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A REMOTE SENSING-BASED APPROACH FOR MAPPING TREE COVER IN THE GREAT PLAINS

OUTLINE

- Research need
- Current state of Great Plains tree cover assessment
- Forest Inventory and Analysis Program
- Progression of our mapping research
  - Current state of research
- Summary

RESEARCH NEED – Why map tree cover in the Great Plains?

- Because it's important!
  - Provides a wide range of ecological and economical benefits
  - Recognition of this is increasing!
- Despite their importance, trees outside forests (TOF) are not explicitly inventoried or monitored
  - GIS datasets of fine-scale tree features over large geographic areas do not exist

RESEARCH NEED (continued)

- USDA Agroforestry Strategic Framework, Fiscal Year 2011-2016
  - "increase awareness and support of agroforestry"

    -Thomas J. Vilsack, Secretary of Agriculture
  - Strategic Goal 3 – Integration
    - "Incorporate agroforestry into an all-lands approach to conservation and economic development"
    - Desired outcome: USDA agencies understand, use, and integrate agroforestry into their policies and programs to maximize benefits and services to citizens.
    - Strategy #2: Work within USDA to establish a comprehensive, continuous national inventory of on-the-ground applications of agroforestry practices/systems or include in existing inventory structures (e.g., Forest Inventory and Analysis or the National Resources Inventory).

HOW DO WE ASSESS TREE COVER IN THE GREAT PLAINS?

- Sample-based survey approach
  - Devise a sampling scheme and collect data on the ground
- Image-based approach
  - Feature extraction from remotely-sensed imagery

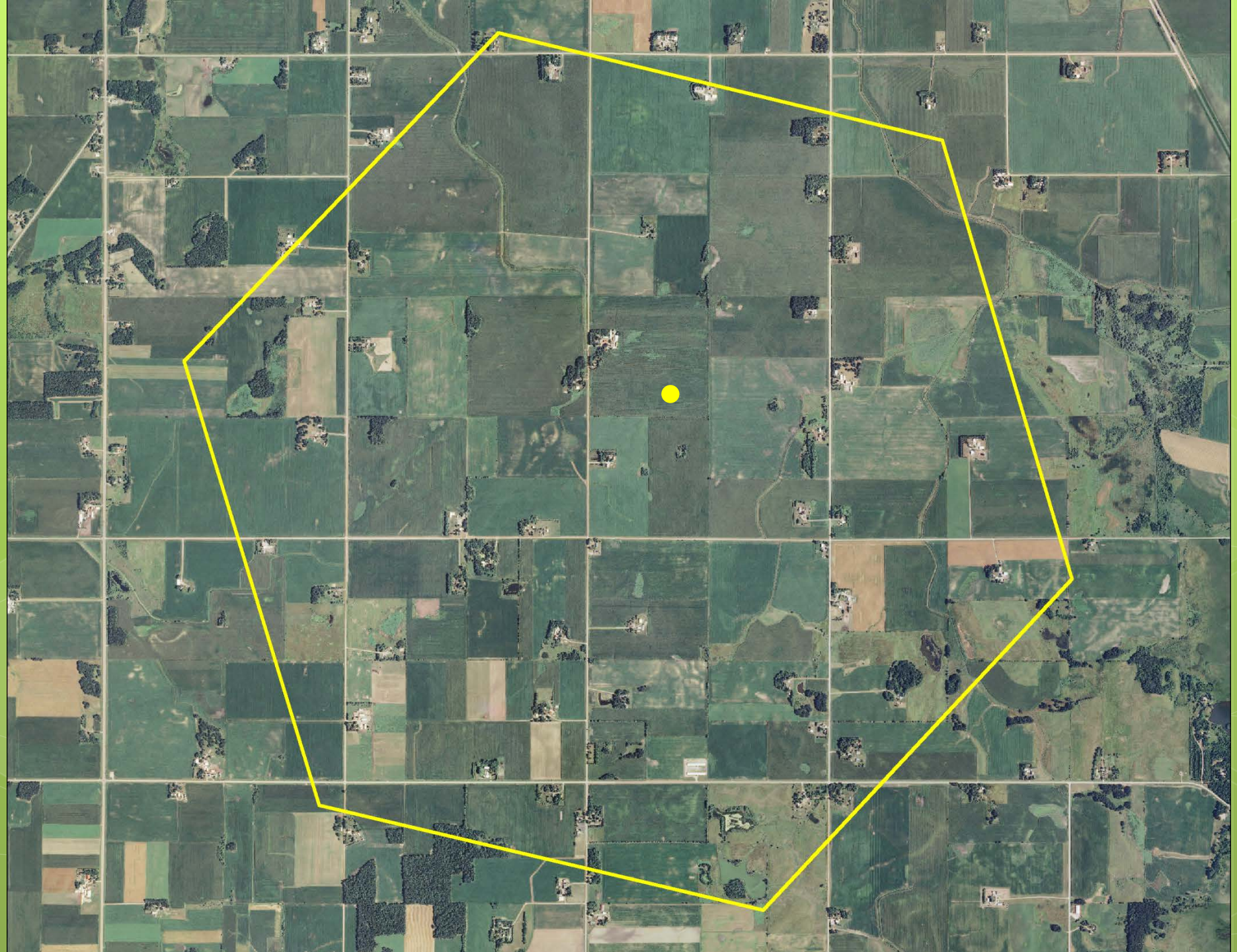
CURRENT LARGE-AREA SURVEYS IN THE U.S.

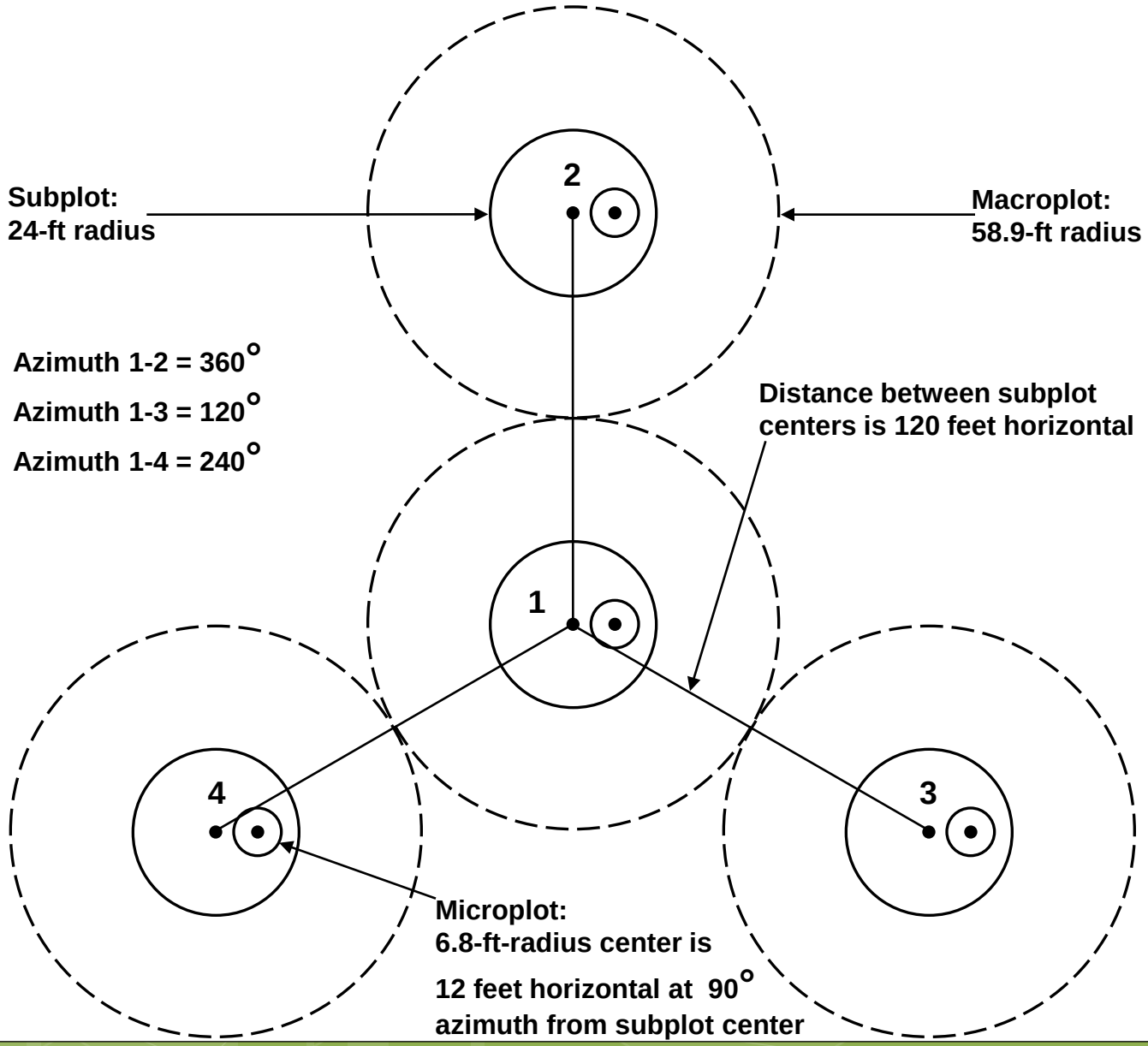
- Forest Inventory and Analysis National Program (FIA) – USDA Forest Service
- Natural Resources Inventory (NRI) – USDA Natural Resources Conservation Service (NRCS)
- Great Plains Tree and Forest Invasives Initiative (GPI)
  - cooperative project of USDA Forest Service and state forestry agencies in ND, SD, NE, and KS
- Urban tree assessment – USDA Forest Service

