Application of High Resolution Elevation Data (LiDAR) to Assess Natural and Anthropogenic Agricultural Features Affecting the Transport of Pesticides at Multiple Spatial Scales

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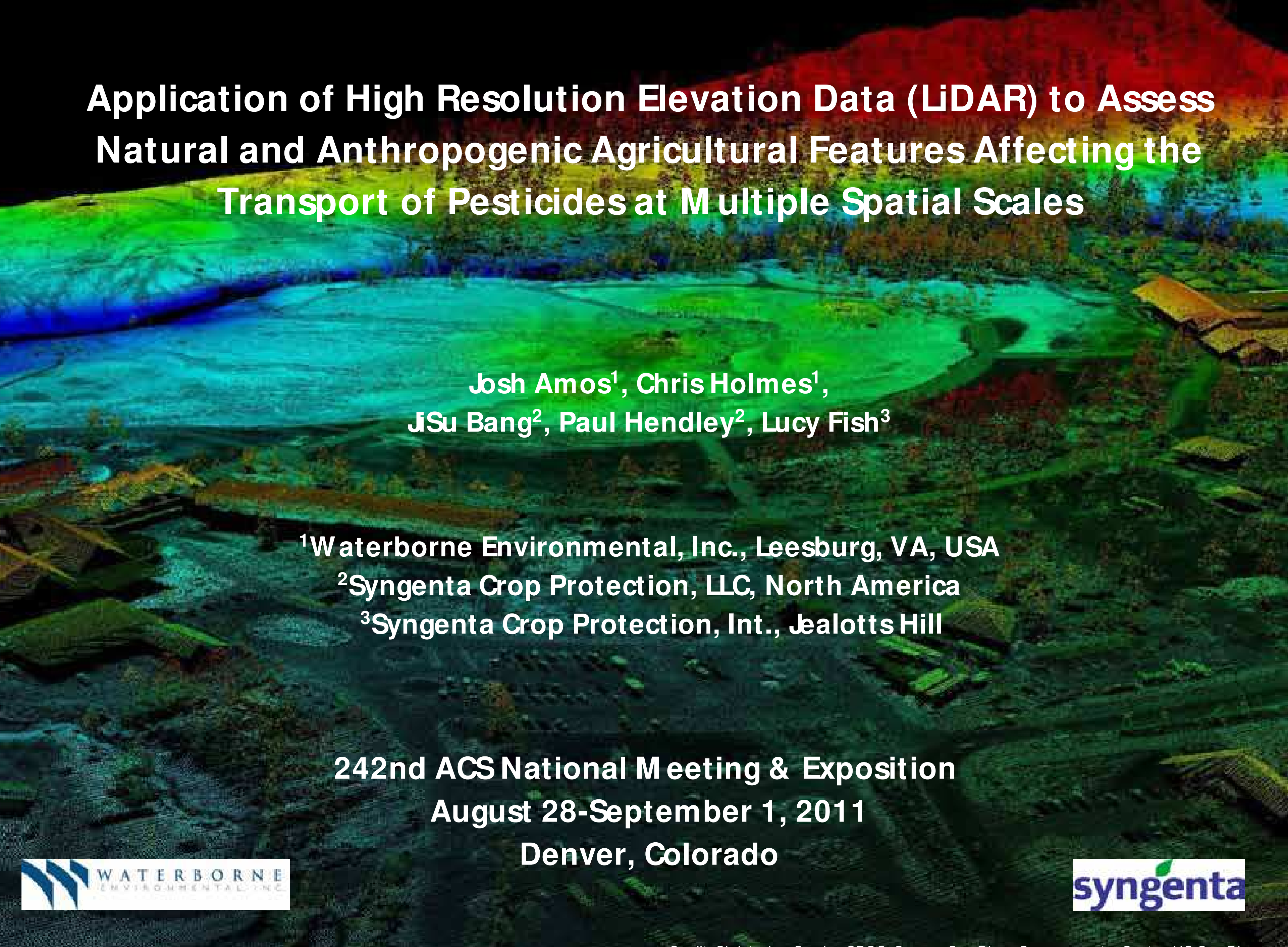
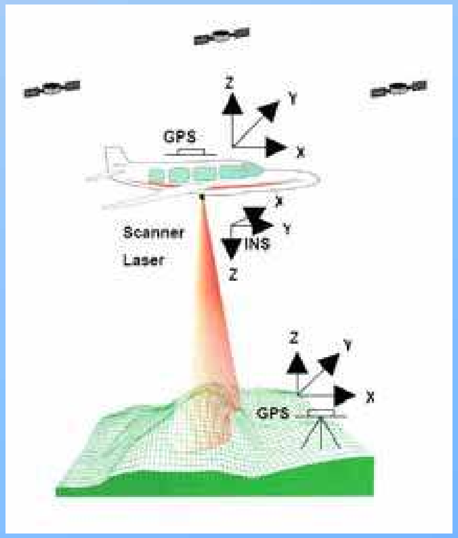


Credit: Christopher Crosby, SDSC. Source: San Diego Supercomputer Center, UC San Diego

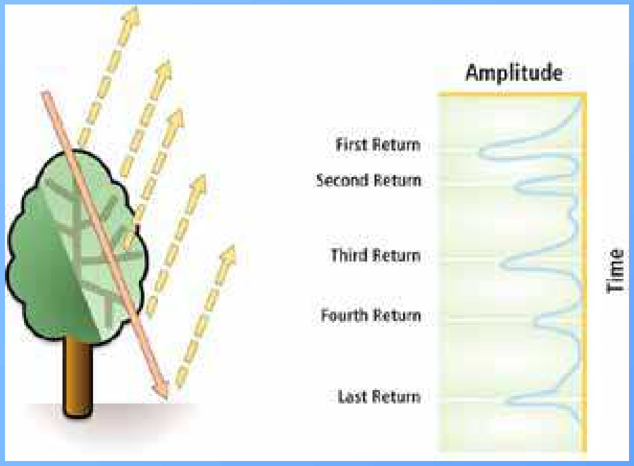
What is LiDAR?

