Vegetation Structure for Habitat Characterization & Biodiversity Assessment: Status and Needs

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NASA Veg3D & BIOMASS Workshop

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Outline

PART I: Ecological Rationale and State of the Art (Goetz)

- Structural Dependency of Biodiversity
- Recent Results

PART II: Needs and Requirements (Bergen)

- Summary: What We Have Learned to Date
- Summary: Importance
- Workshop

Some Background

- Biodiversity:
  - combination of species richness *and* abundance
  - more work done with vegetation diversity than animal
  - Most of the latter birds & butterflies (best data / most easily observed)..

- Habitat:
  - heterogeneity known to be linked to richness / abundance
    - relationships f (scale/grain, organism, etc)
  - heterogeneity metrics can be derived from RS
    - *Landscape Structure*: the spatial heterogeneity of an area composed of interacting habitat patches.
    - *Vertical Structure*: the bottom to top configuration or complexity of above-ground vegetation.

Structural Dependency of Taxonomic Groups

Individual species presence or absence dependent on specific structural characteristics

- e.g. Bird Species associated with Foliage Height Diversity, Vertical Habitat Structure, other indices.

Spotted Owl

Pine Warbler

Kirtland's Warbler

MacArthur & MacArthur, *On Bird Species Diversity,* Ecology 1961
MacArthur & Horn, *Foliage Profile by Vertical Measurements*, Ecol. 1969

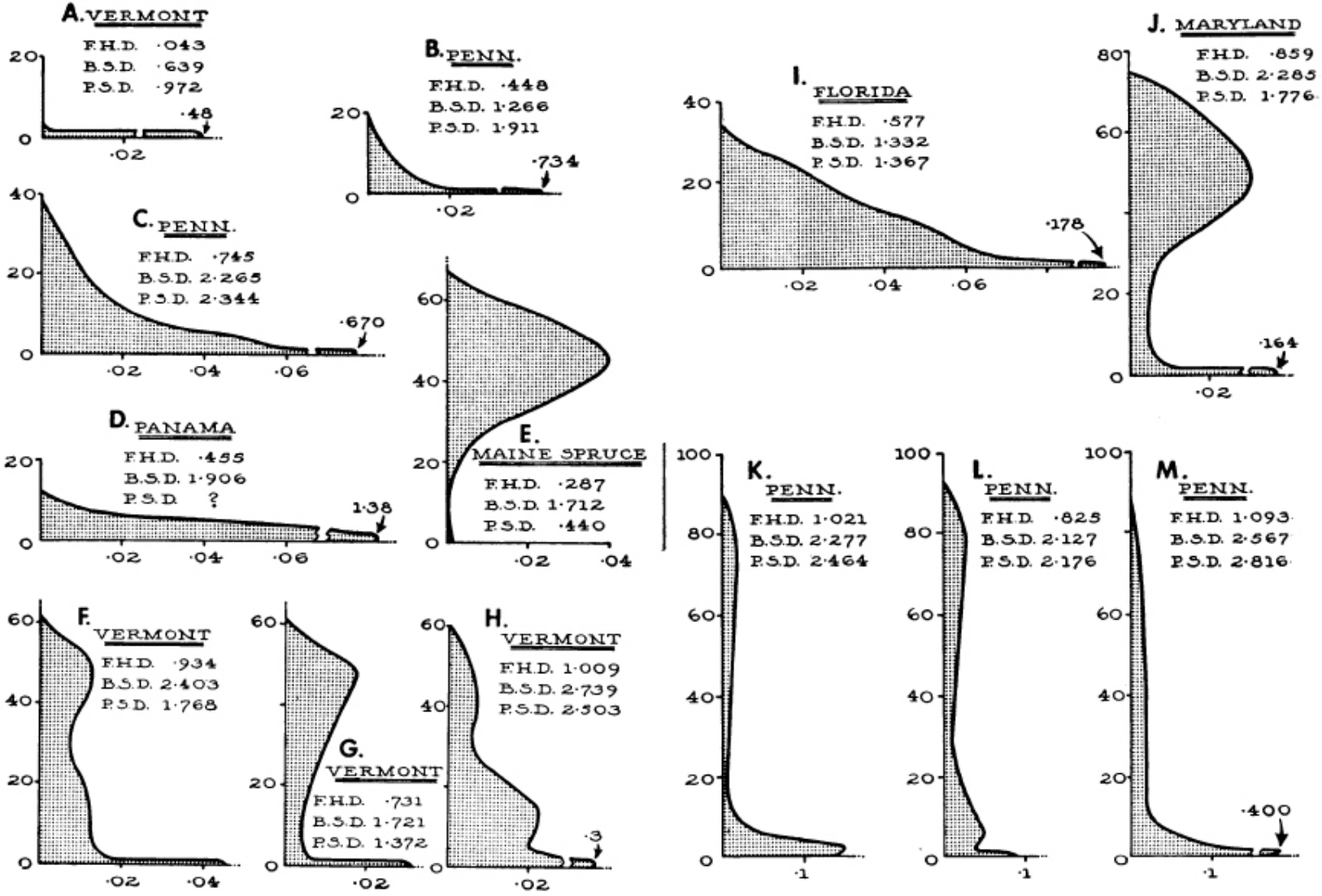
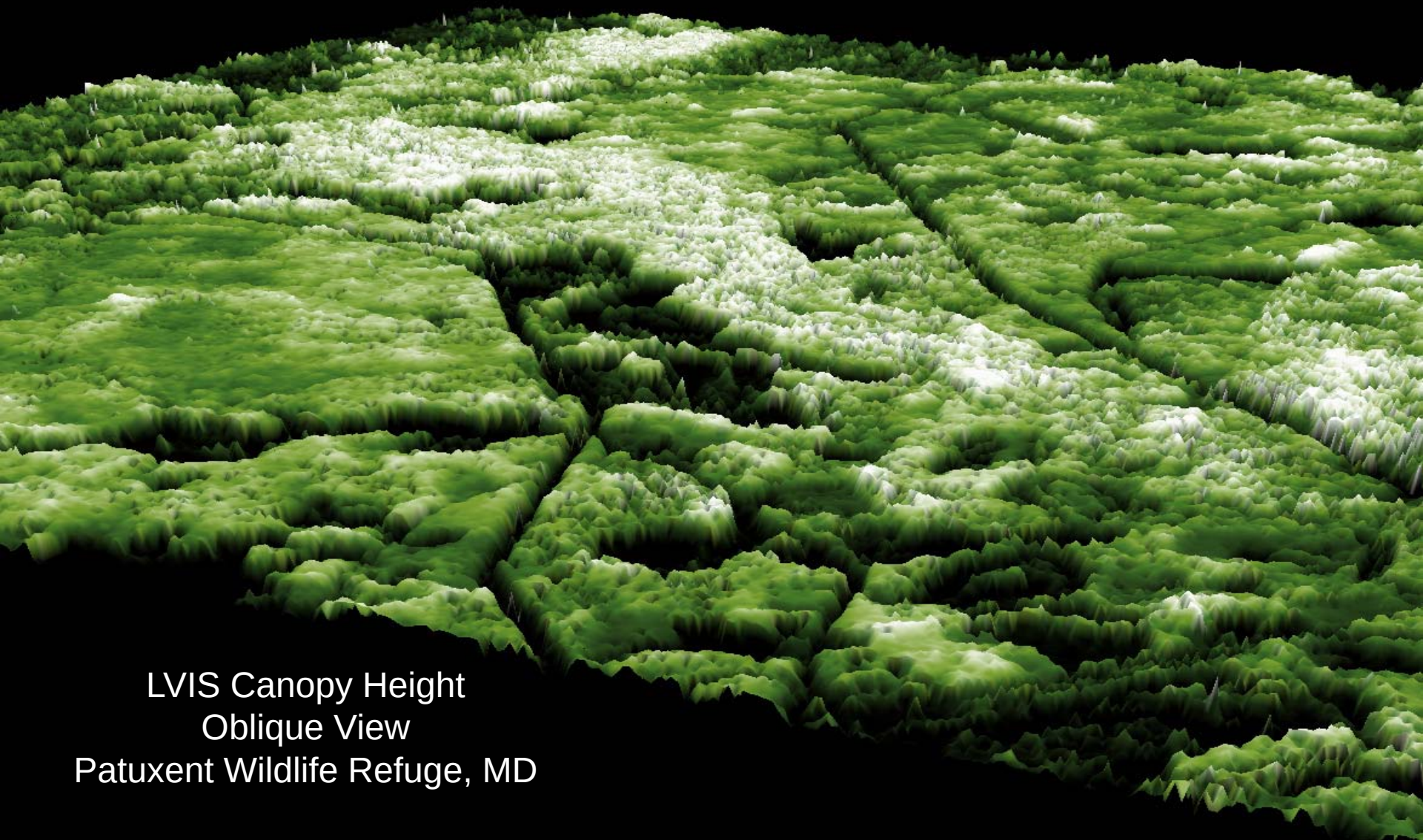