- However, these surveys only provide partial information regarding TOF and do not provide detailed spatial information other than point locations

FOREST INVENTORY & ANALYSIS (FIA)

- Goal – complete statewide inventory of forest land every 5 years
  - Provide estimates of area, volume, species, etc.
- Uses a formal definition of forest land
  - Minimum area = 1 acre
  - Minimum width = 120 feet
- Sampling intensity = 1 plot per ~6,000 acres
- Each plot is 1/6 acre




Subplot:
24-ft radius
Macroplot:
58.9-ft radius
2
Azimuth 1-2 = 360°
Azimuth 1-3 = 120°
Azimuth 1-4 = 240°
Distance between subplot centers is 120 feet horizontal
1
4
3
Microplot:
6.8-ft-radius center is
12 feet horizontal at 90°
azimuth from subplot center

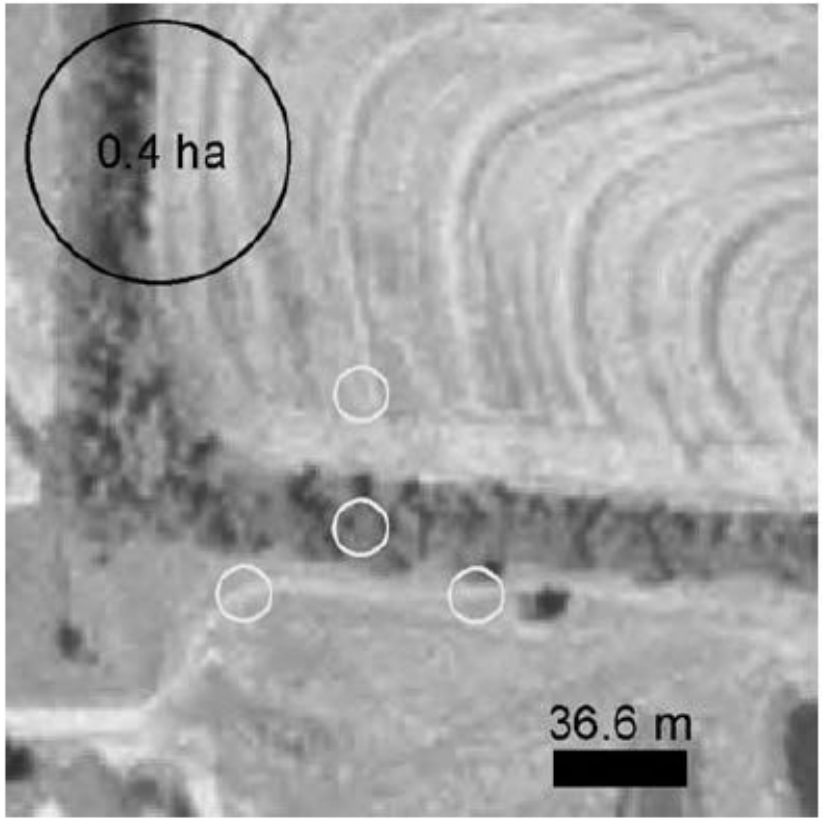
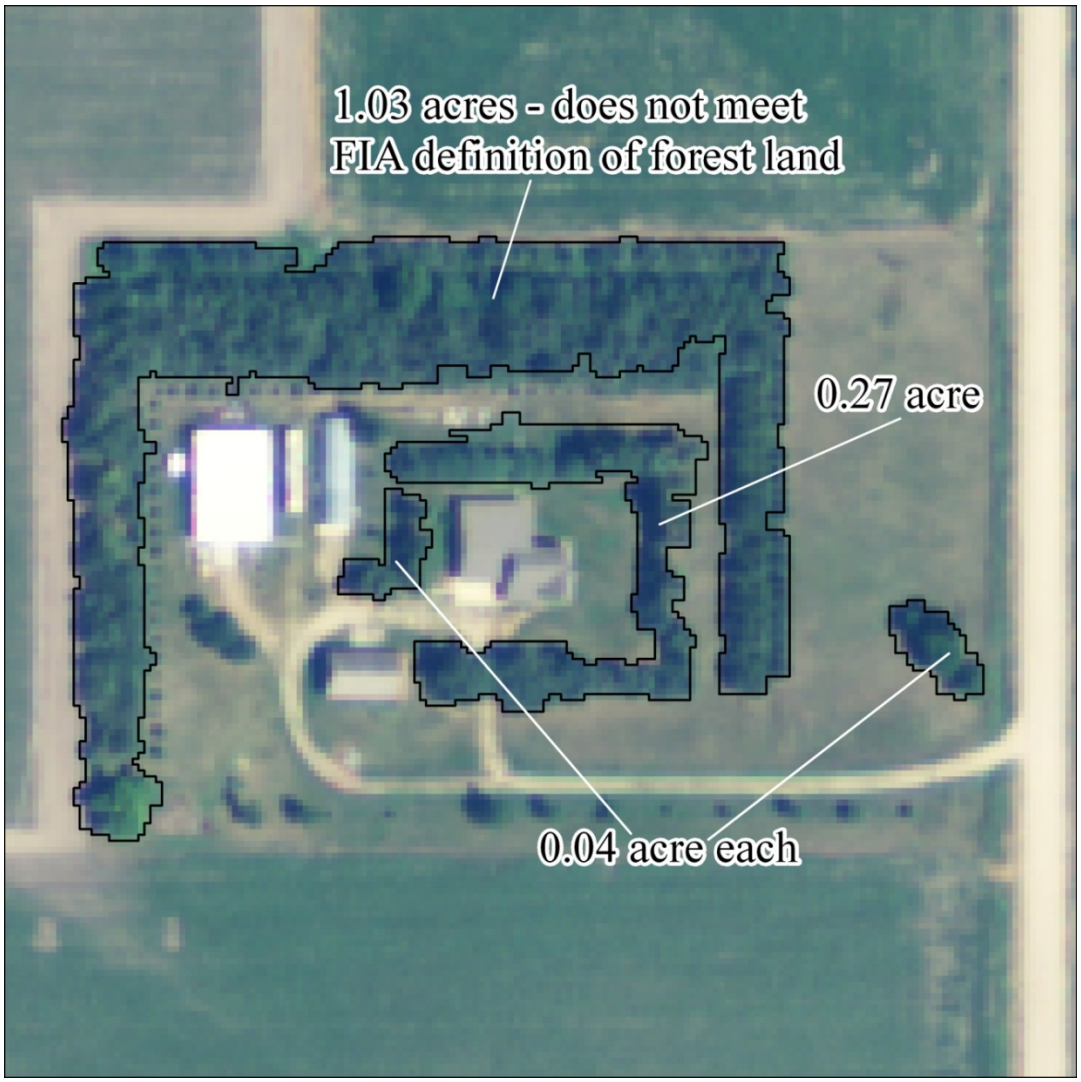
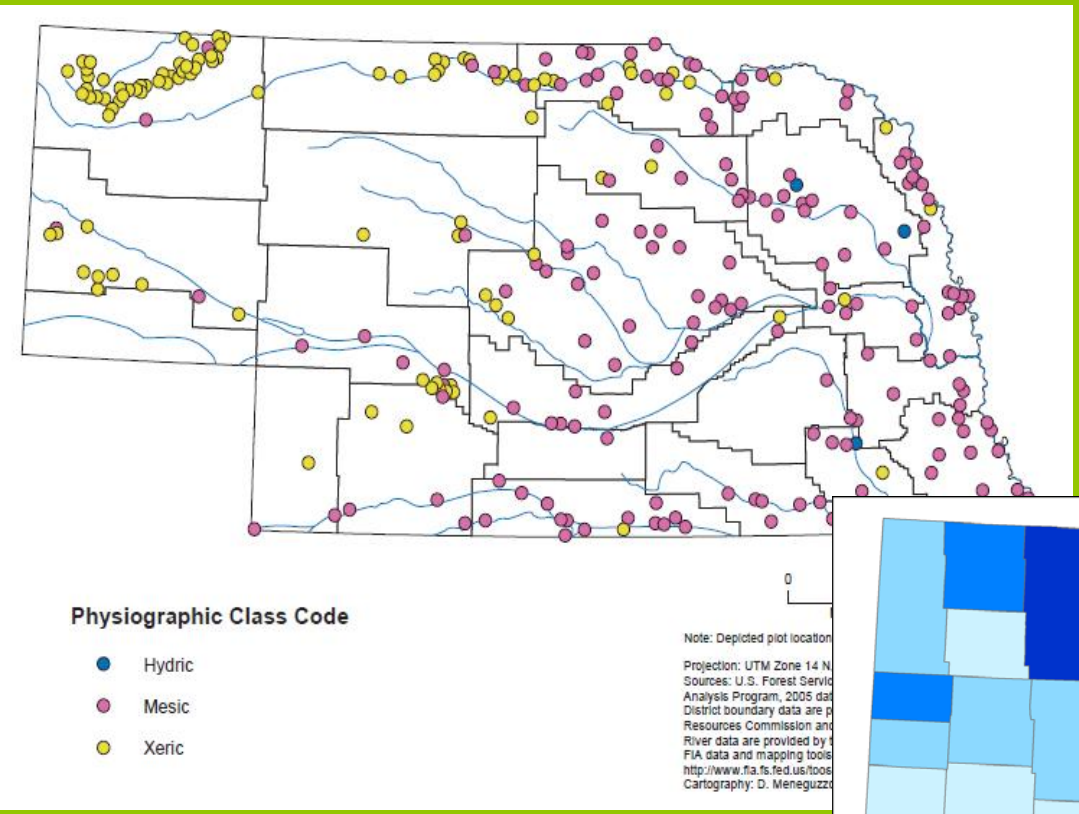