LiDAR = Light Detection And Ranging

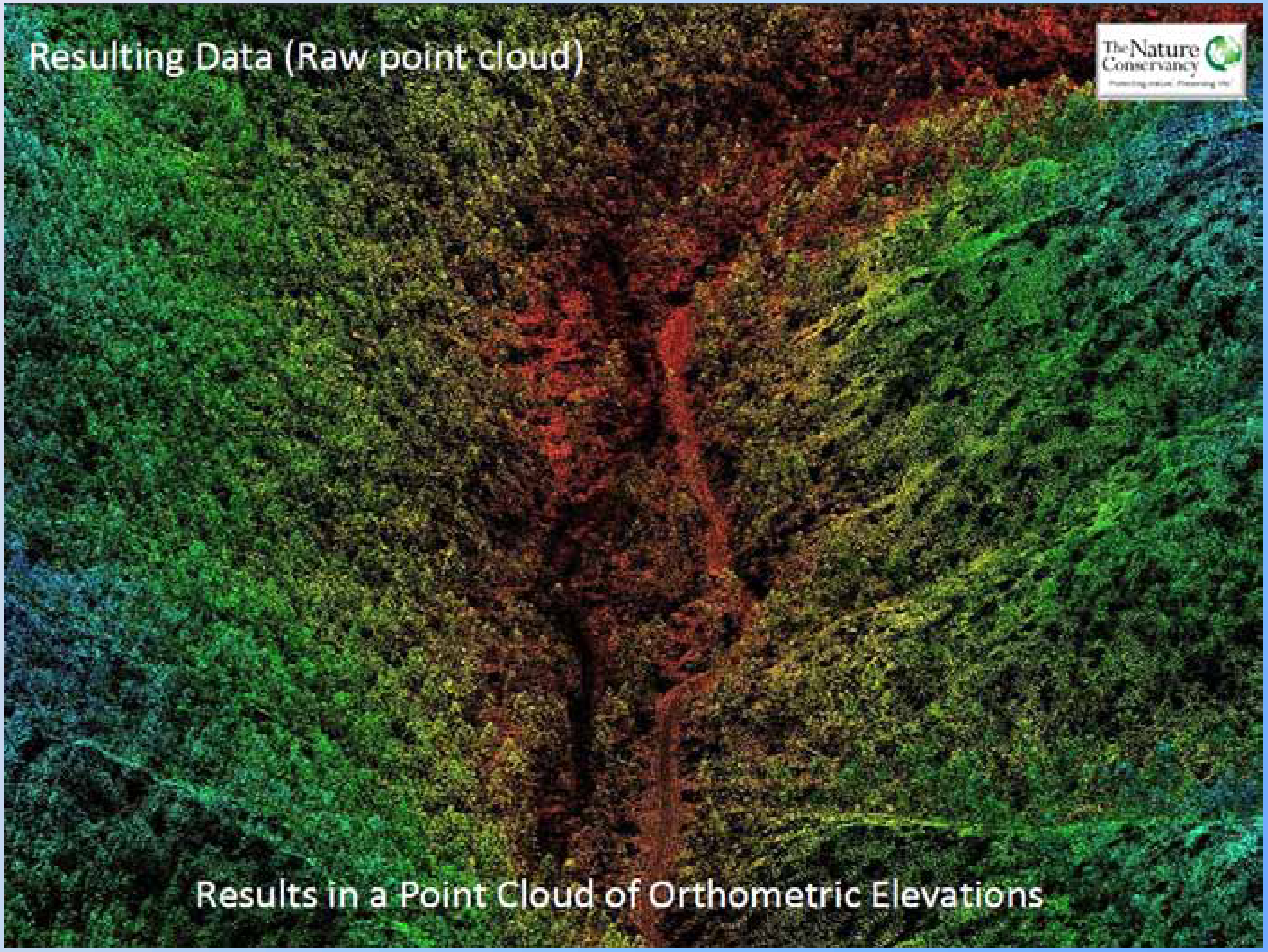
- Measures distance (range) to an object
  - Records x, y, z position of laser energy returned from an object as a function of travel time
  - Uses wavelength in infrared (terrestrial applications) or green (bathymetric applications) spectrum



- Multiple returns per pulse
  - Initial returns for Digital Surface Models of vegetation, buildings & above ground features
  - Final returns for Digital Elevation Models of bare earth surface



Resulting Data (raw point cloud)



Study Objective

Assess the utility of LiDAR to identify landscape features affecting the transport of agricultural chemicals, such as:

- Presence of engineered features
  - Terracing
  - Contour farming
  - Irrigation – boom, furrow
- Micro-elevation changes within a field impacting hydrologic processes
  - Sources of contributing surface flow
  - In-field storage of flow accumulation – local depressions without outlets --- indicators of drainage system inlets & standpipes
  - Flow direction, accumulation and drainage paths leading to points of entry into streams
- Characterization of vegetation in the non-agricultural landscape
  - Height, density, structure composition

Materials & Methods

Standard LiDAR data and GIS software were used throughout the project to enhance accessibility