FIG. 1. The densities of foliage (measured in square feet of leaf silhouette per cubic foot of space) are plotted along the abscissae. The height in feet above the ground is the ordinate. F.H.D. is foliage height diversity, B.S.D. is bird species diversity, and P.S.D. is plant species diversity.

Recent Results / Case Studies

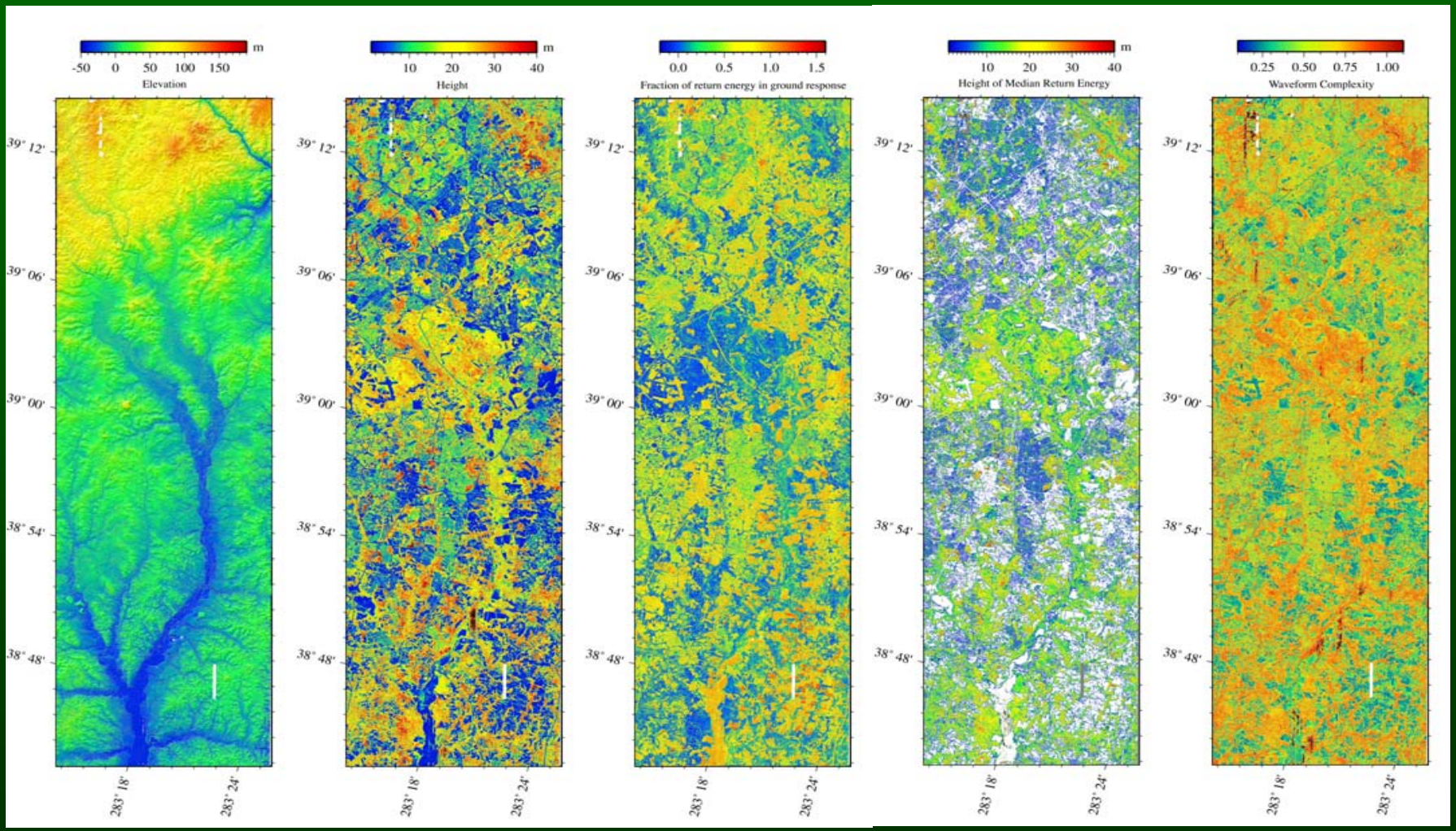
Remote sensing metrics are related to habitat heterogeneity



LVIS Canopy Height
Oblique View
Patuxent Wildlife Refuge, MD

Direct Retrievals from LIDAR Return Waveforms (Patuxent)

Data from the Laser Vegetation Imaging Sensor (LVIS)