Fig. 3 The FIA circular plot design shown against a background with a linear planting of working trees. In this case, the planting does not meet the minimum width requirement for forest land

Perry, C.H., C.W. Woodall, G.C. Liknes, and M.M. Schoeneberger. 2008. Filling the gap: improving estimates of working tree resources in agricultural landscapes. *Agroforestry Systems:* DOI 10.1007/s10457-008-9125-6.

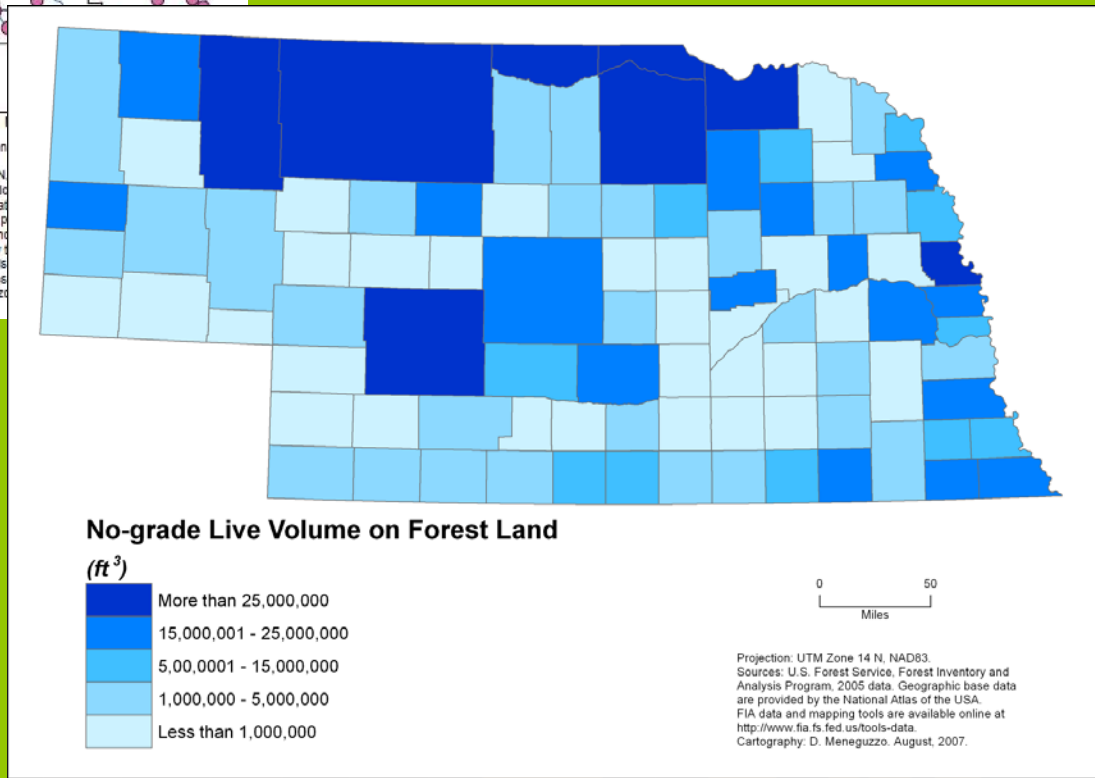

1.03 acres - does not meet
FIA definition of forest land
0.27 acre
0.04 acre each

Examples of map output from FIA data



Dot map that displays plot information at one point.

County choropleth map that shows forest information summarized to the county level.



HOW DOES FIA FIT INTO THE STRATEGIC FRAMEWORK?

- Gathers data on large windbreaks and other tree cover that meets the definition of forest land
- Photo interpretation phase – opportunity to gather data regarding agroforestry functions and land cover data
- While it would be desirable to just go out and measure trees on ALL plots, this is cost prohibitive so an alternative approach must be developed

AN IMAGE-BASED APPROACH TO SUPPLEMENT THE FIA INVENTORY

- Remotely-sensed imagery or land cover products derived from satellite or aerial imagery
- Needs:
  - extensive coverage (entire Great Plains region)
  - high enough resolution to identify single, or small groups of, trees
- National Land Cover Database (NLCD)
  - Coverage = good
  - Spatial resolution = too coarse

Satellite Image
(30 meter spatial resolution)

Aerial Photograph
(1 meter spatial resolution)

IMAGE CREDIT:
http://www.csc.noaa.gov/products/sccoasts/html/rsdetail.htm

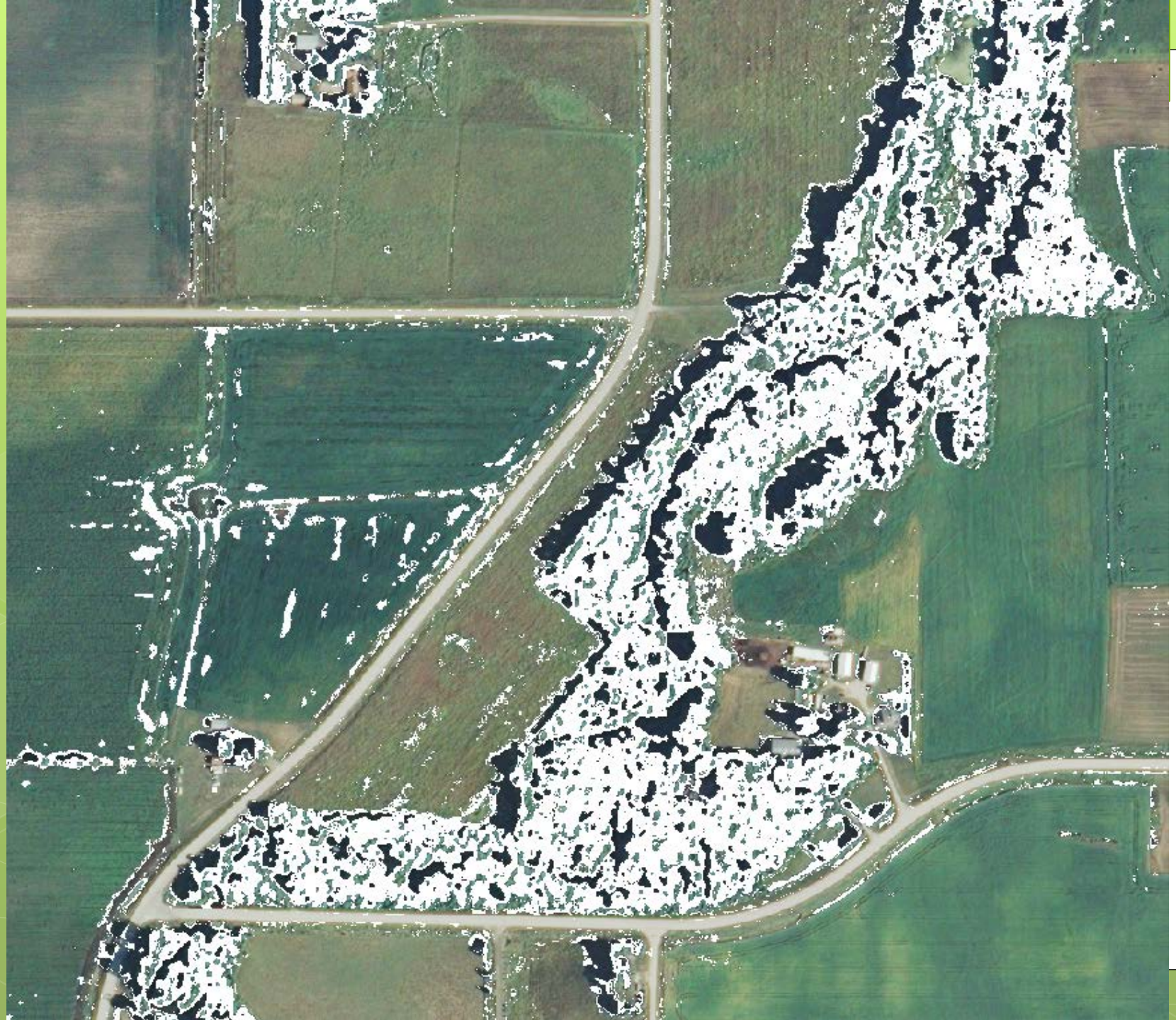
NLCD tree cover class

SOLUTION: AERIAL IMAGERY

- Small tree-covered areas are easily recognizable
- National Agriculture Imagery Program (NAIP)
  - Imagery available at no cost
  - Nationwide coverage
  - 1-meter imagery procured on a 3-5 year cycle