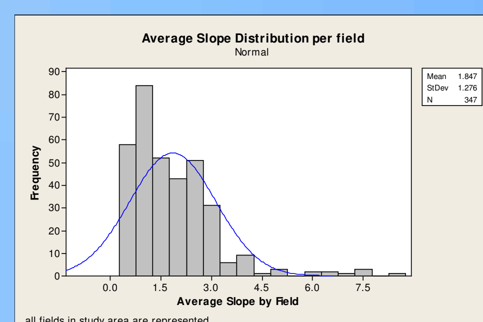
- Data source
  - LiDAR – 1.4 m spacing by Nebraska Department of Game and Natural Resources (collected winter '09)
  - At least 22 states have their own state-wide LIDAR datasets, many more individual counties have data
  - Most acquired to meet FEMA flood mapping standards – consistent point spacing, accuracy, format

- Format, software, & functions
  - 3D point cloud converted to 2D raster
  - ArcGIS with Spatial Analyst & 3D Analyst
  - Standard GIS operations applied

Study Area

The study area is a watershed in southeast Nebraska

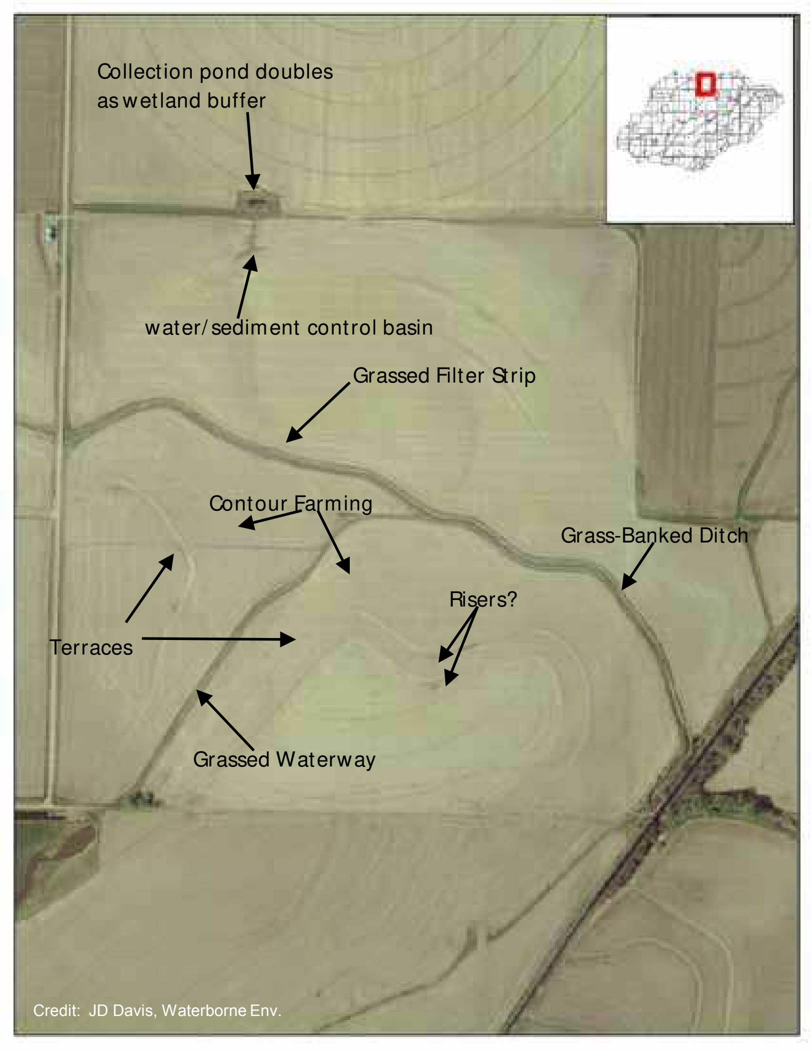
- 22 square mile headwater watershed
- Densely cropped with corn and soybean
- Topography is low relief except near stream corridors and in some fields to the south
- Mean slope of 1.8% across all fields calculated from LiDAR



Application of Remote Sensing to Reveal Management Practices

Remote sensing accommodates assessments across large study areas

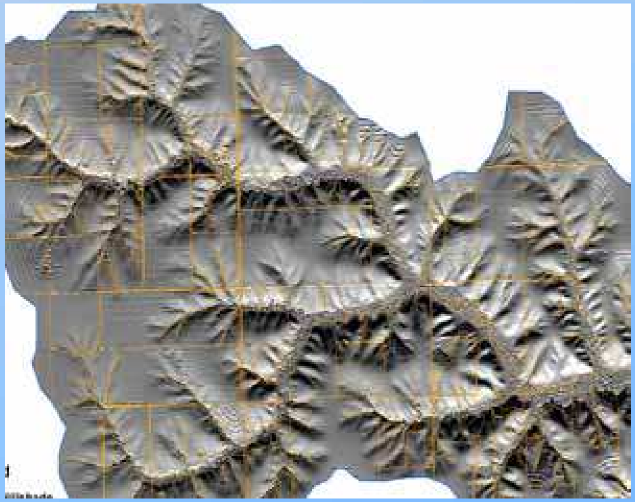
- Aerial photography reveals agricultural practices at the field scale to the trained photo-interpretor
- Process is time consuming because conducted one field at time & is subjective
- Are these features present in the LiDAR and can they be extracted by software for an entire watershed rather than on a field by field basis?

