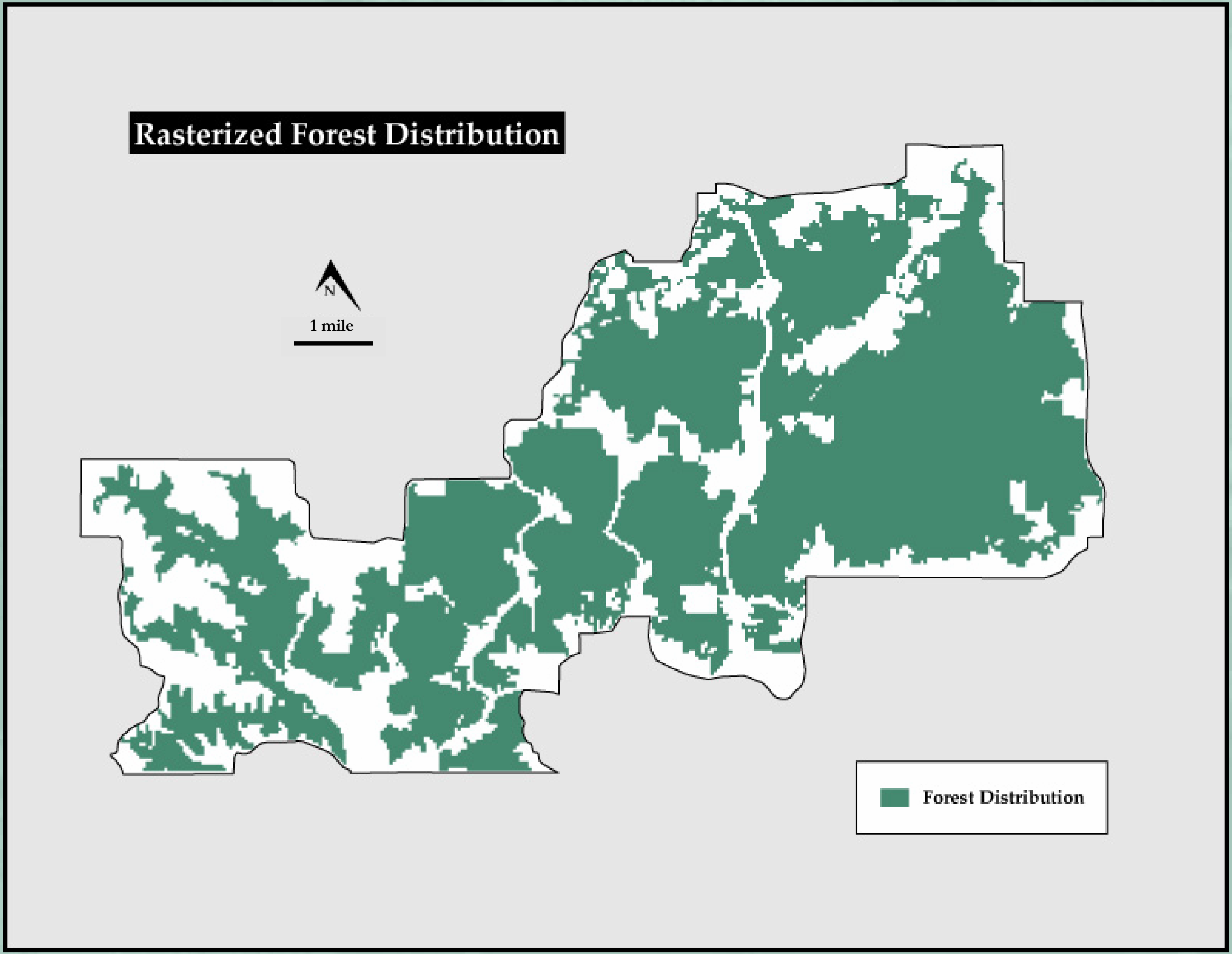

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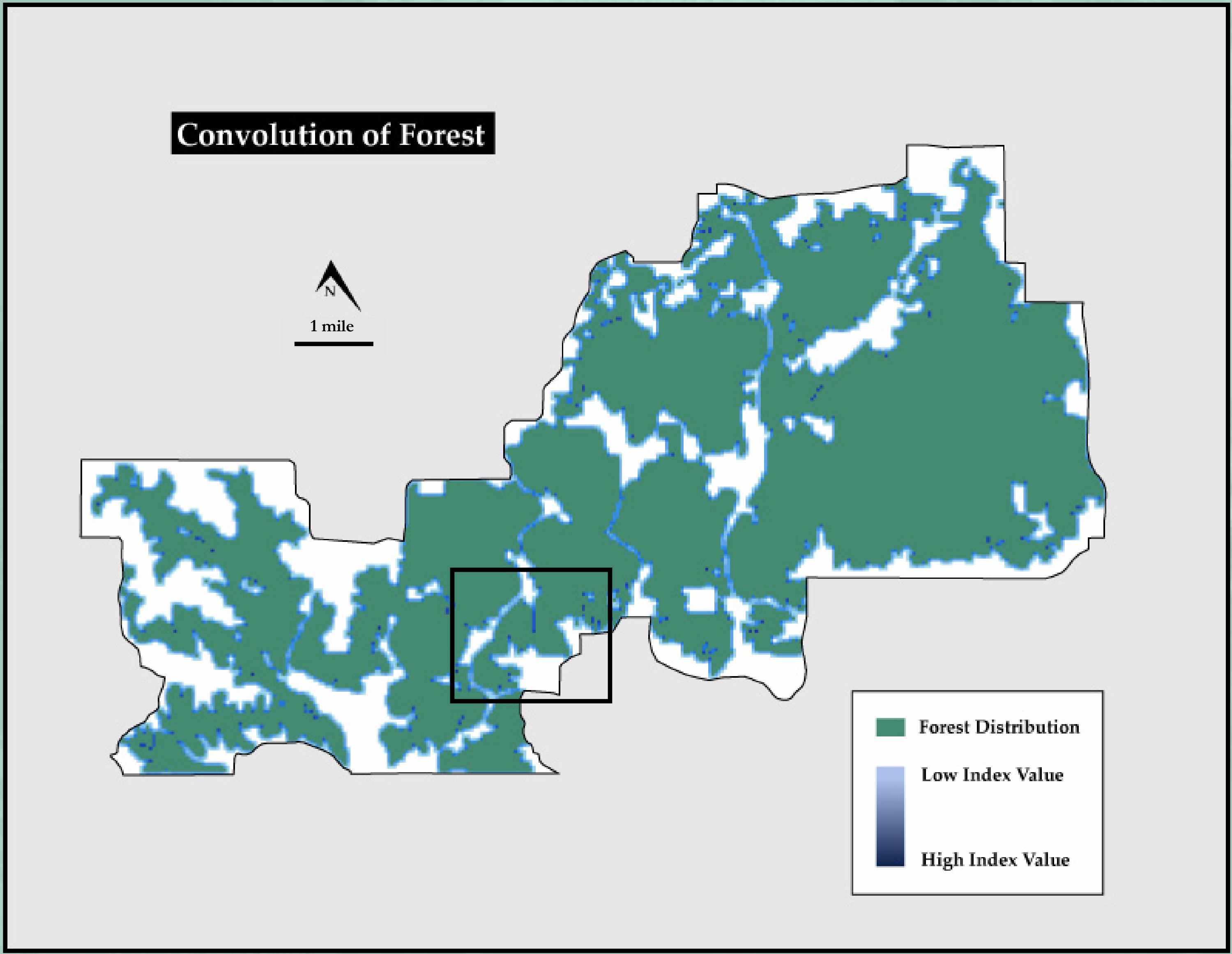