Elevation

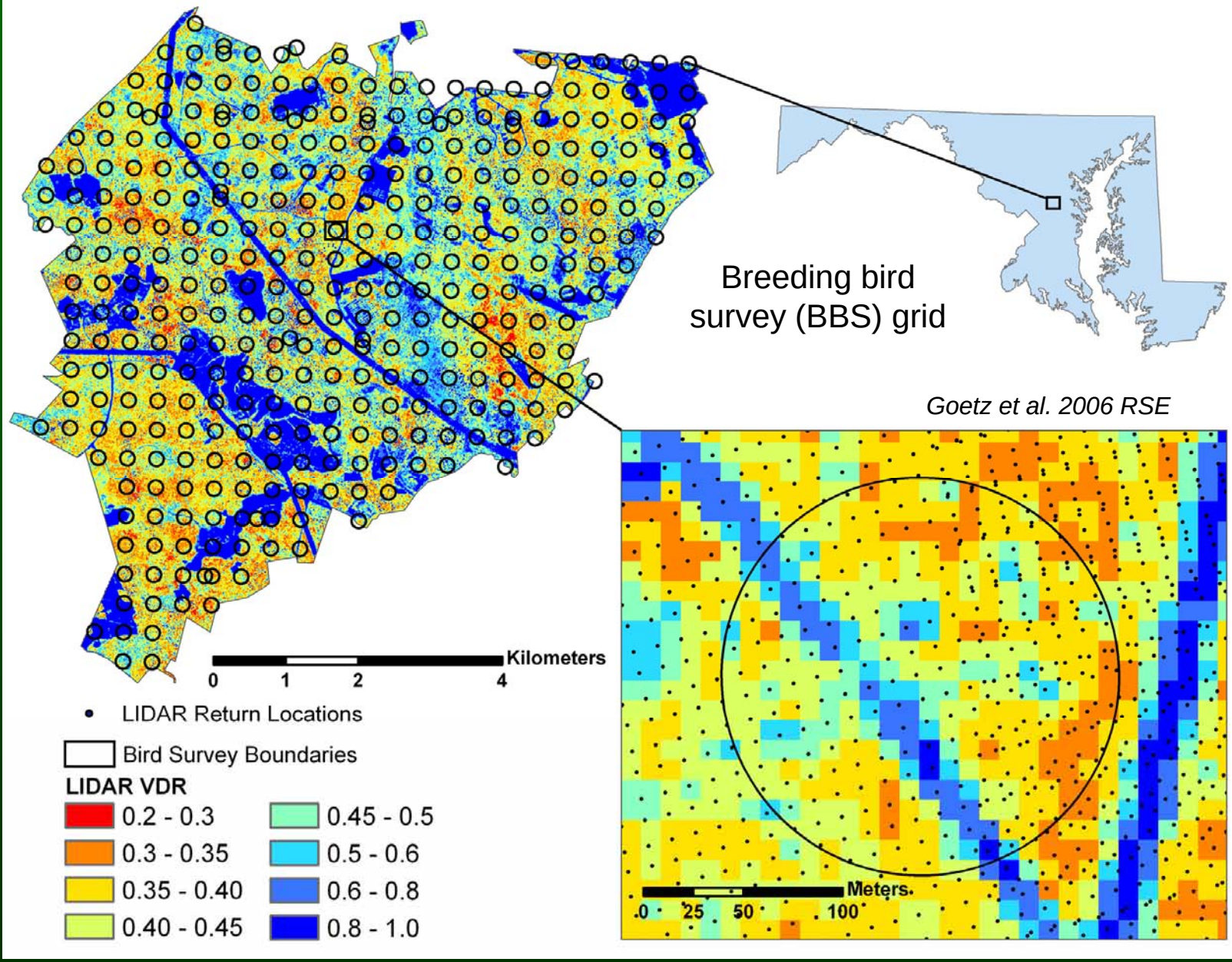
Canopy Height

Fraction Ground Energy

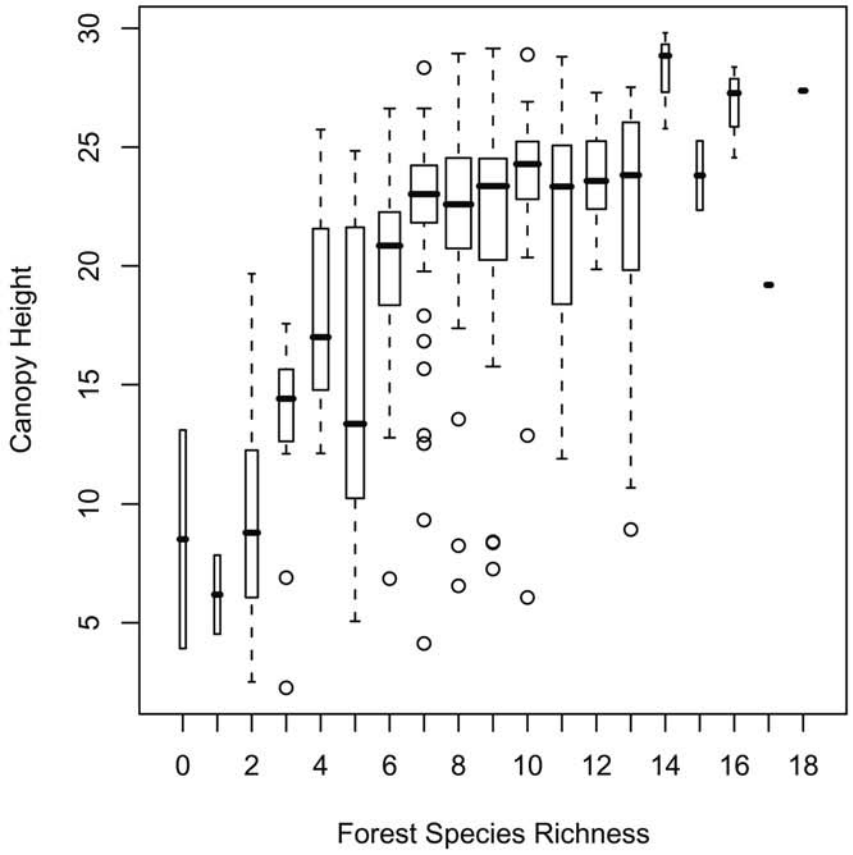
HOME

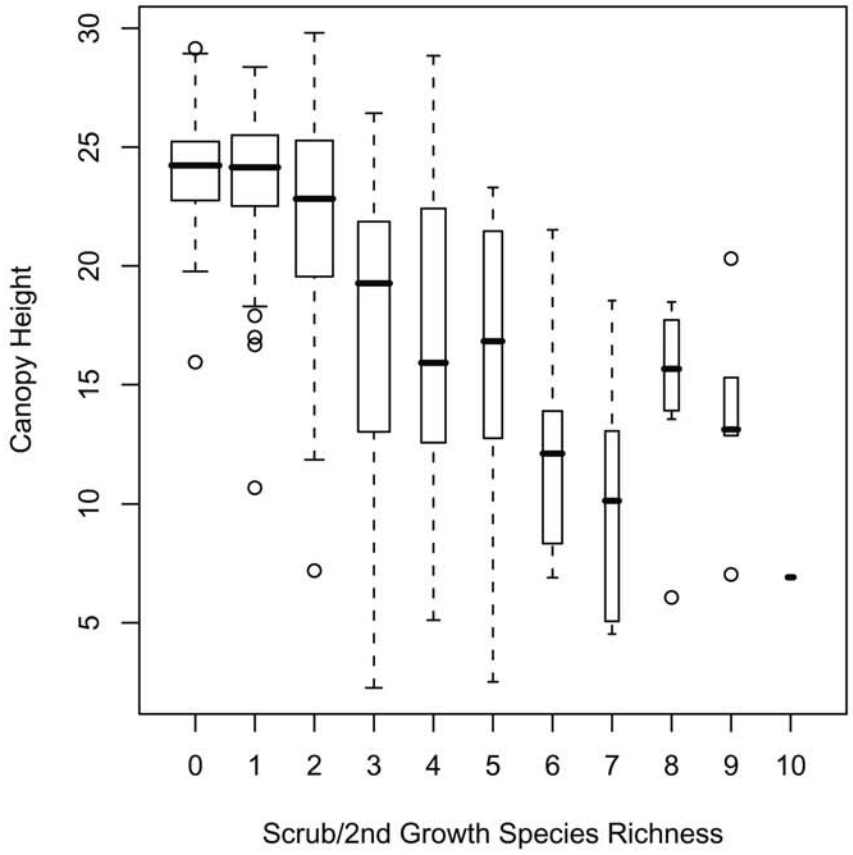