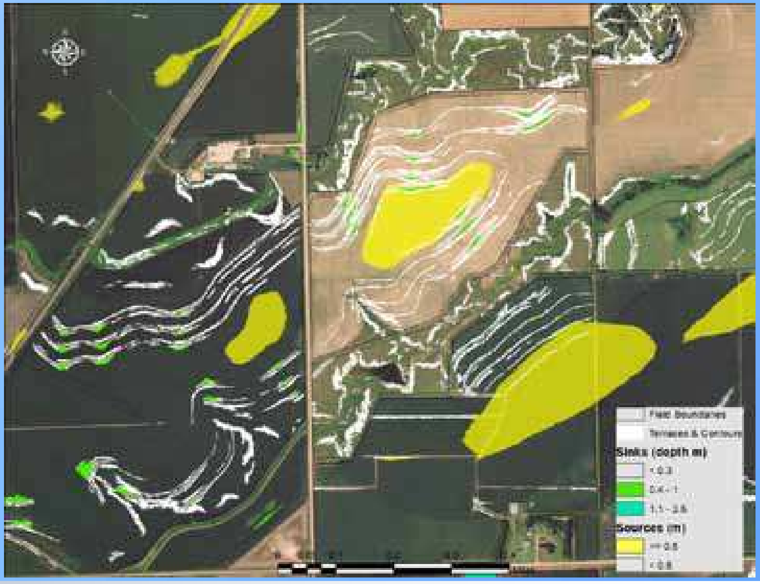


Terracing & Contour Farming

What linear features were present in the LiDAR?

- Terracing & contour farming were visible in the LiDAR DEM as linear features & qualitatively assessed for each field in the watershed
- GIS operations (edge detection of slope raster) were used to extract linear features and quantify them by field

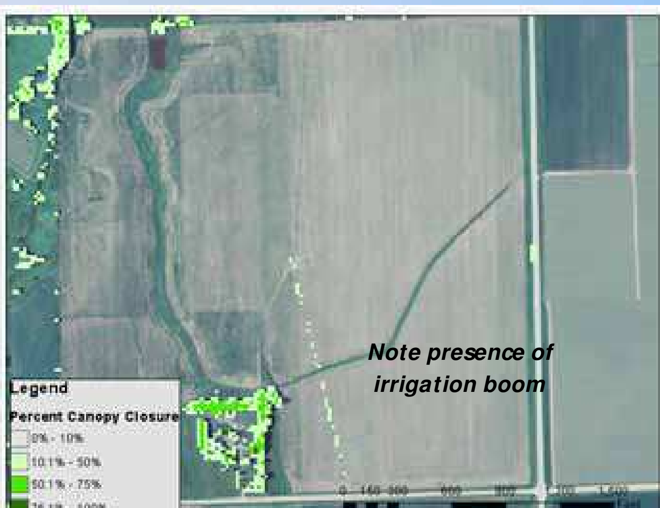




Irrigation

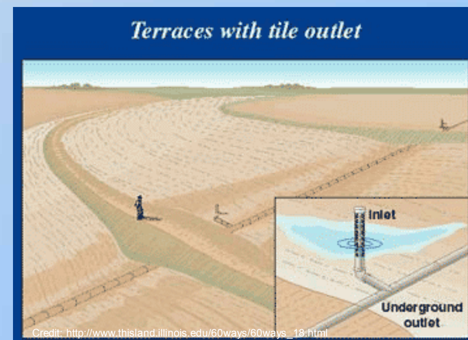
A simple way to locate irrigated fields

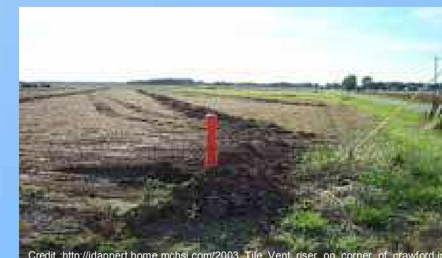
- Irrigation booms (both pivot and side-roll) remain in the vegetation class as thin, linear features
- The number of fields in the watershed can be quantified by overlaying them with a GIS layer of field boundaries

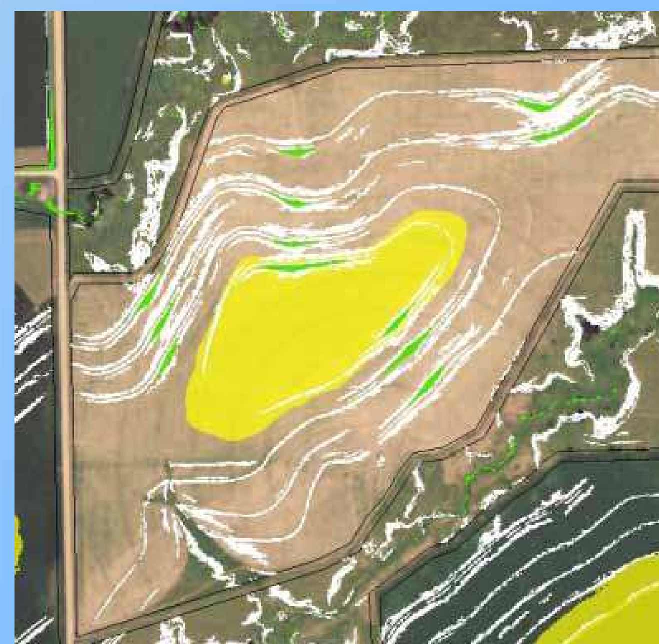


Subsurface Drains

- In-field depressions (sinks) may indicate surface water management practices, such as:
  - Water/sediment control basins
  - Collection ponds/ wetlands
  - Inlets to stand pipes leading to subsurface drainage systems; e.g. tile drains
- Sinks identified in the LiDAR DEM were inspected for the presence of drainage stand pipes using aerial photography