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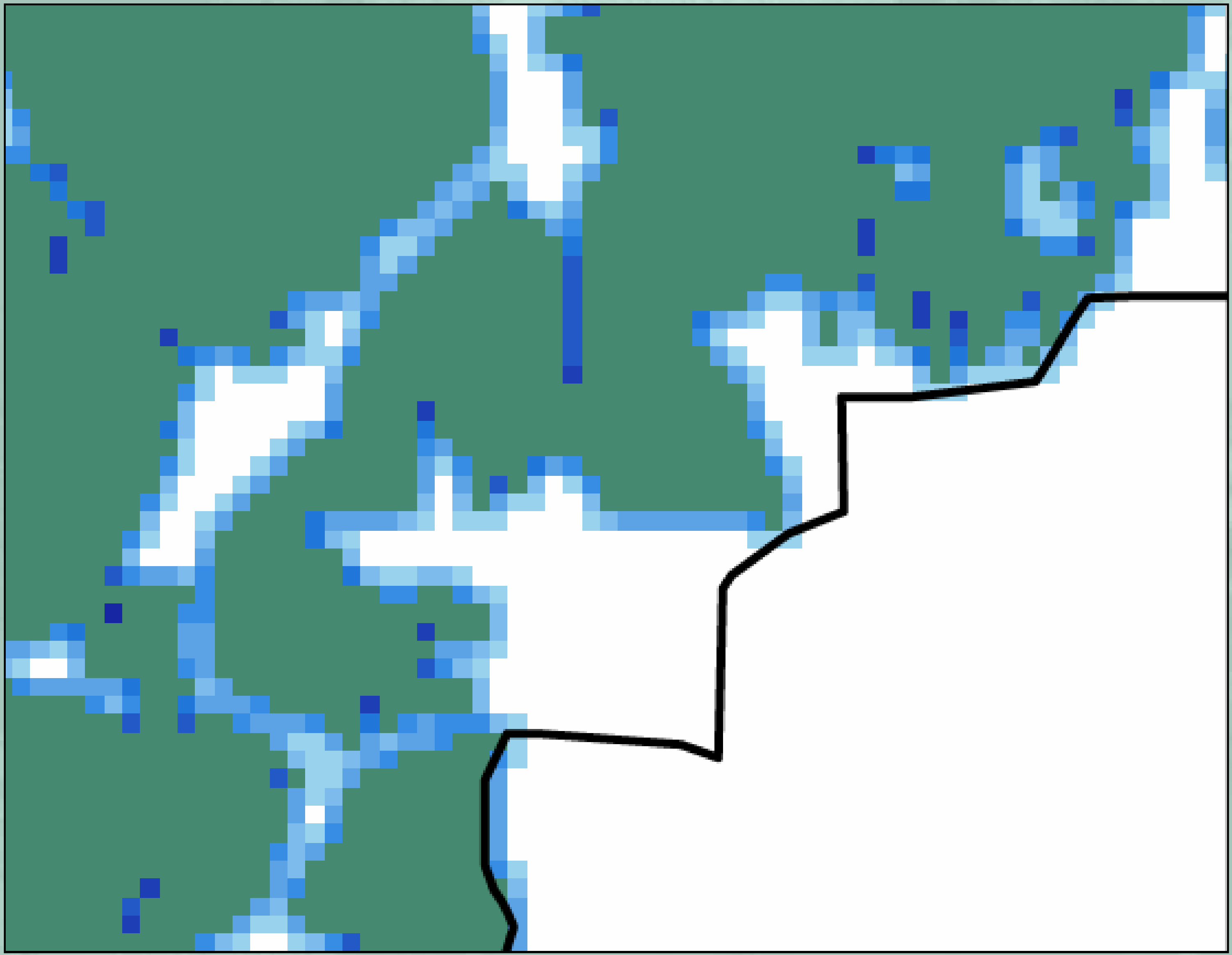

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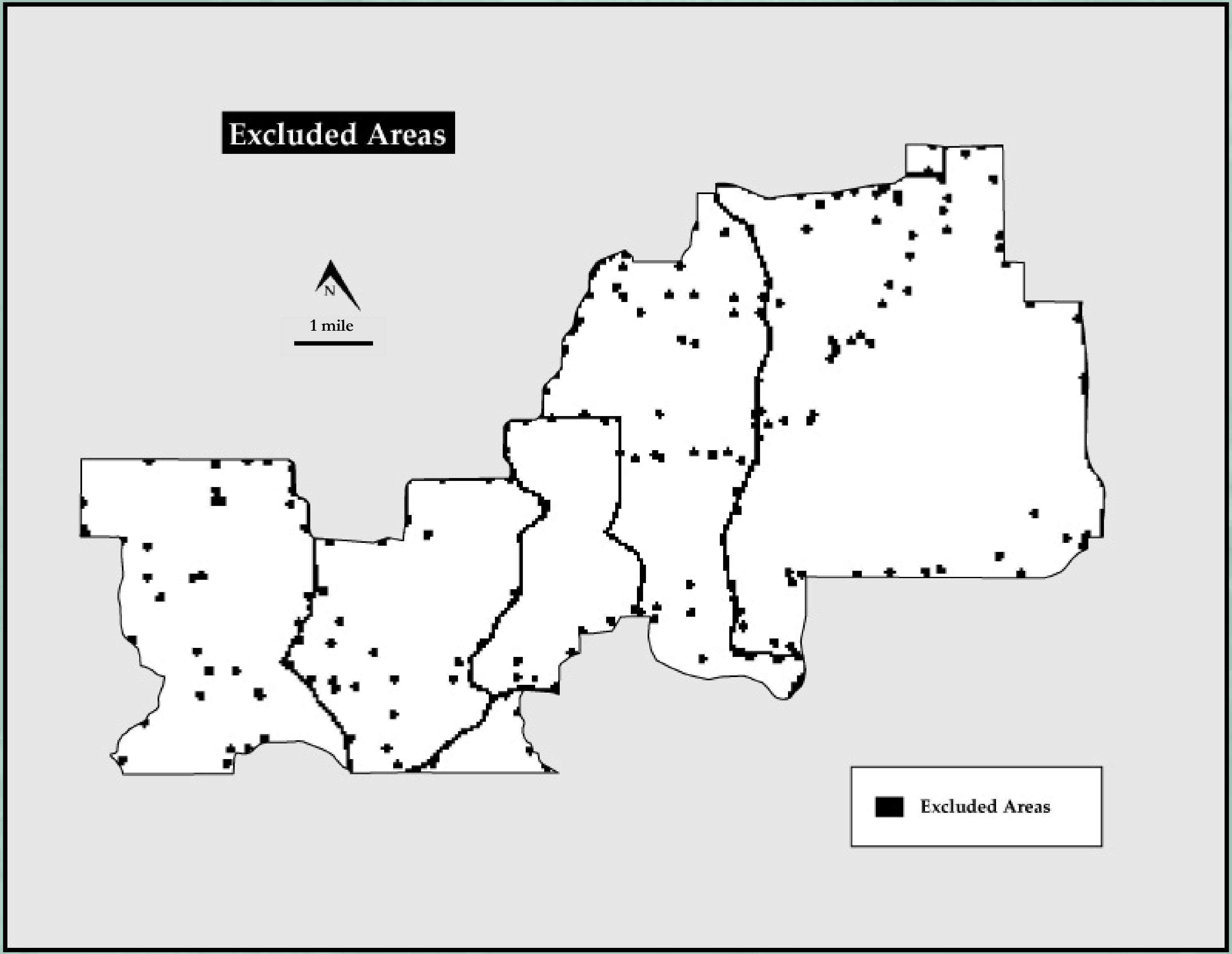

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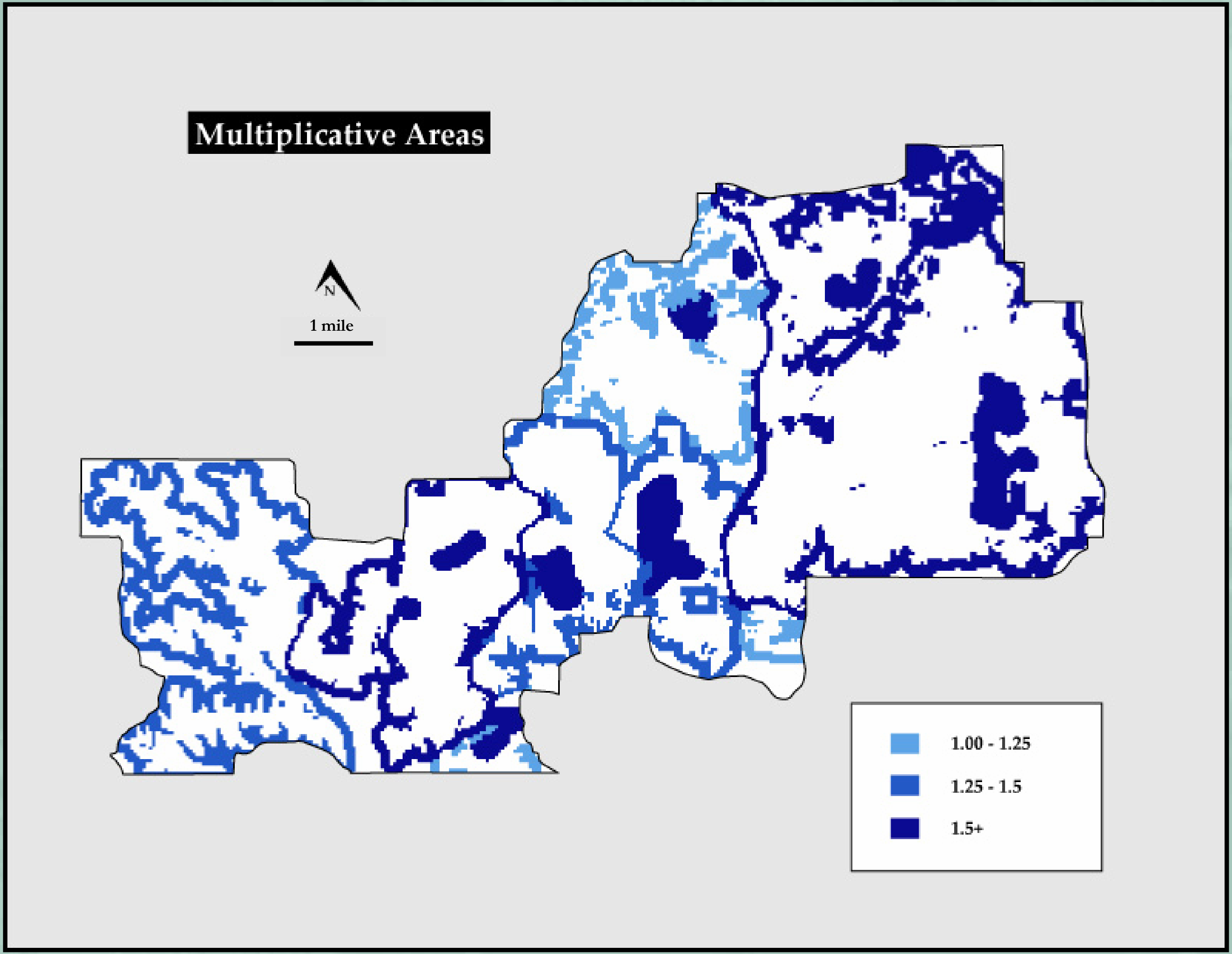