CHALLENGES: NAIP IMAGERY

- High-resolution imagery is more complex to work with
  - Traditional image classification methods are inadequate
    - Salt-and-pepper effect in the output
- Image acquisition occurs over several months by different contractors
  - Inconsistent output products
  - Shadows are problematic



Example of inconsistent output

RESEARCH OBJECTIVE

- Develop an efficient approach for mapping tree/land cover using aerial imagery
  - Robust for various issues encountered with the imagery and the different landscapes in the Great Plains
  - Repeatable over time for monitoring purposes

PROGRESSION OF RESEARCH

- Perry et al. (2008) – identified that "working tree" resources are underestimated by at least 20% in the Plains States (ND, SD, NE, KS)
- Liknes et al. (2010) – mapped tree cover in Pembina County, ND using 1-m NAIP imagery
- Meneguzzo et al. (in press) – mapped tree cover in Steele County, MN using 1-m NAIP imagery with NIR band
- Research shifted to Nebraska – mapped 5 classes of land cover for several counties
  - Was thought to be too simple = expanded number of land cover classes to 14

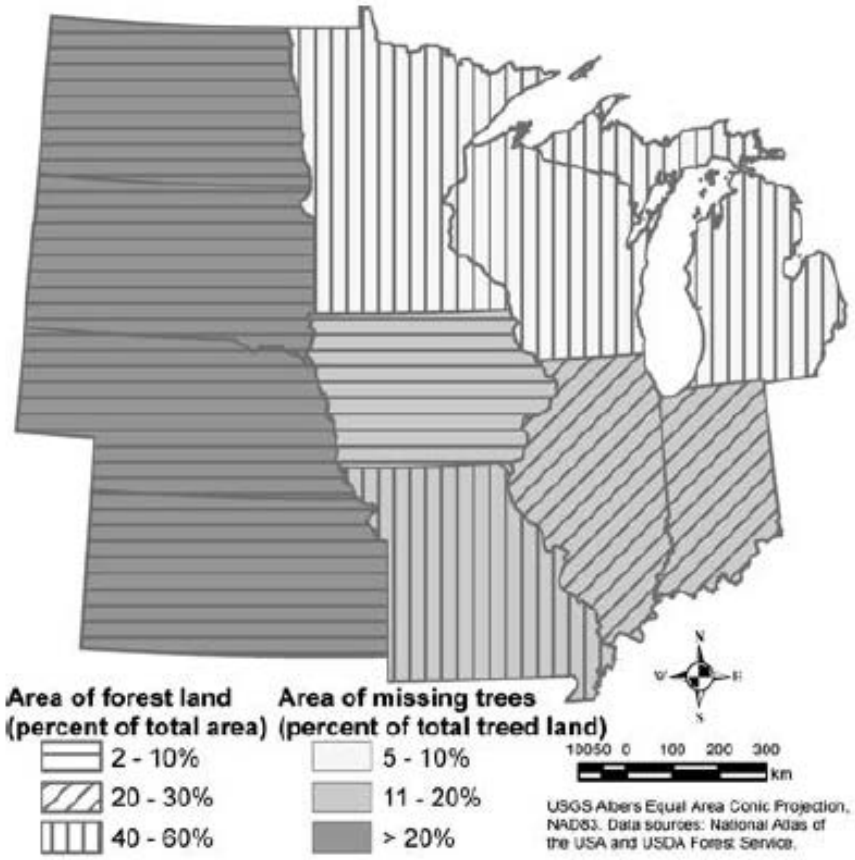


Fig. 5 Forest land and missing tree fractions derived from FIA data. Missing tree fraction is determined by comparing FIA forest land area estimates with MODIS VCF estimates of tree canopy cover

Perry, C.H., C.W. Woodall, G.C. Liknes, and M.M. Schoeneberger. 2008. Filling the gap: improving estimates of working tree resources in agricultural landscapes. *Agroforestry Systems:* DOI 10.1007/s10457-008-9125-6.

Figure 5. A 1-m resolution tree cover probability map for Pembina County, North Dakota, based on 2003 NAIP imagery. A north/south stripe just to the east of center is noticeable, probably due to radiometric differences in the imagery. In the enlarged area, agricultural fields are erroneously assigned a high tree cover probability to the east of the vertical, dashed black line.

Liknes, Greg C.; Perry, Charles H.; Meneguzzo, Dacia M. 2010. Assessing tree cover in agricultural landscapes using high-resolution aerial imagery. Journal of Terrestrial Observation. 2(1): 38-55.