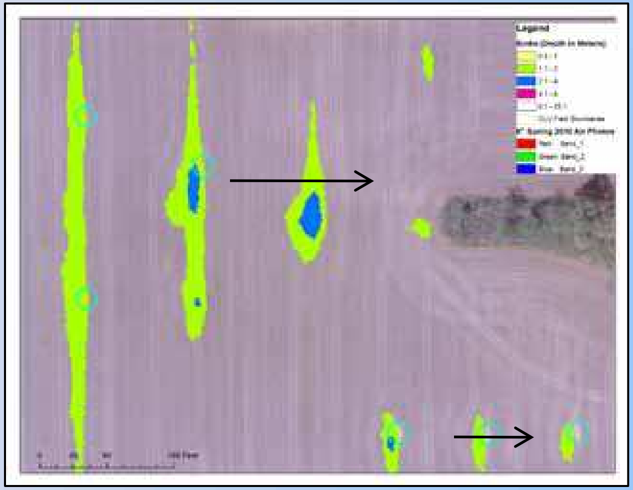


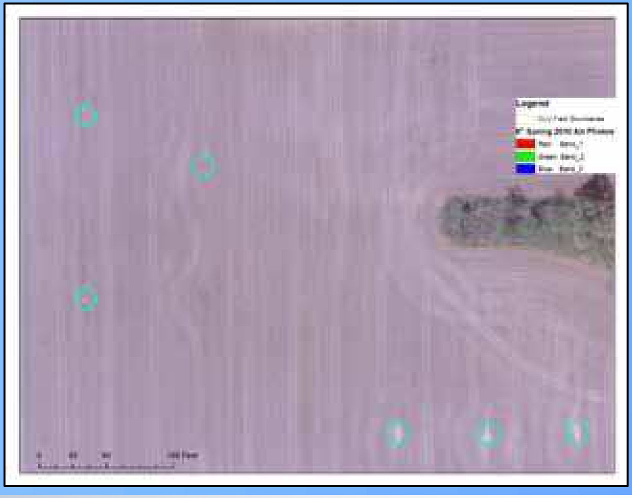


Note inlets (green) to terrace (white) tiles

Subsurface Drains

In-field sinks were often correlated with tile drainage stand pipes



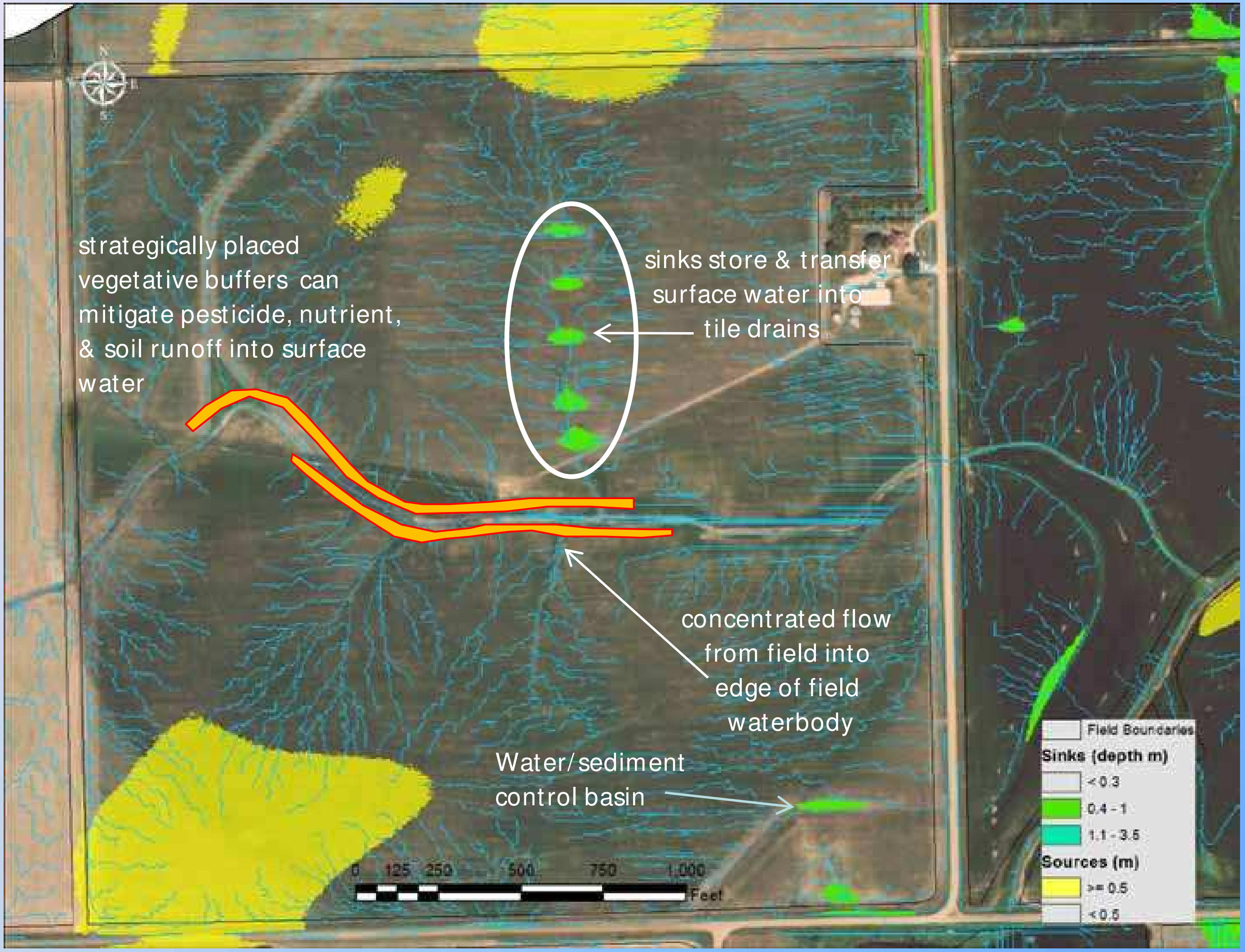


In-Field Flow & Buffers

Targeting fields that may benefit from BMPs by combining LiDAR flow rasters with engineered features and aerial photos