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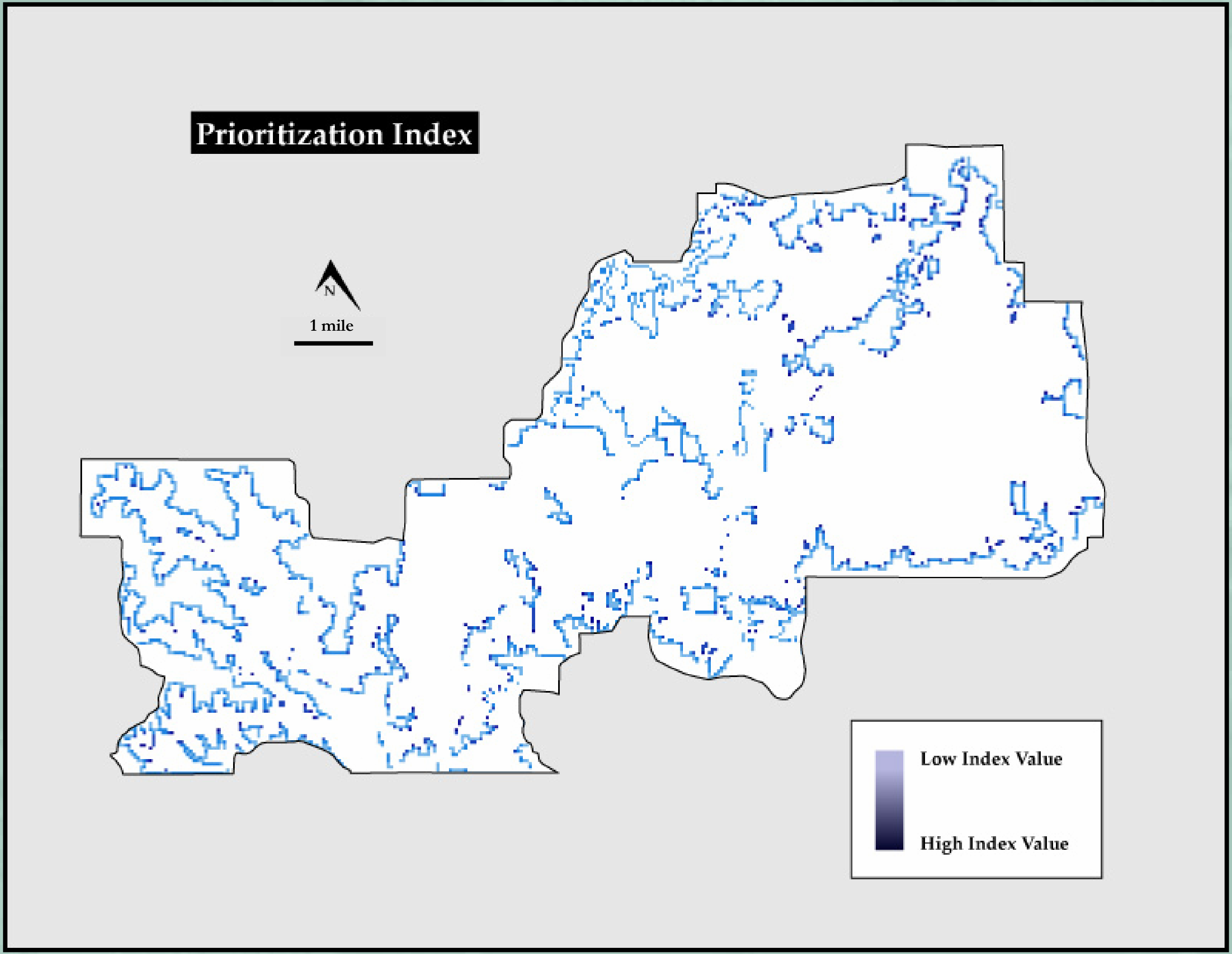

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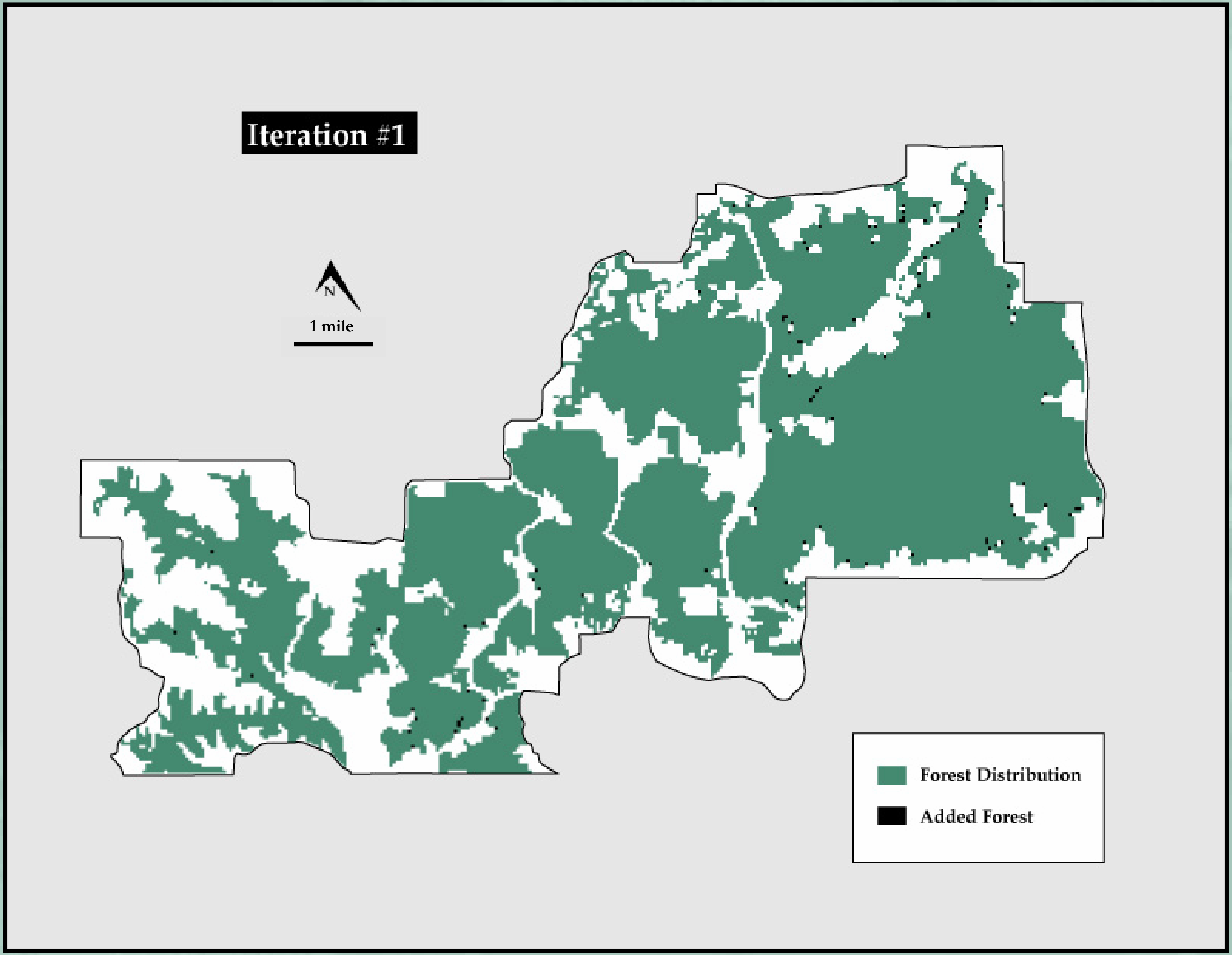