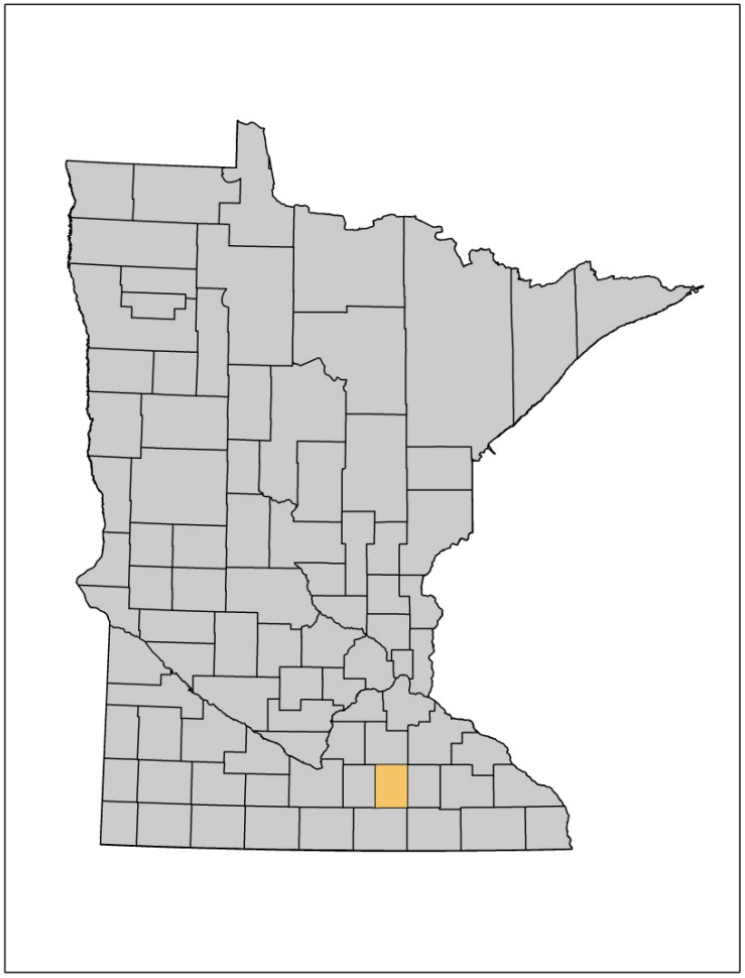
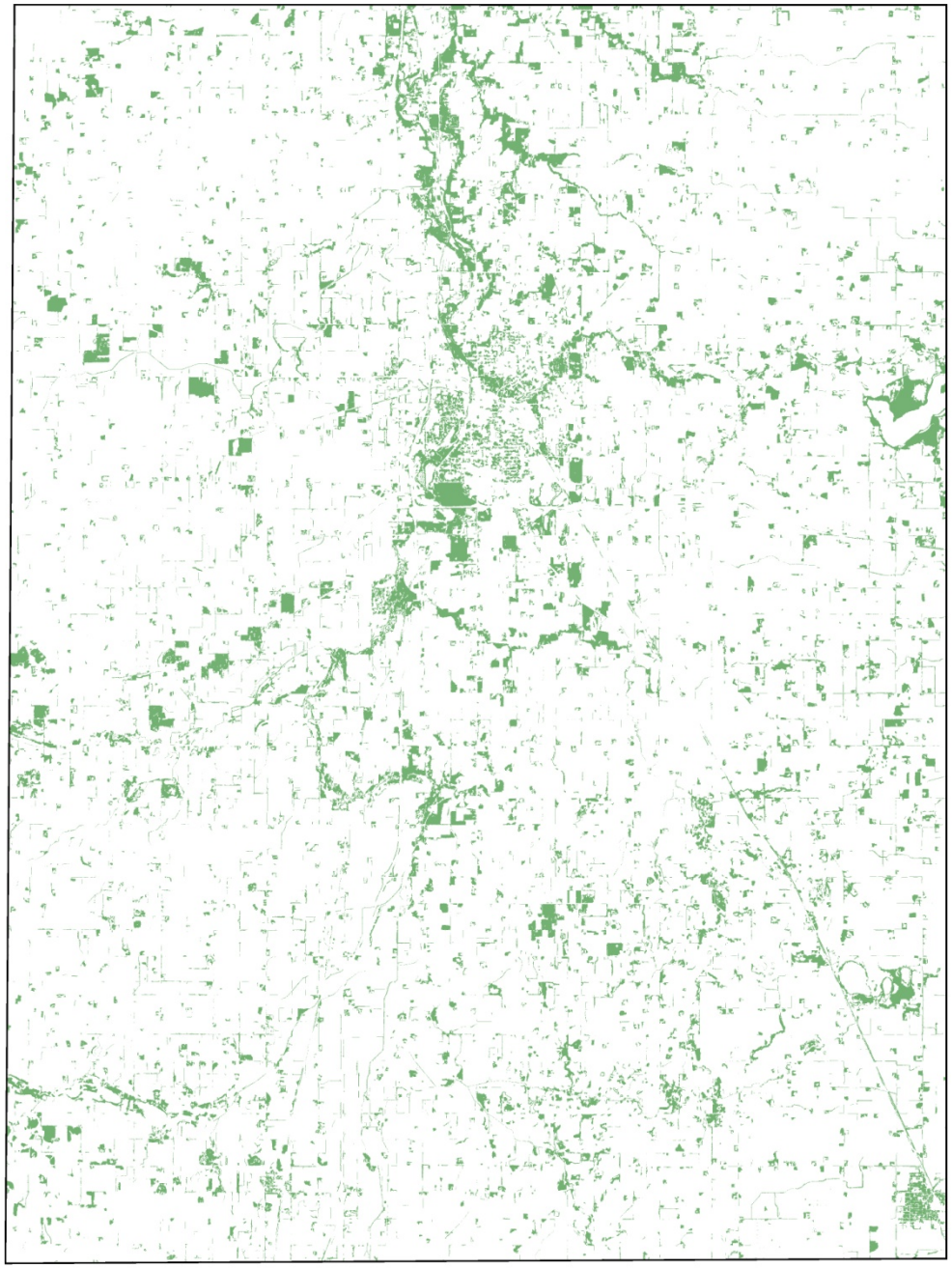
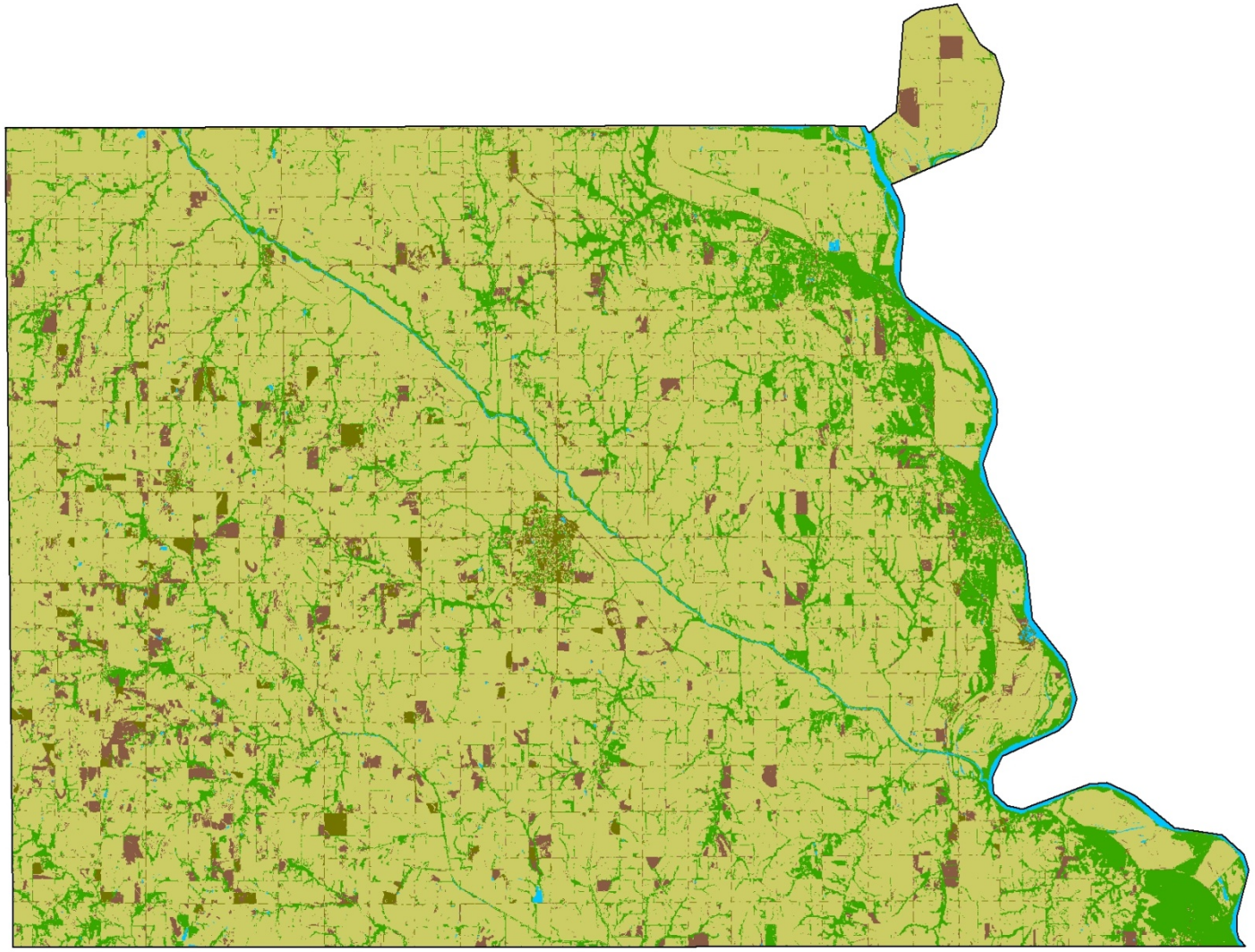


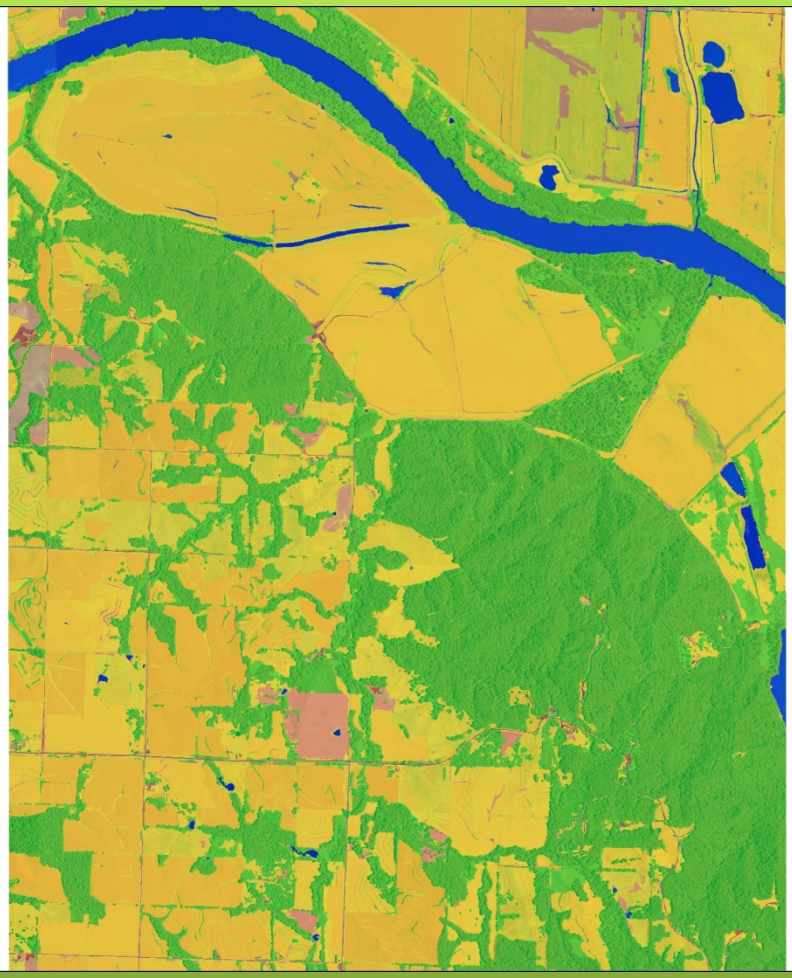
Image-derived estimate of tree-covered area was ~24,000 acres larger than the FIA estimate!