- Flow accumulation grids generated from the LiDAR DEM map surface water patterns from within a field to the edge of a field or into a waterbody
- A better view of the processes governing water movement away from a field is achievable when in-field flow is combined with engineered features, aerial photography, soils, etc
- High resolution hydrology derivatives are suitable for use in recommending vegetative buffers along waterbodies with the potential for exposure to concentrated runoff from fields

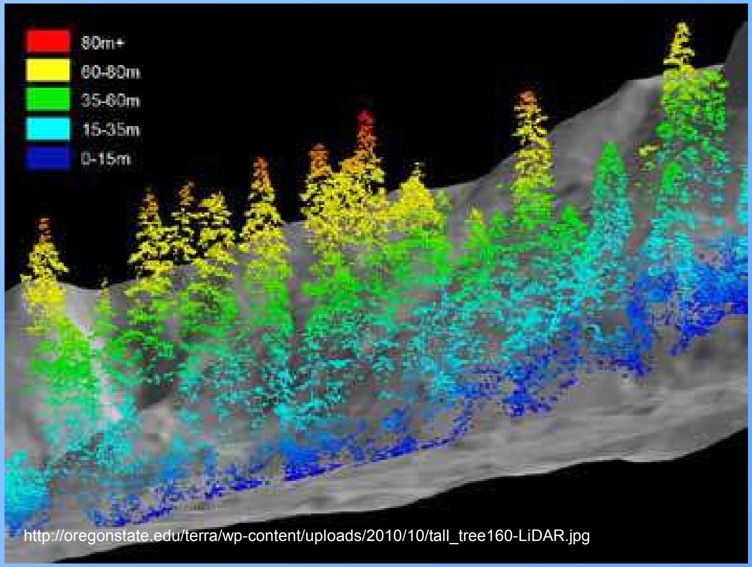
In-Field Flow & Buffers



Vegetation Composition

Digital Surface Models of vegetation (& buildings, irrigation) were generated from the initial return LiDAR points

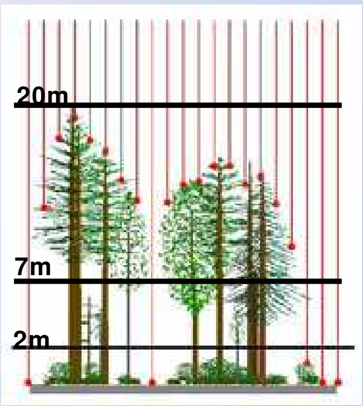
- Standard vegetation metrics derived from forestry applications are readily calculated using raster math & are useful for characterizing:
  - Vegetation metrics within riparian buffers & corridors (vegetation diversity , canopy cover, and height)
  - Wind breaks that may restrict spray drift transport
  - Non-target & endangered species colonization sites