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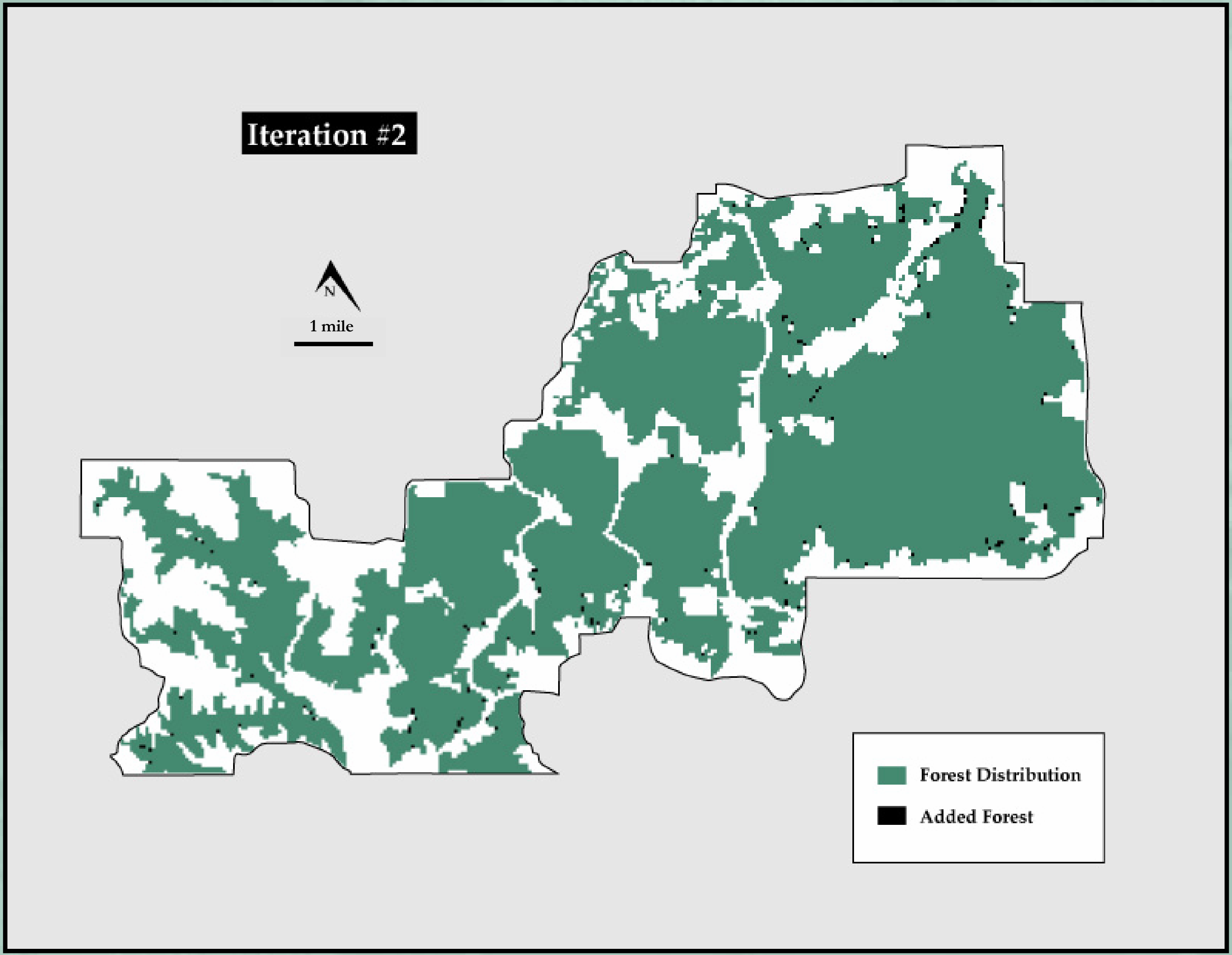

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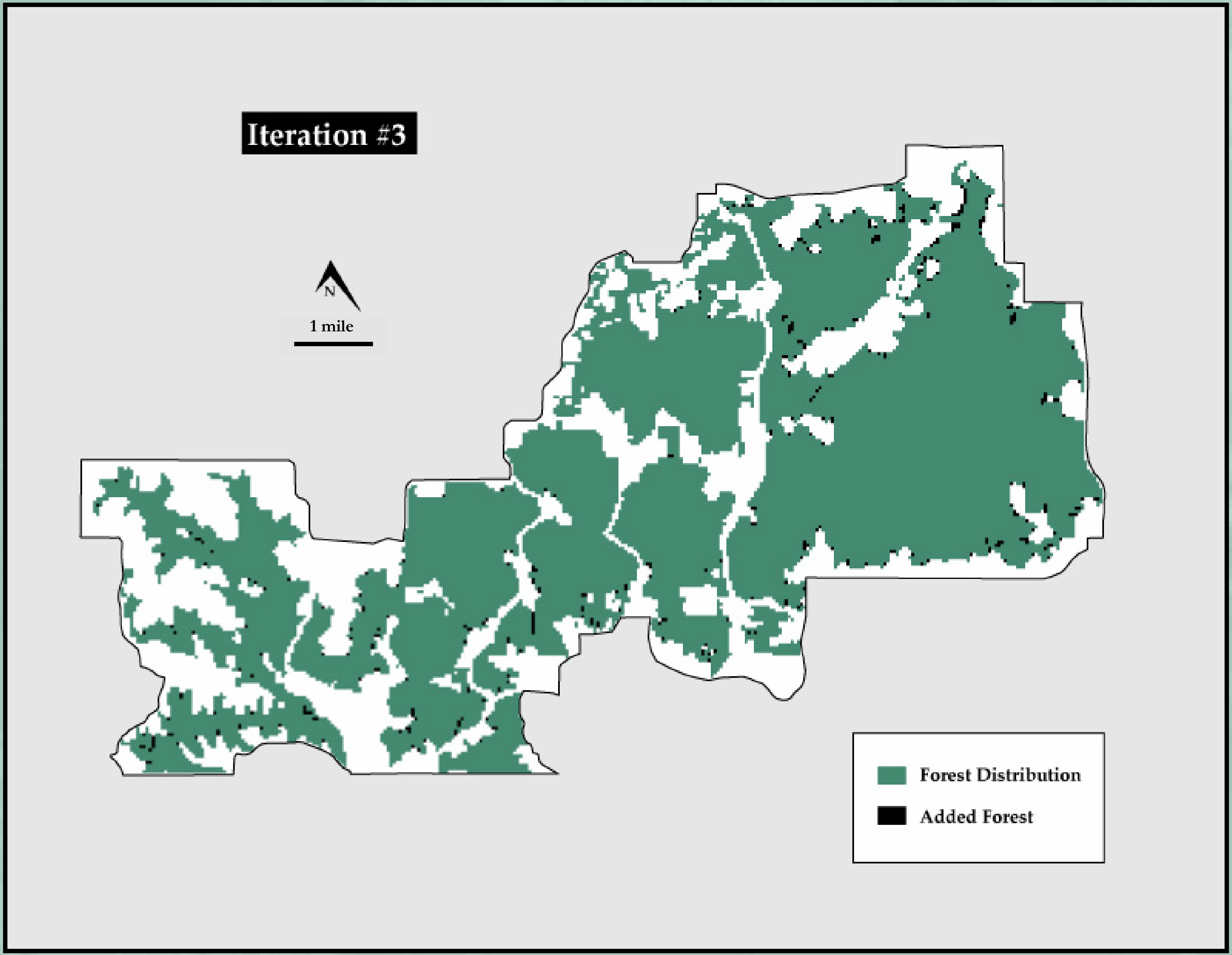

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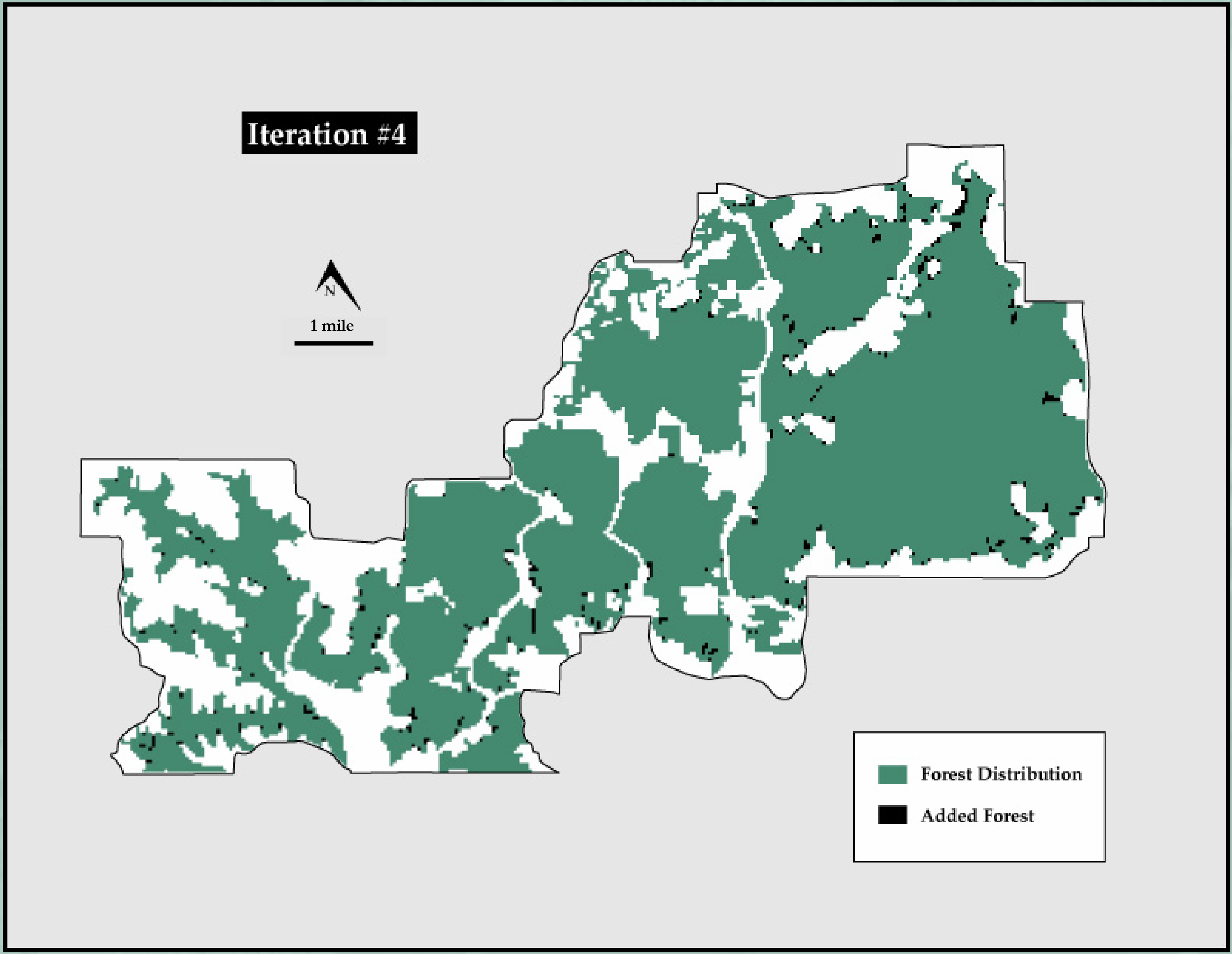