Vertical Complexity

Lidar metrics related to habitat & bird species diversity



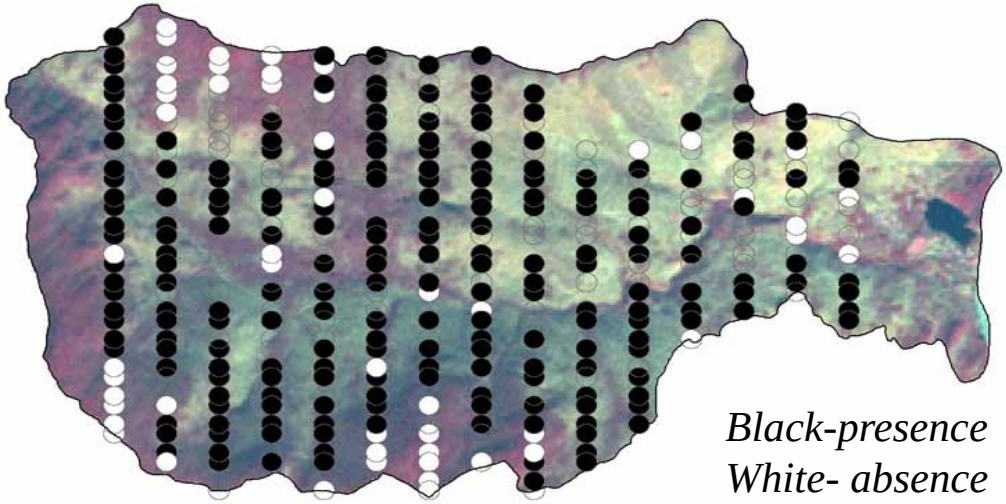
Canopy Height & Bird Species Richness at PNWR