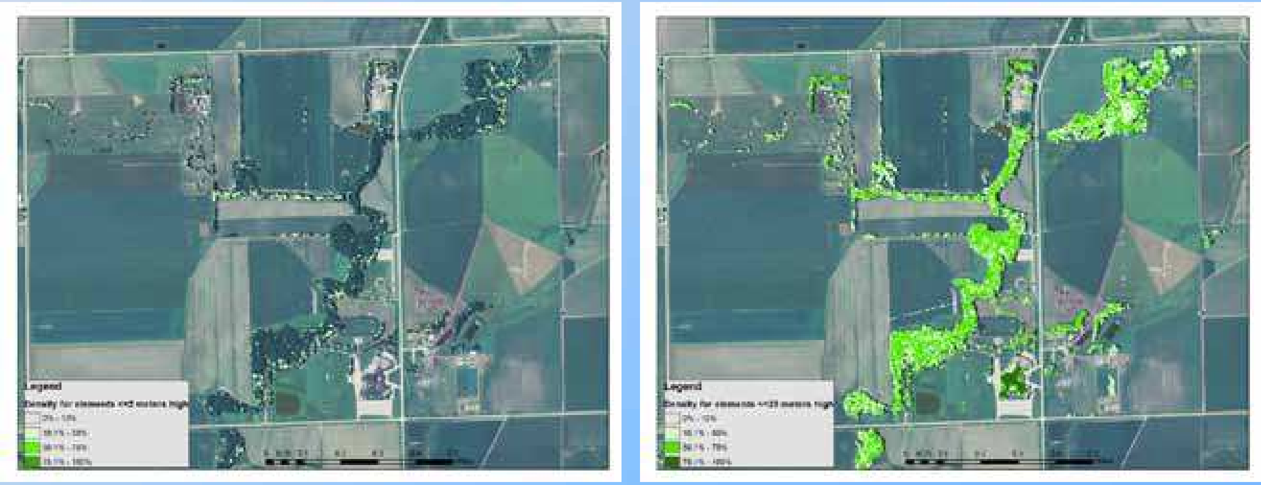


Vegetation Composition

% Vegetation Density

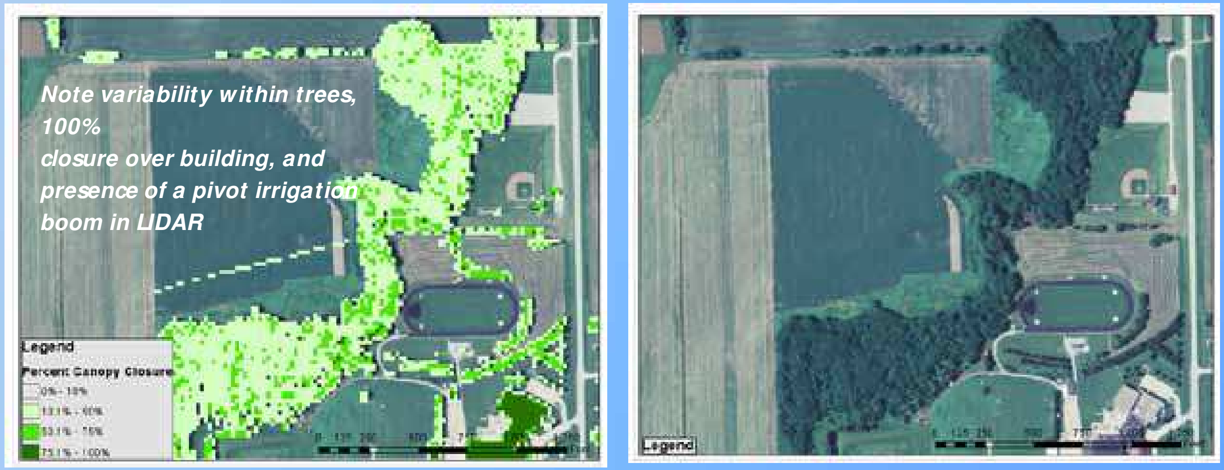
$$\frac{\text{\# of all returns over height break}}{\text{total \# of returns per unit area}}$$





Percent Vegetation Density

Cell size must be larger then individual tree crowns. Cell sizes >=15 m produce good results



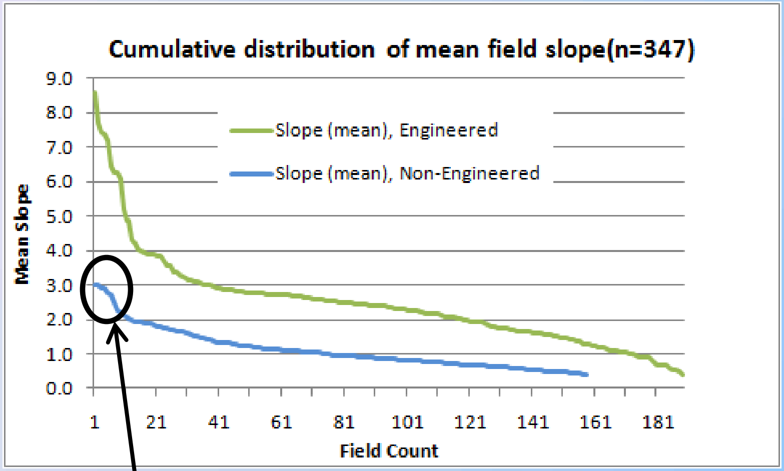
Percent Canopy Closure

% Canopy Closure

$$\frac{\text{\# of 1}^{st}\text{ returns over height break}}{\text{total \# of 1}^{st}\text{ returns per unit area}}$$

Mean Field Slope

Can field scale statistics describing slope & elevation be used to identify fields that might benefit from management practices?



are these the fields to prioritize for further examination?

"Engineered" fields are those with stand pipes or terracing (n=189)

"Non-Engineered" fields do not have discernable stand pipes or terracing (n=157)

a clear distinction between the groups exists

Observations

Engineered fields have a higher mean slope that Non-engineered

All fields with mean slope >3% are Engineered

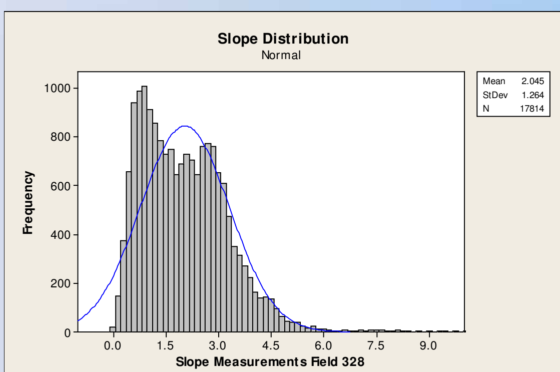
Only 8% of Non-engineered fields have mean slope > 2%

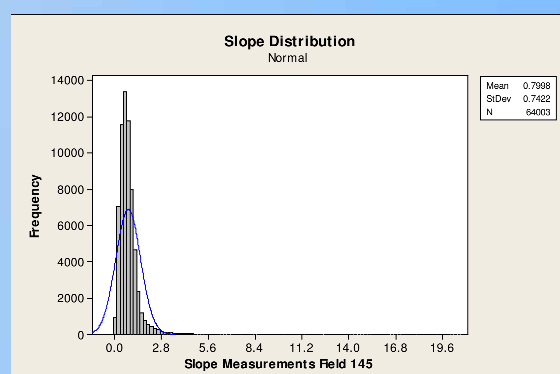
While 63% of Engineered fields have a mean field slope > 2%

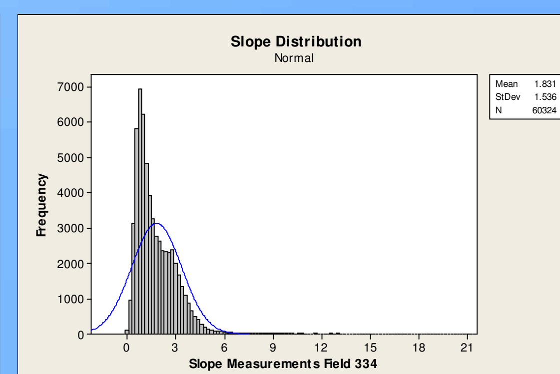
Within Field Slope Distributions

Can field scale statistics describing slope & elevation be used to identify fields that might need management practices?