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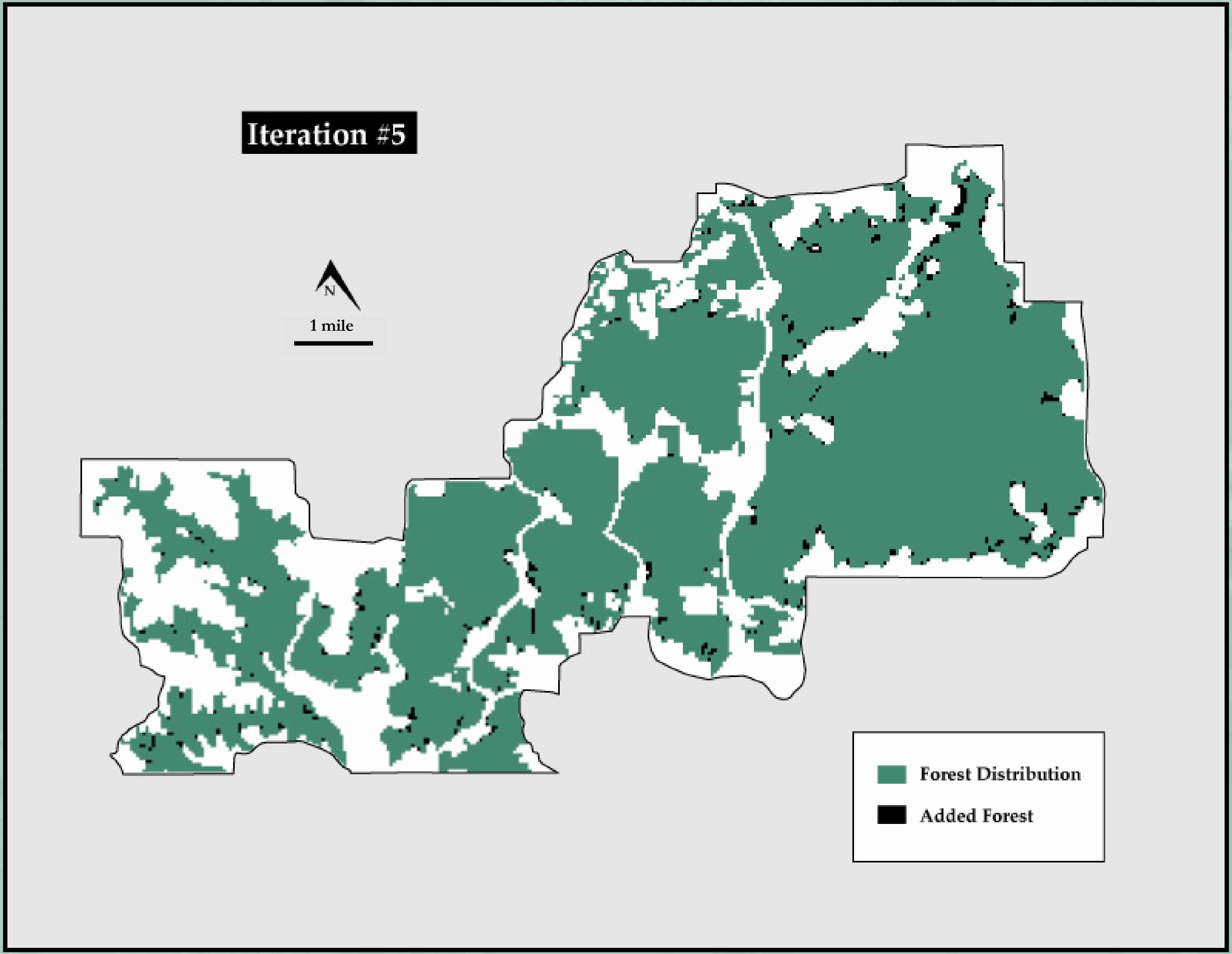

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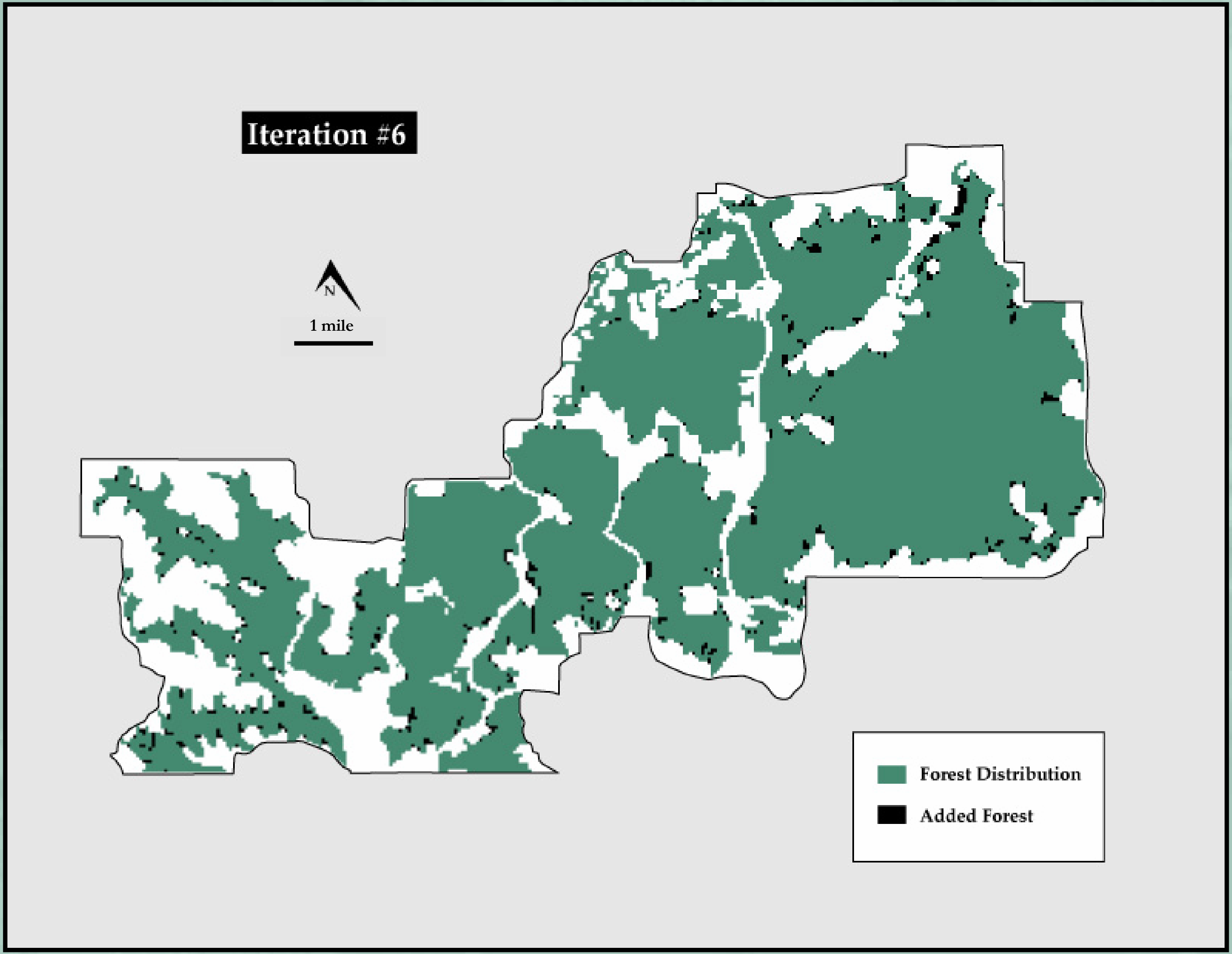