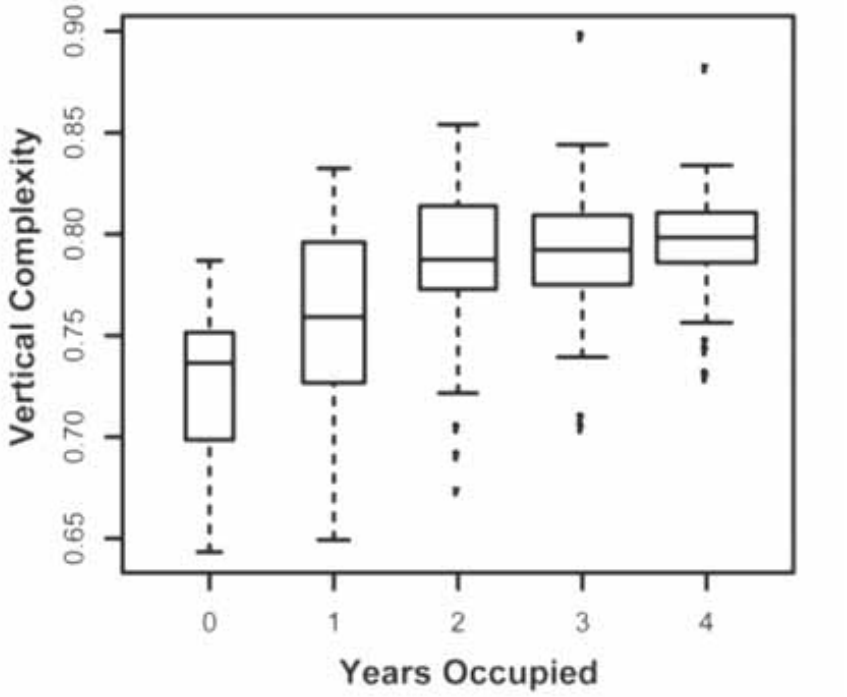


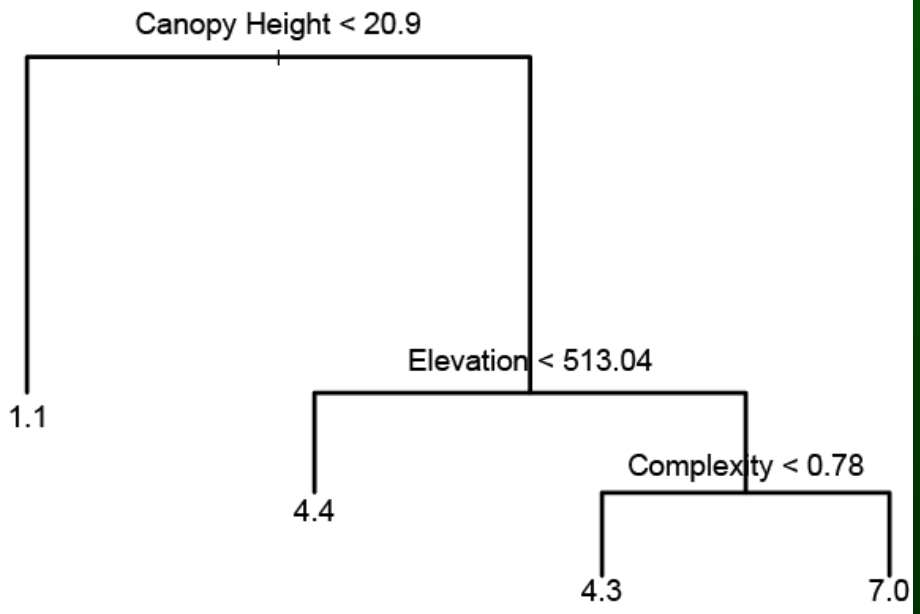
See poster for map of species richness

Habitat use by the Black-throated Blue Warbler, HBEF



Black-presence
White- absence

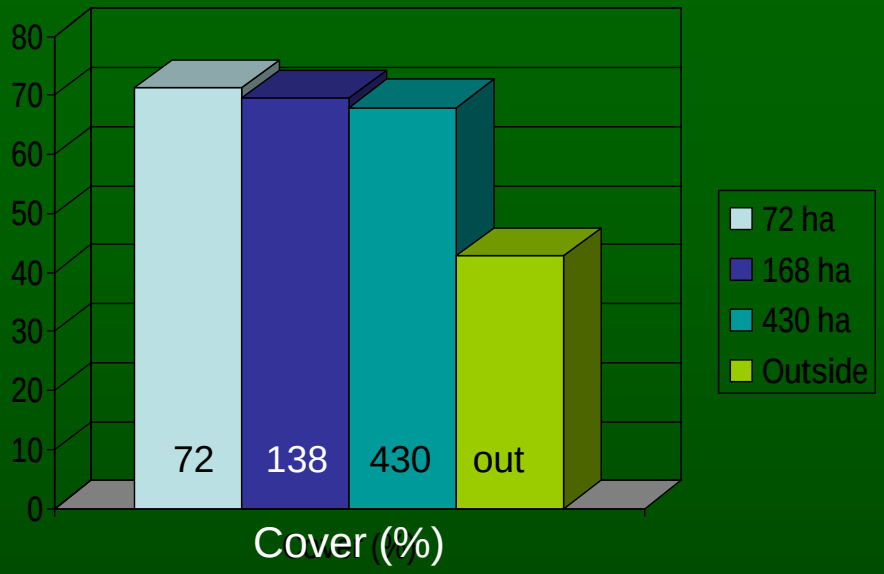




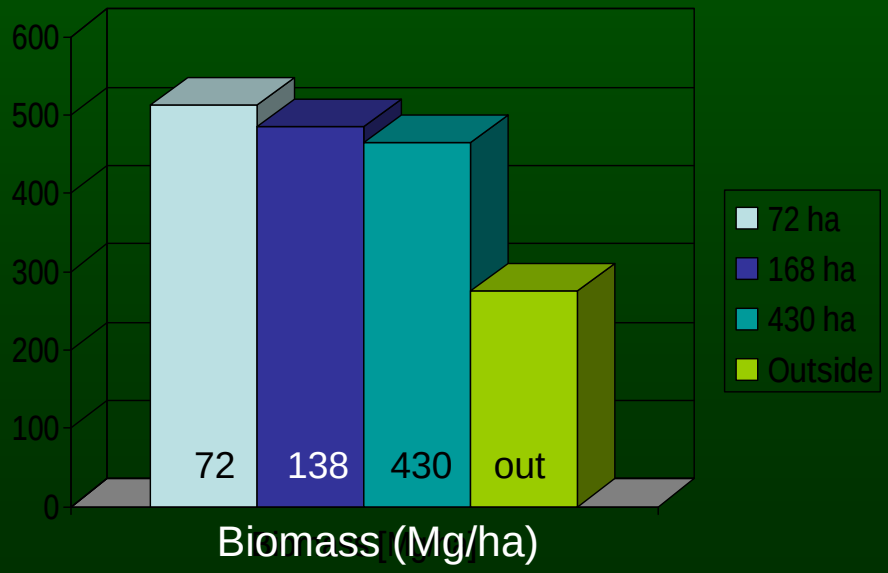
Goetz et al. forthcoming

Lidar-Derived Habitat Metrics: CA Spotted Owl

Height (m)



Cover (%)

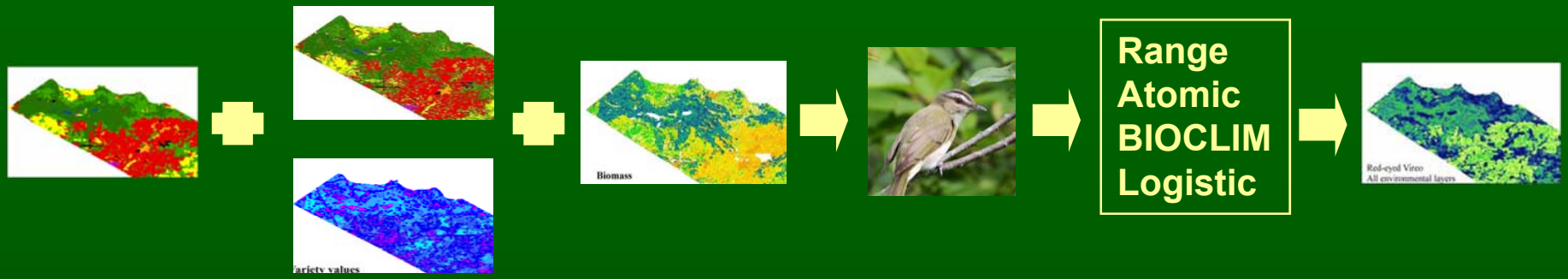


Biomass (Mg/ha)

Large difference in structure outside “owl analysis areas”

Dubayah, Hyde & Hunsaker

Multi-sensor Fusion is Advantageous



Landsat: land-cover composition

Landsat: horizontal structure -majority -variety

SAR: volumetric structure -biomass

Species Occurrence: point samples from field

Modeling: GARP (or GLM, GAM, MaxEnt, etc)