- q Previous chart examined a single value (mean) for a field
- q LiDAR provided a slope value for every 9 square meters (resampled from 1 meter to 3 meters to reduce noise)
- q Within field slope distribution are another way to look at the data
- q Examining the curves of Engineered against Non-engineered field may help prioritize where to focus search for fields that need improvements





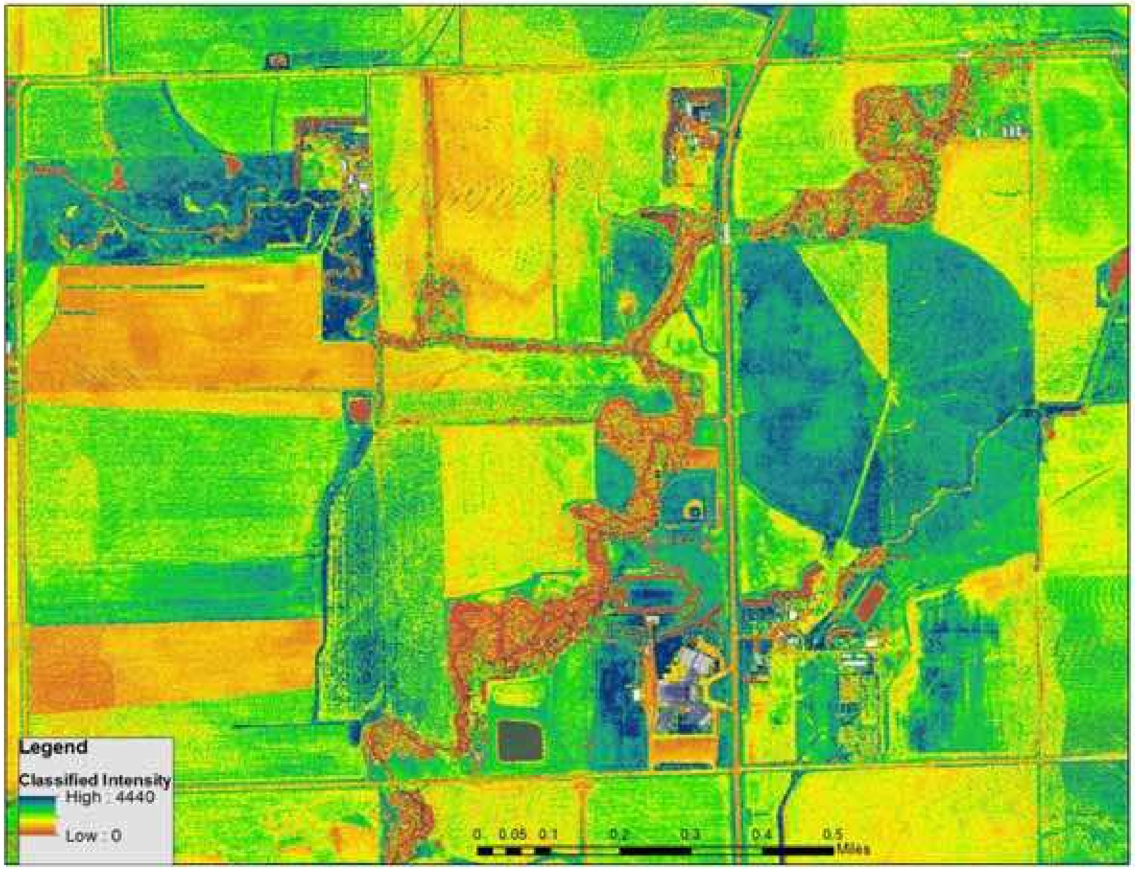


Future Work - LiDAR Intensity

Potential use of LiDAR Intensity to distinguish tillage practices

- Intensity measures the strength of the return pulses (not the time), and therefore contains different information

- Neighboring, similar looking fields visible in aerial photos have very different intensity values



Summary

The following LiDAR-derived metrics were assessed in this project

Engineered Feature Extraction

- Identified & extracted engineered features visible in LiDAR as linear features
- Summarized those features for each field within the watershed

In-Field Surface Flow

- Identified in-field storage and contributing sources of surface water
- Located preferential flow pathways from fields to adjacent waterbodies

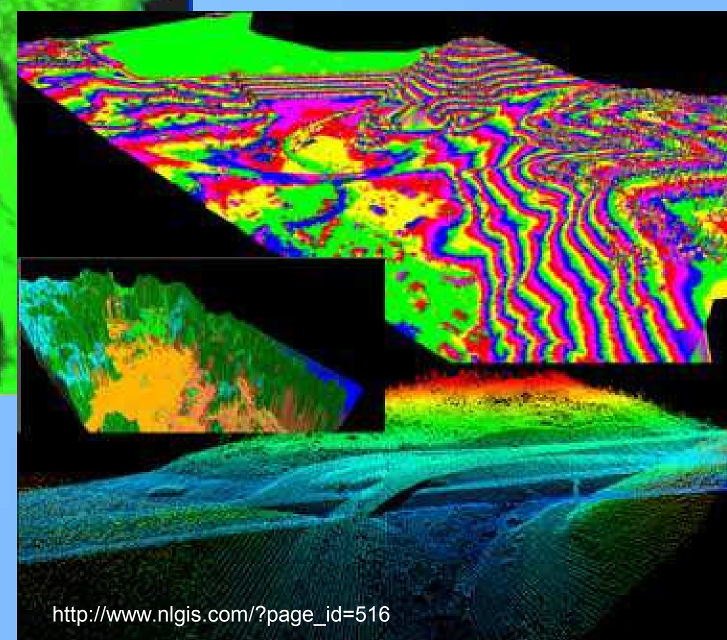
Vegetation Compo-sition

- Characterized the non-agricultural domain - riparian buffers, spray drift vegetated buffers
- calculated height, density, structure metrics

Acknowledgements

- LiDAR data provided by Nebraska Department of Game and Natural Resources, Lincoln Office (Gayle Follmer & Staci Par)
- Jay Davis, MS, Waterborne Environmental, Inc.

Questions?



Thank you