Final land cover classification
Nemaha County, NE

- Water
- Tree cover
- Agriculture/other vegetation
- Manmade
- Other not vegetated/bare soil



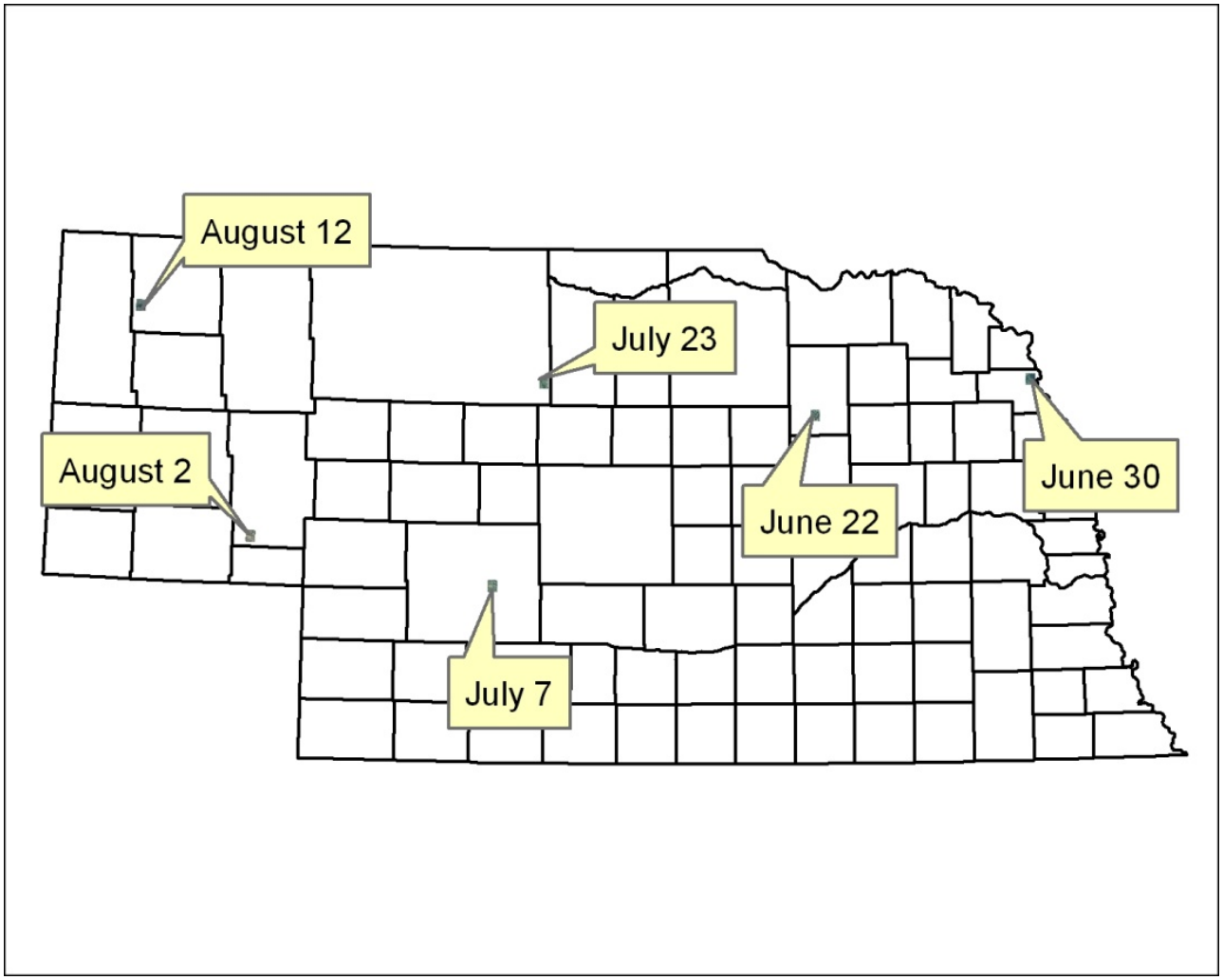
CURRENT RESEARCH STUDY

- 6 study areas in Nebraska
  - 2 images for each month (June, July, August)
- Object-based image analysis (OBIA) approach to conduct a land cover classification of each image
  - 14 land cover classes

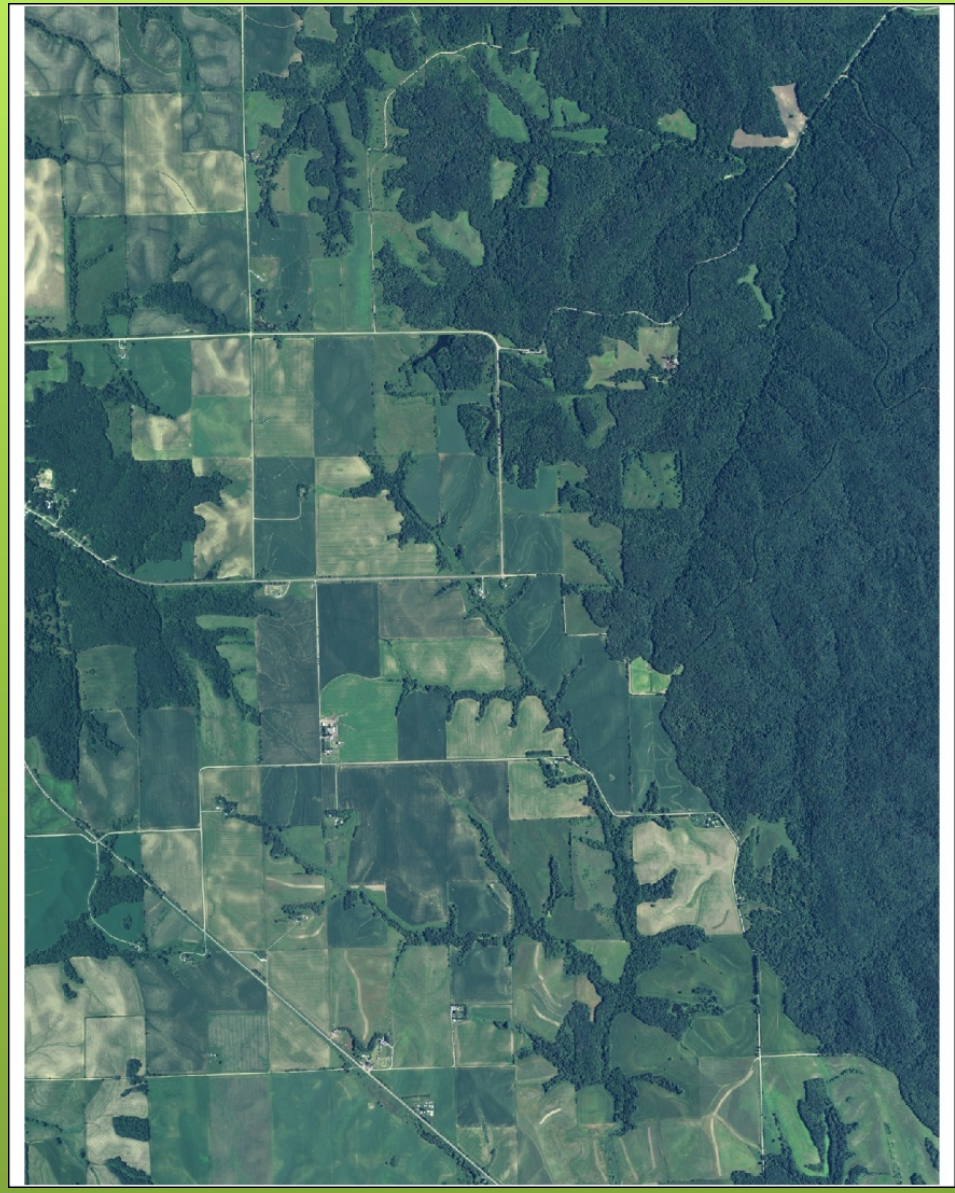
LAND COVER CLASSIFICATION SCHEME

- Trees
- Shrubs
- Grassland
- Wetland/wet soil
- Mixed vegetation
- Agricultural vegetation
- Harvested/bare agricultural fields
- Developed vegetation (yards, golf courses)
- Natural barren/sparse vegetation
- Buildings
- Roads/impervious surface
- Other urban (mixed of development and vegetation)
- Open water
- Shadows