Modeled Habitat

Bergen, Gilboy & Brown, 2007

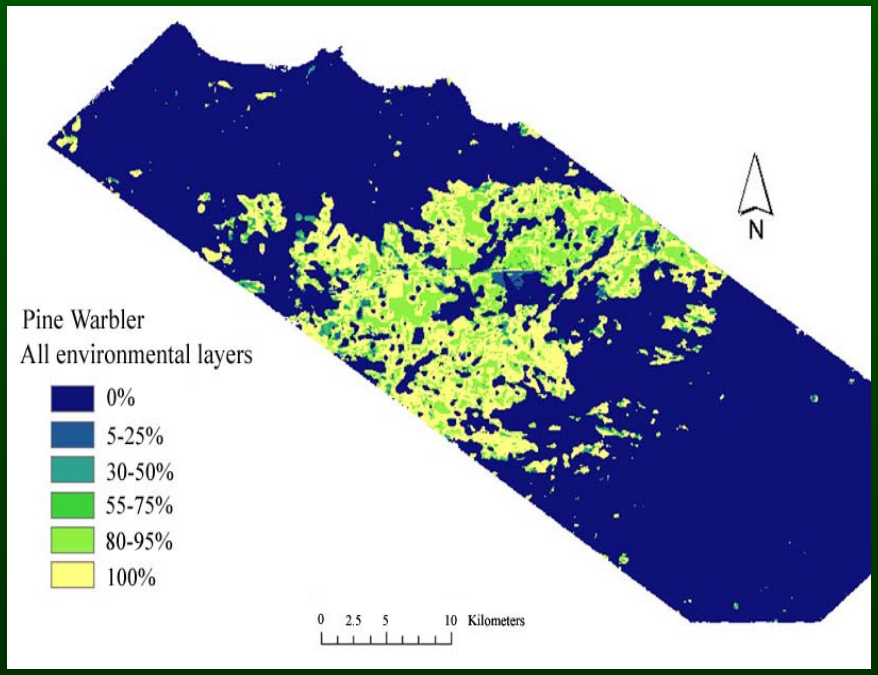
- Allows for simultaneous characterization of "multi-dimensional" structure – both horizontal (landscape structure) and volumetric (biomass)
- Landscape structure from optical sensors (e.g. Landsat)
- Volumetric structure (i.e. biomass, height) from SAR, InSAR, and/or Lidar

Multi-sensor Fusion

Pine Warbler

Known Primary habitat:
Mature conifers

Observed Secondary habitat:
Younger conifers



Bergen, Gilboy & Brown, 2007

- Best model included vegetation type, biomass, and patch size (> 20% improvement in accuracy over vegetation type alone)
- The above model created more realistic habitat models and maps:
  - Only **conifer** areas selected
  - Higher **biomass** conifer areas selected
  - **Majority** layer
    - allowed habitat selection if surrounded by a *majority* of suitable habitat;
    - de-selected highly fragmented areas

Ivory-Bill Woodpecker - Management Factors

Important Forest Structure Variables

Primary

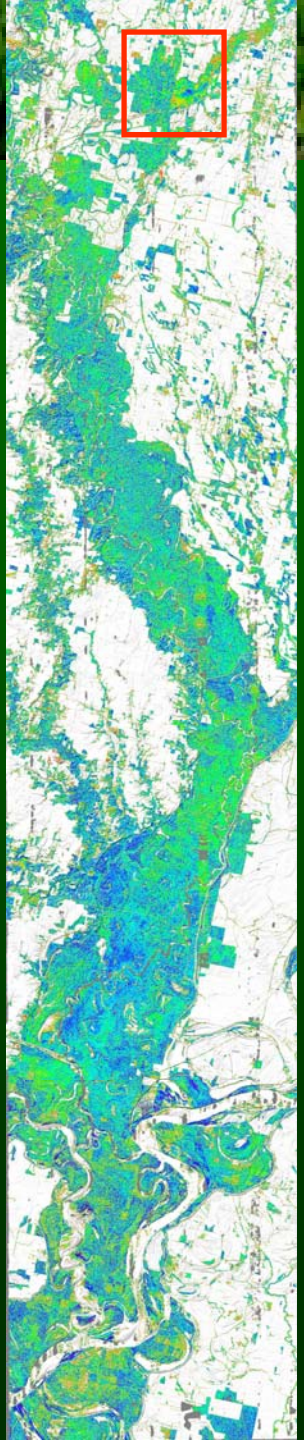
- Overstory cover
- Midstory cover
- Basal area/biomass
- Tree stocking

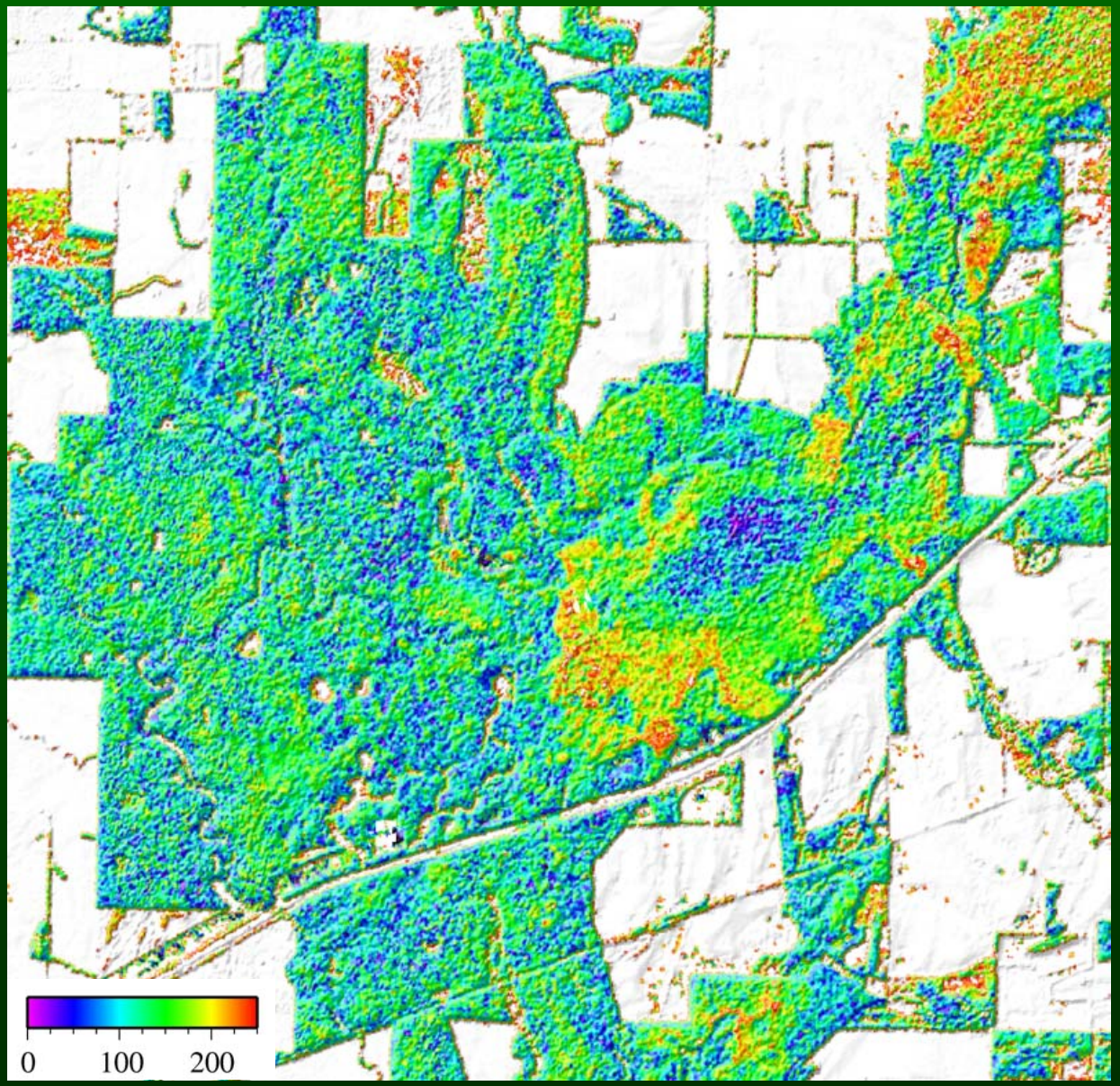
Secondary

- Dominant tree height
- Understory cover
- Coarse woody debris
- Cavity trees
- Den trees
- Standing dead
- Species (life form)

