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
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
Macroplot: 58.9-ft radius

Microplot: 6.8-ft-radius center is 12 feet horizontal at 90° azimuth from subplot center

Subplot: 24-ft radius

Azimuth 1-2 = 360°
Azimuth 1-3 = 120°
Azimuth 1-4 = 240°

Distance between subplot centers is 120 feet horizontal
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.

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.

No-grade Live Volume on Forest Land

- More than 25,000,000
- 15,000,001 - 25,000,000
- 5,000,001 - 15,000,000
- 1,000,000 - 5,000,000
- Less than 1,000,000
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
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
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

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

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<tr>
<th>Image</th>
<th>Classification Accuracy</th>
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<tr>
<td>June 22</td>
<td>77%</td>
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<tr>
<td>June 30</td>
<td>75%</td>
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<tr>
<td>July 7</td>
<td>75%</td>
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<td>July 23</td>
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<td>August 2</td>
<td>79%</td>
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<td>August 12</td>
<td>78%</td>
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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)

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