STUDY AREAS – NEBRASKA, USA



June



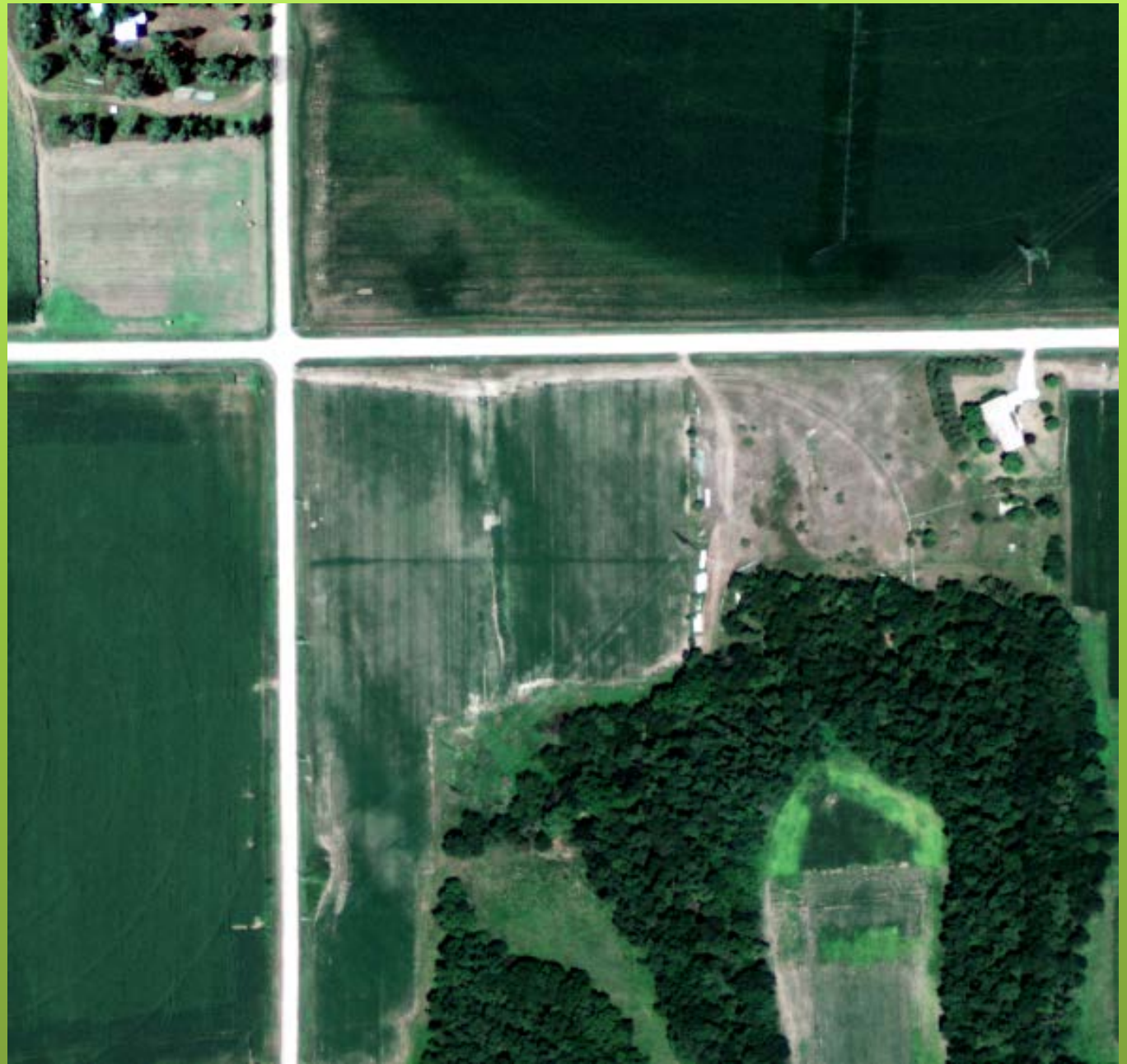
July

August

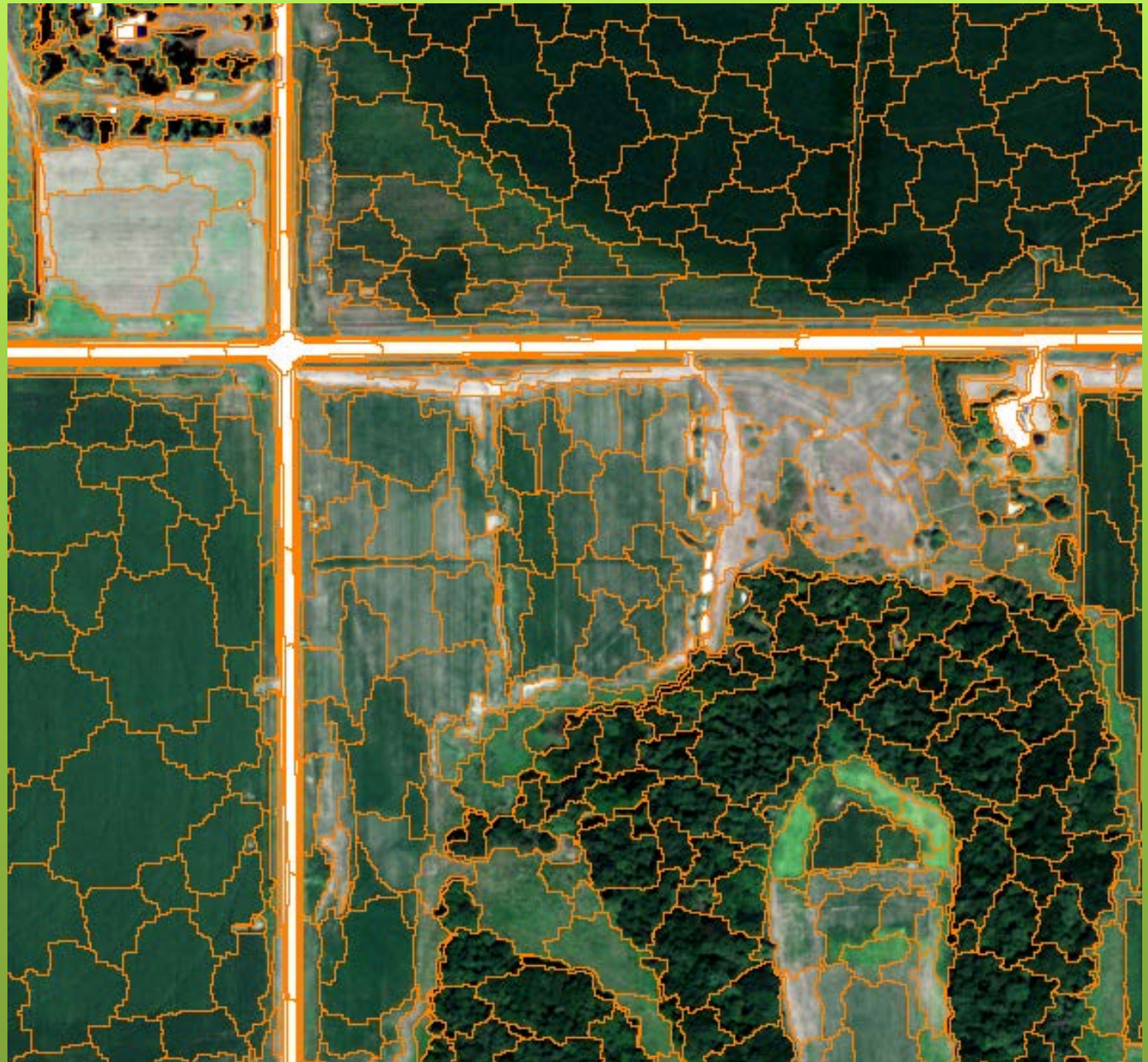
WHAT IS OBJECT-BASED IMAGE ANALYSIS (OBIA)?

- Simulates human interpretation of identifying objects in an image
  - Groups pixels into “image objects” that are representative of your landscape features of interest
    - Examples: rooftop of a building, group of trees
    - Classification occurs on image objects rather than individual pixels
      - Results in higher classification accuracy

For example...



1st level of image objects



Use procedures to reduce the number of image objects – more representative of actual landscape features and easier to manage.