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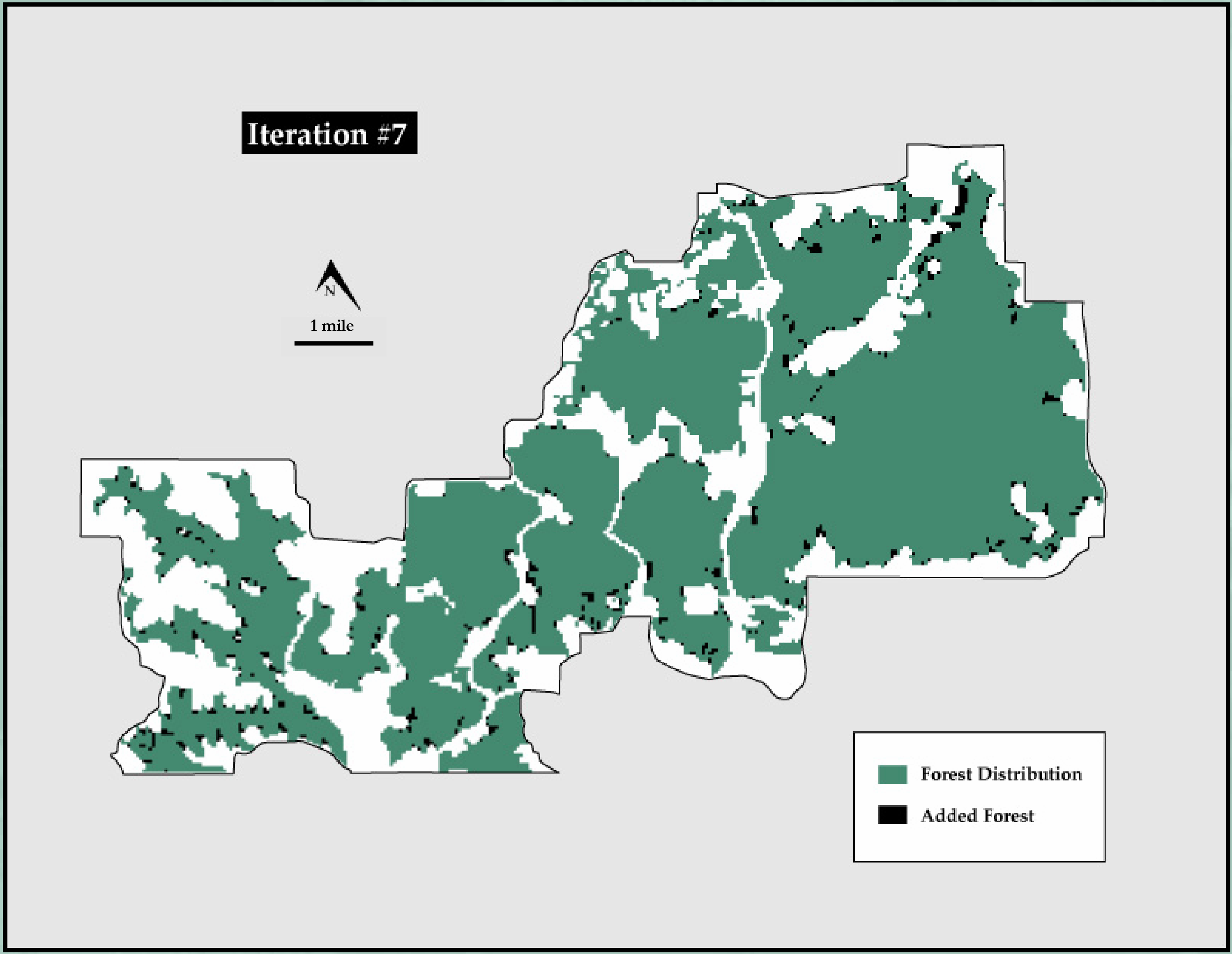

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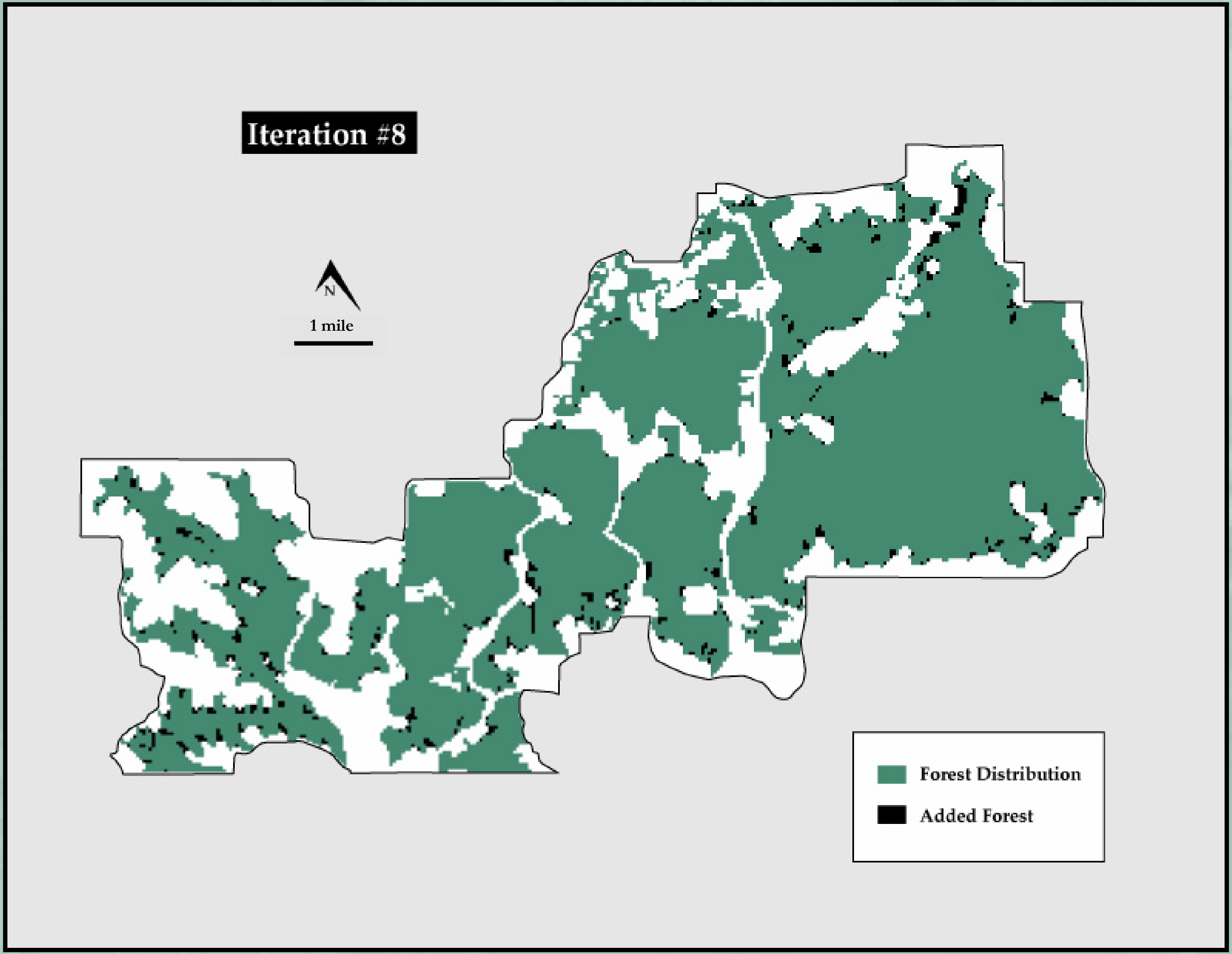

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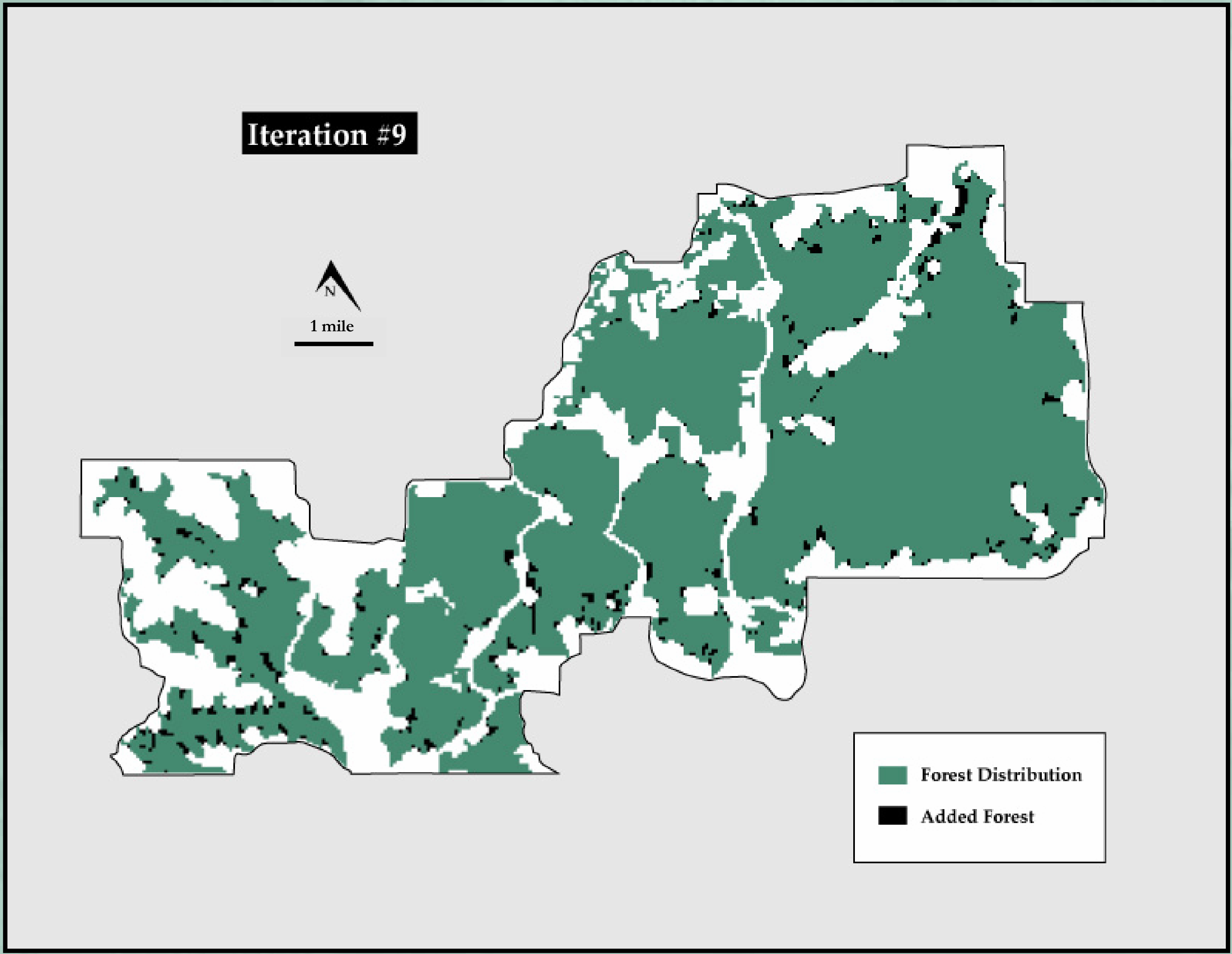