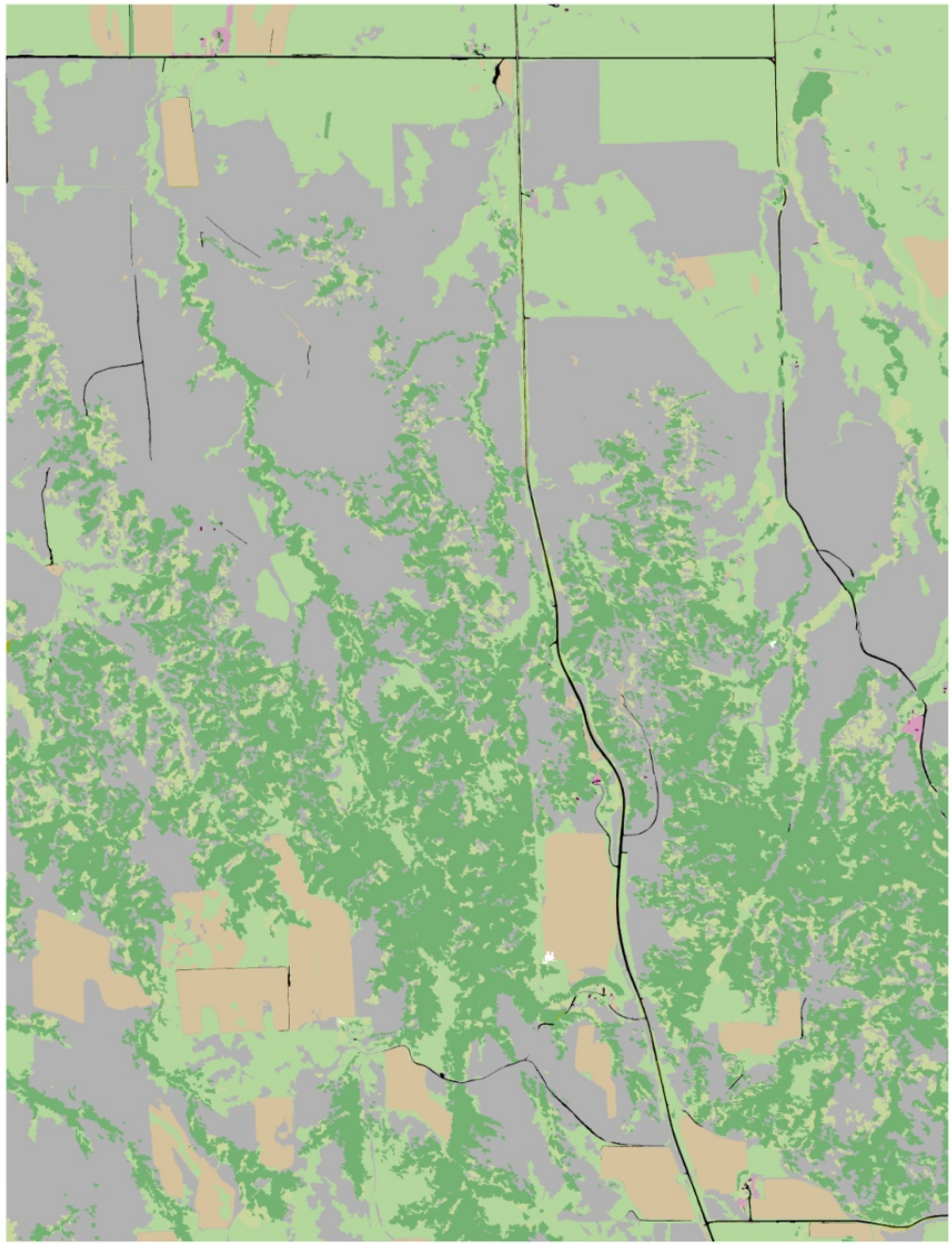
Land Cover Classification

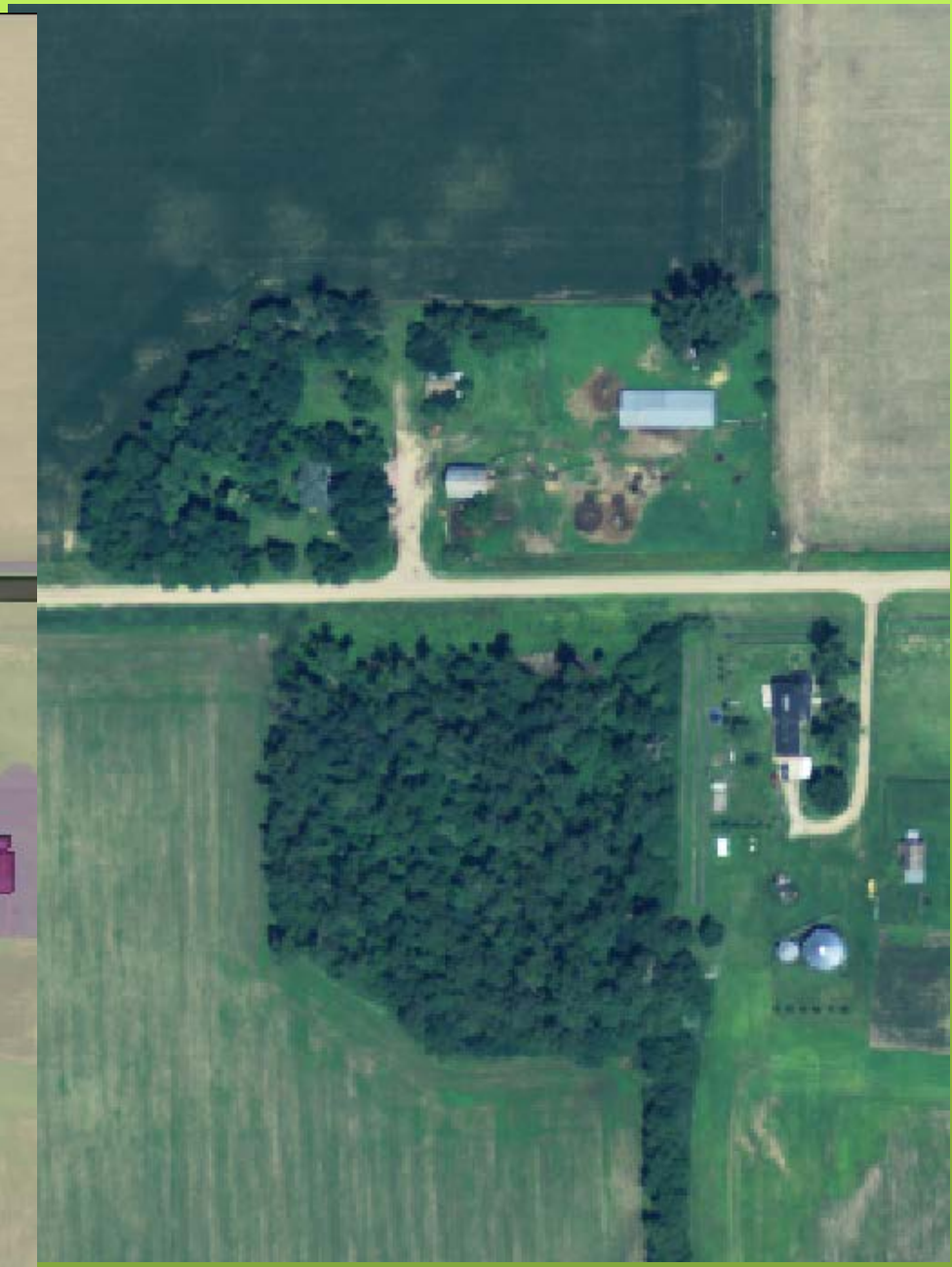
- Random Forests algorithm (RF) was used to build a model to predict the land cover class for each image object
  - Uses the attribute data of the image objects as predictor variables
  - Uses an out-of-bag sample to assess classification accuracy

August 12 Image

Predicted land cover class

- Tree
- Grassland
- Wetland
- Mixed vegetation
- Agricultural
- Developed vegetation
- Natural barren
- Water
- Harvested agricultural
- Buildings
- Roads/impervious surface
- Urban mix





INITIAL RESULTS

Image	Classification Accuracy
June 22	77%
June 30	75%
July 7	75%
July 23	87%
August 2	79%
August 12	78%

- Confusion between:
  - “tree”/”grassland”/”agricultural” and “mixed vegetation” classes
  - “natural barren” and the various “urban” classes

INITIAL EVALUATION AND THOUGHTS…

- Thought it worked pretty well given the large number of classes but there is room for improvement!
- May have too many "vegetation" classes – not practical or necessary?
  - Collapse some of the classes?
- Perhaps a series of geographically-based models would work better?
- Land cover mapping from aerial imagery is difficult so now I know why high-resolution datasets are NOT readily available!

SUMMARY

- Challenging process but the output datasets have much potential
  - More detailed version of NLCD, which has been called the ‘“workhorse” of landscape ecology …’ Wulder and Franklin (2007)
    - Spatial pattern assessments, wildlife studies
  - Determine ecosystem function of trees
  - Biomass assessment when combined with LiDar data (e.g., Rentsch et al. 2011)

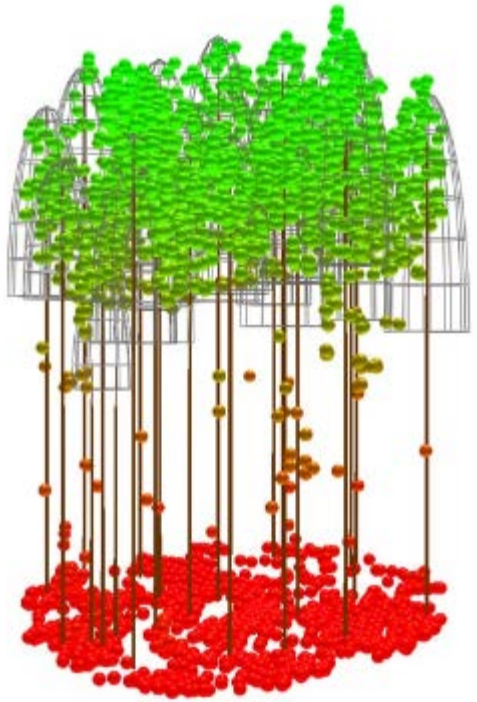


Image Source Page:
http://www.cfr.washington.edu/research.pfc/research/jfsp/index.htm

SUMMARY (continued)

- Identify gaps for windbreak, etc. placement
- Baseline for monitoring tree cover and even land use change
- Could be used in a number of geospatial analyses/operations
  - connectivity/corridor analyses

FUTURE WORK

- Further evaluating the results and decide how best to proceed with mapping
- Determine ecosystem function for tree polygons
- Make output datasets available via the web

FEEDBACK?

- As potential users, what do you think?
- Would this type of output data meet your needs?
- Suggestions for improvement?
- Please let me know!

QUESTIONS?

Thank you!

Image credit: Natural Resource Conservation Service