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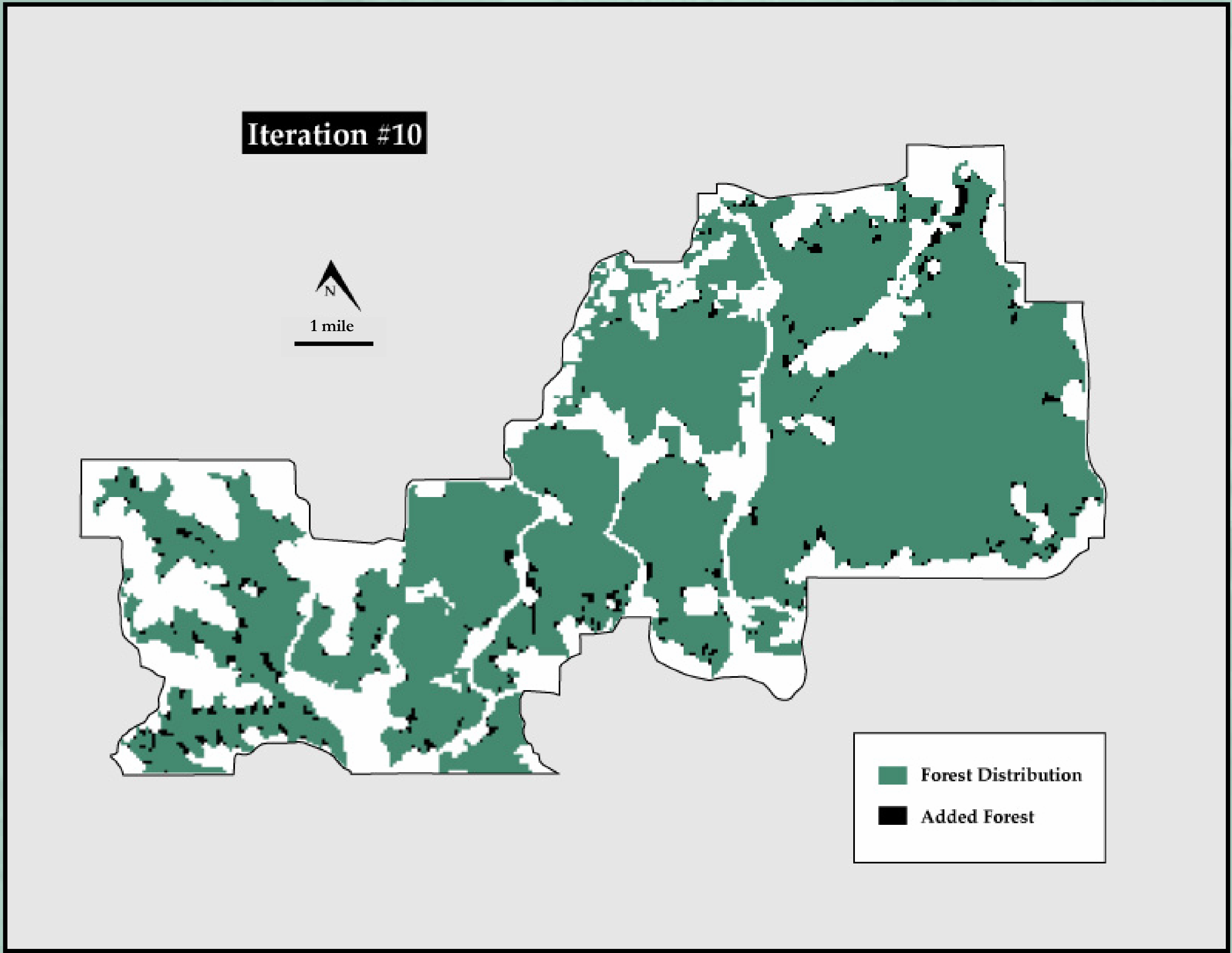


The Case Study

- Decrease of Fragmentation

1. Original Compactness Value: 0.08989
2. Updated Compactness Value: 0.11269

* a 25% increase

- Overall Changes

1. Original Forest: 93,951,797m²
2. Updated Forest: 97,796,310m²

* a difference of 3,844,513m² (a 4% increase)

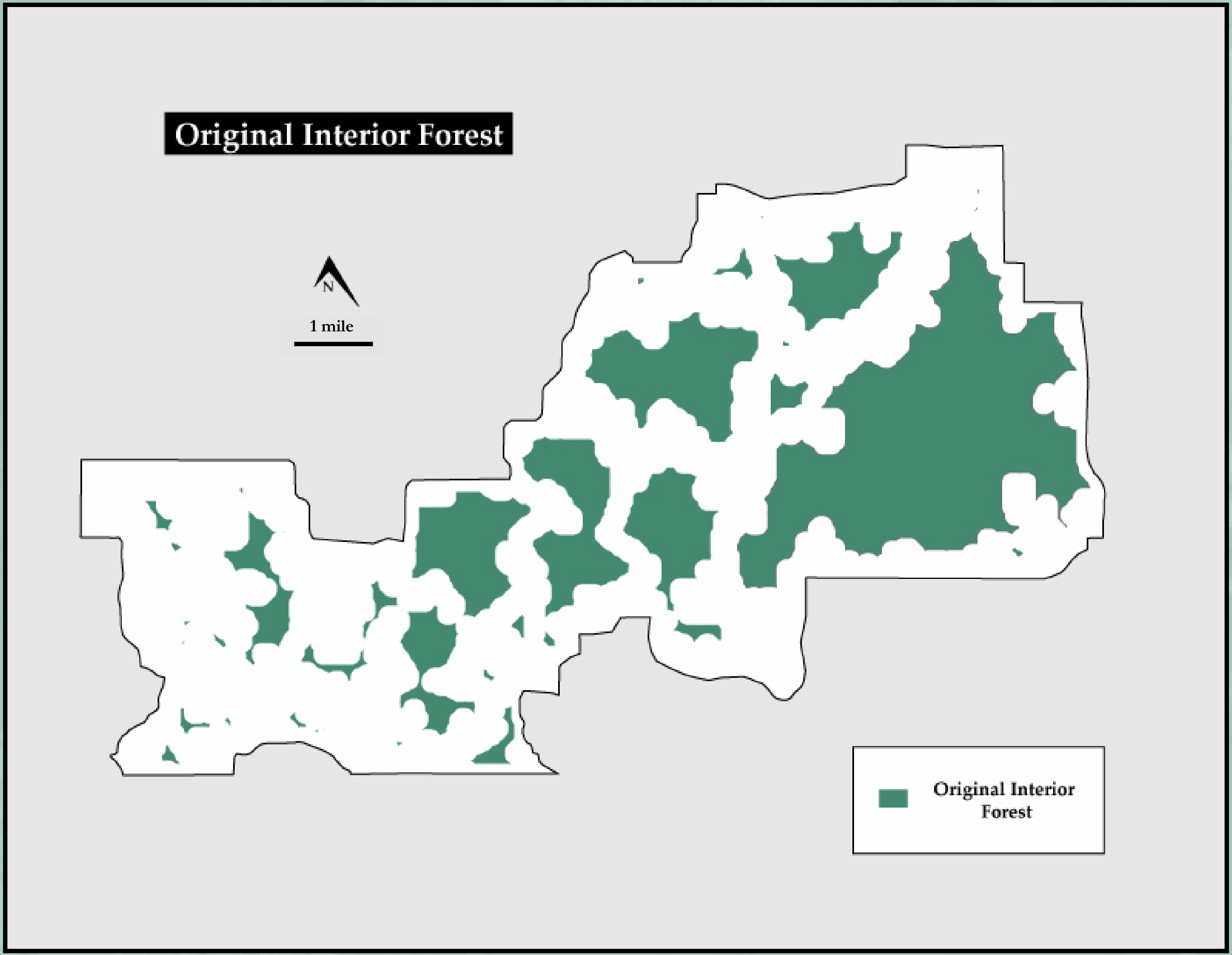
- Increase of Interior Area

1. Original Interior Forest: 45,271,414m² (48%)
2. Updated Interior Forest: 54,284,087m² (56%)

* a difference of 9,012,673m² (an 8% increase)

***Because our addition of 3.8km² of total habitat yields a return of 9.0km² of interior habitat, we get a 235% return on our restoration investment!**

The Case Study



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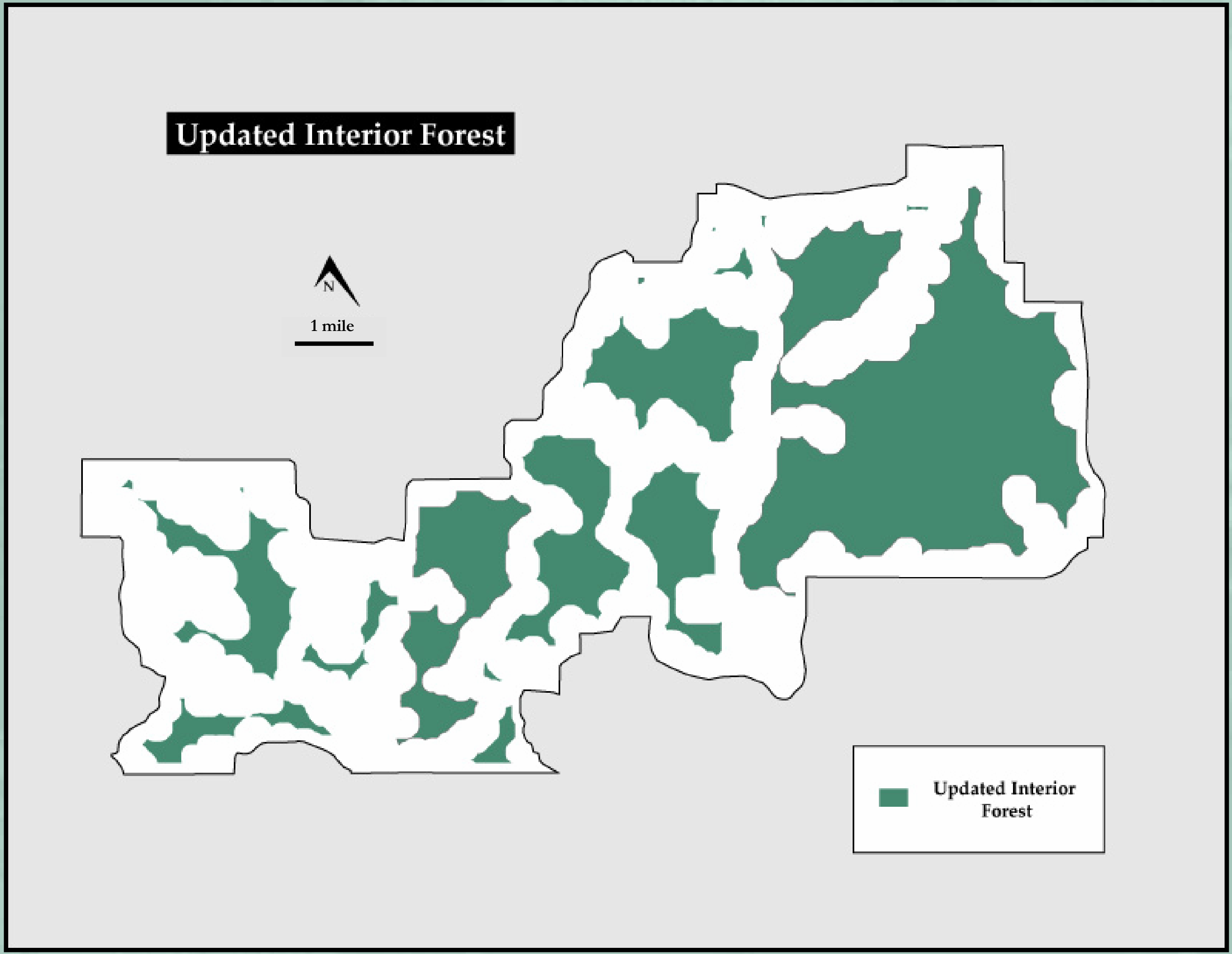

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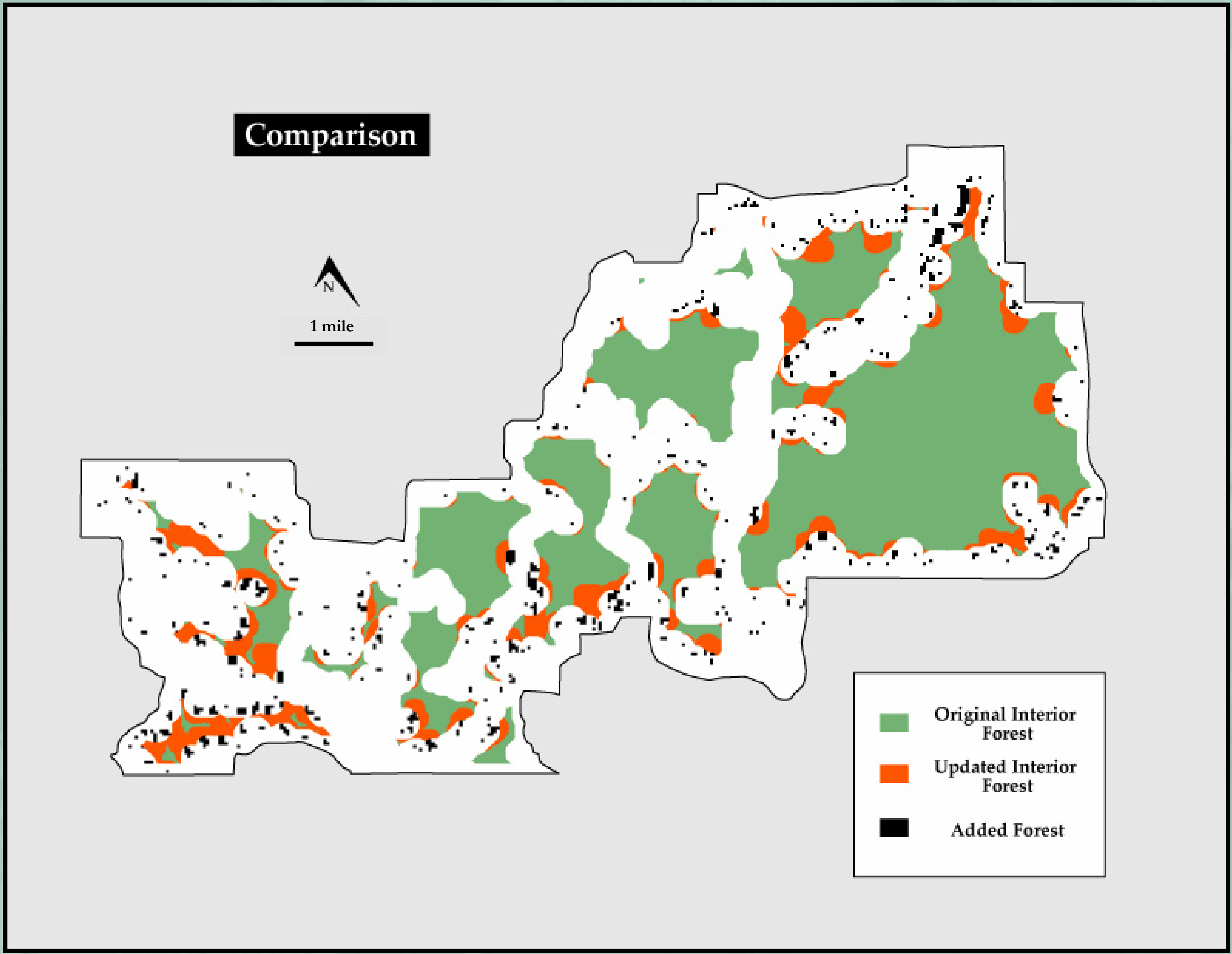

Closing Remarks

- The AutoPASS method provides an optimal way to select sites for restoration based on shape. The resulting prioritization grid is a tool to help select sites, but should not be used blindly in resource allocation without ground evaluation.

- The method also allows the integration of domain specific knowledge. However, quantifying such knowledge is in many cases subjective and should be left to experts in the discipline.

- The choice of critical value is pivotal in the analysis. As we suggested, the value should be at least ‘7’ to ensure improvement of shape in areas where there are no multiplicative criteria.

- The potential for creating more interior habitat per unit total area restored highlights an important economic advantage of AutoPASS analysis. The tool facilitates more appropriate allocation of restoration funding, providing literally “more bang for the buck”.

Questions?

Thank you for your time,

~ Rob and Jesse