Remote sensing used to derive relevant variables

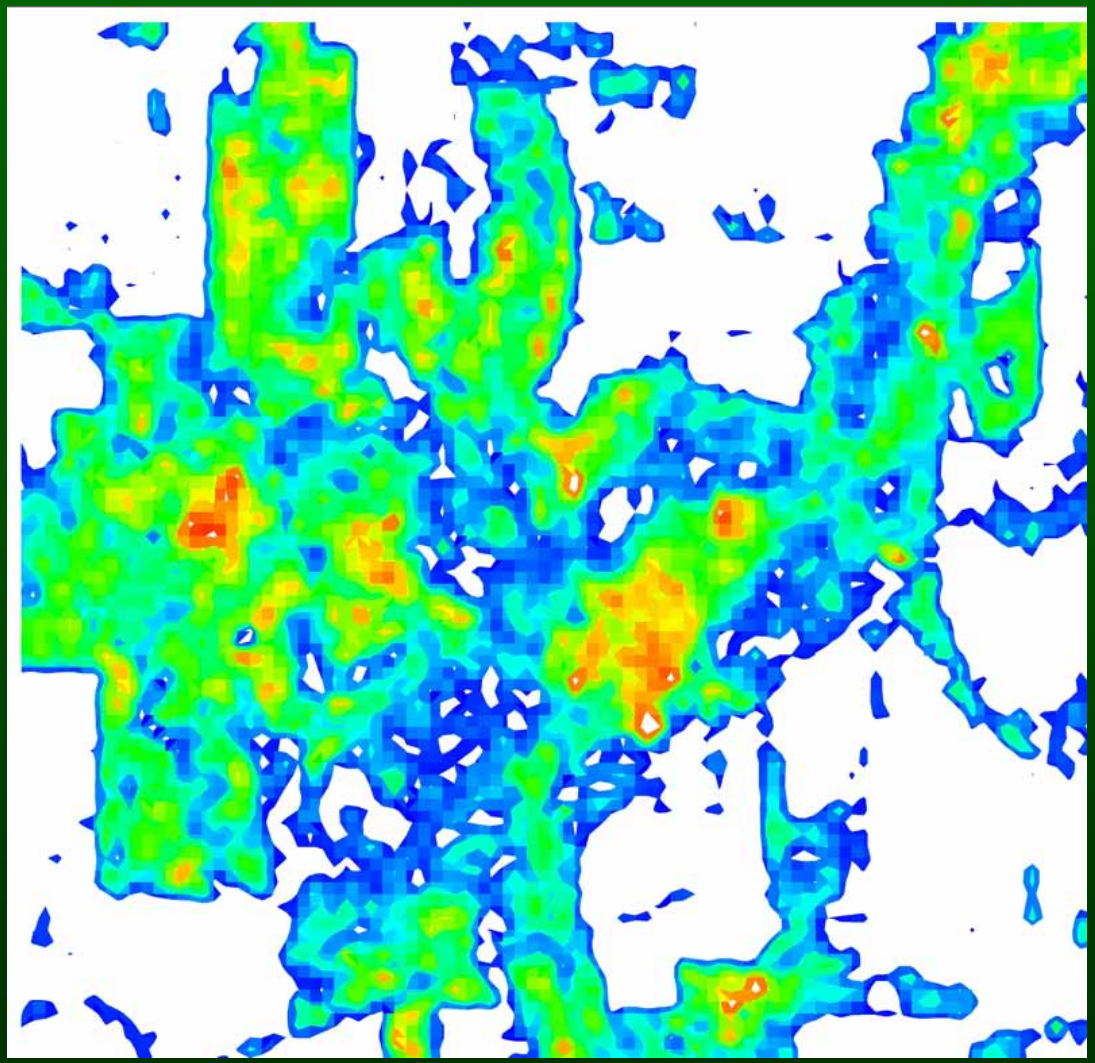
LVIS Basal Area

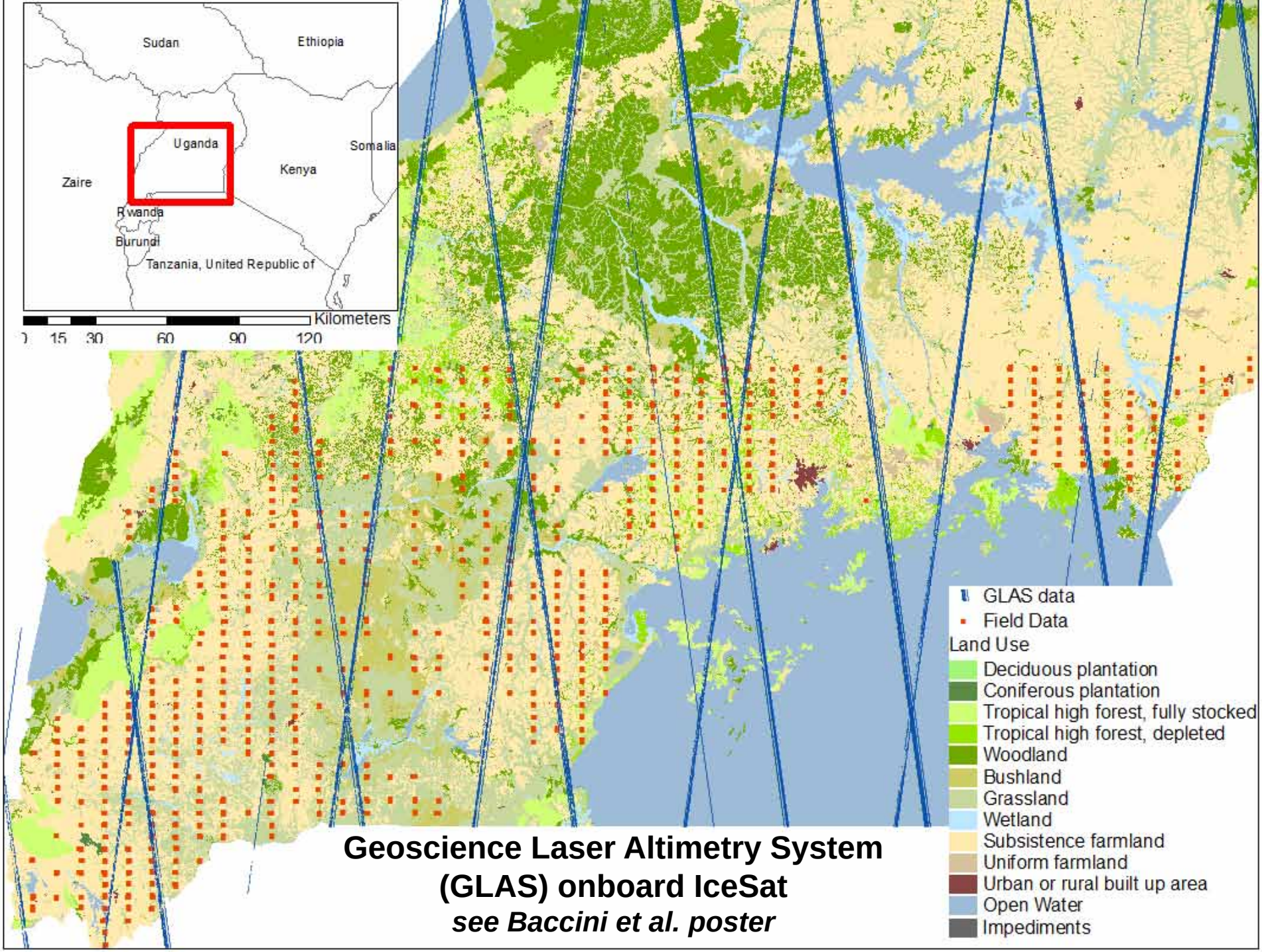




Ivory-Bill Habitat Hot-Spots

- Variables combined to identify habitat
- Large tree density (lidar)
  + Open midstory (lidar)
  + Crown dieback (hyper-spec)
- Help guide search (manage recovery?)





Geoscience Laser Altimetry System (GLAS) onboard IceSat

see Baccini et al. poster

PART II: Summary & Needs

PART II: Needs and Requirements

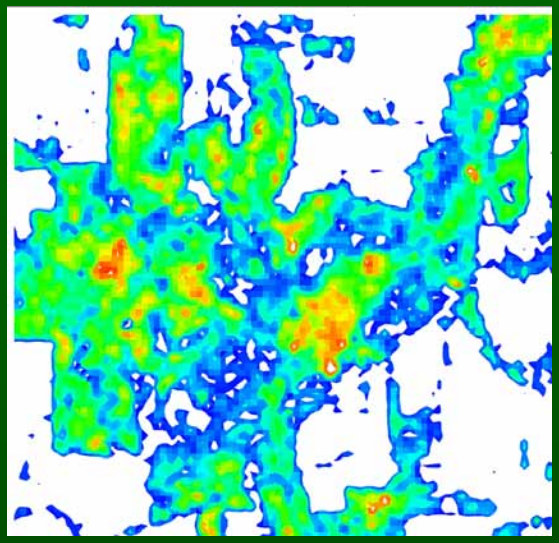
- Summary: What We Have Learned to Date
- Summary: Importance
- Workshop

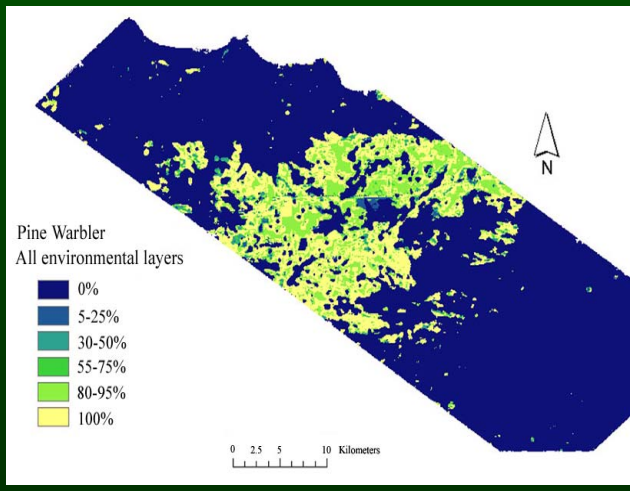
What We Have Learned to Date

- Recent rapid progress in studies
  - Prior to 2004 few studies existed using SAR or Lidar (but see Imhoff, 1997)
  - Since 2004 now several robust published studies are completed and new results are forthcoming
  - The presented studies clearly demonstrate importance and value-add of Veg3D technologies in mapping habitats and biodiversity, in particular of *temperate biome* vegetation and of *birds* as a taxonomic group, and at *landscape* scale
  - But see also *vegetation diversity & tropics* (see Prates-Clark and others) and *invasive species* (see Rosso, Ustin et al)

What We Have Learned to Date

- Why Landscape-Regional Scales?
  - Populations often occur at landscape-regional scales
    - Natural geographic barriers
    - Fragmentation due to human land-use
  - At broader scales (i.e. regions to continents), other parameters important:
    - Temperature, Moisture
    - Physiography
  - Habitat is managed on landscape-regional scales
    - National Forests
    - States
    - Nature Reserves
  - Knowledge
    - Field studies
    - Biodiversity & Habitat using optical data, i.e. Landsat





What We Have Learned to Date

Forest Structural Attributes Desired by Ecologists at 1999 Lake Tahoe Workshop (Hunsaker et al.)

- *canopy cover/LAI*
- *physiognomic or life form diversity*
- *vertical diversity*
  - *surface, under & mid-story, tree canopy*
- *tree height*
- *biomass*
- *crown volume/biomass*
- *height to live crown*
- *tree crown diameter*
- *large tree density*

What We Have Learned to Date

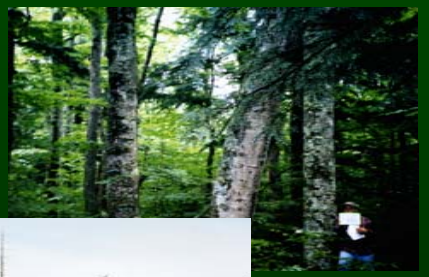
Important Variables for Biodiversity/Habitat WRT Recent Studies

- Cover Type
  - Life form – 30m or better (can get from optical VNIR sensors)
  - Vegetation type – 30m or better (can get from VNIR or hyperspectral)
- Canopy Cover
  - from optical & waveform lidar
- Biomass
  - Surrogate for age-size important to wildlife habitat models
  - Volumetric structure avoids height-density issue
  - +/- 15% at 30m (more precise models)
- Canopy Height
  - Habitat heterogeneity (correlated with avian SR)
- Vertical Distribution of Canopy Elements
  - Overstory-understory presence and life-form (30m or better desired)
  - Vertical complexity (VDR) related to occupancy & richness
  - Mid-story vs. overstory cover matters for many species
- Temporal Variation
  - Temporal change in properties must be monitored

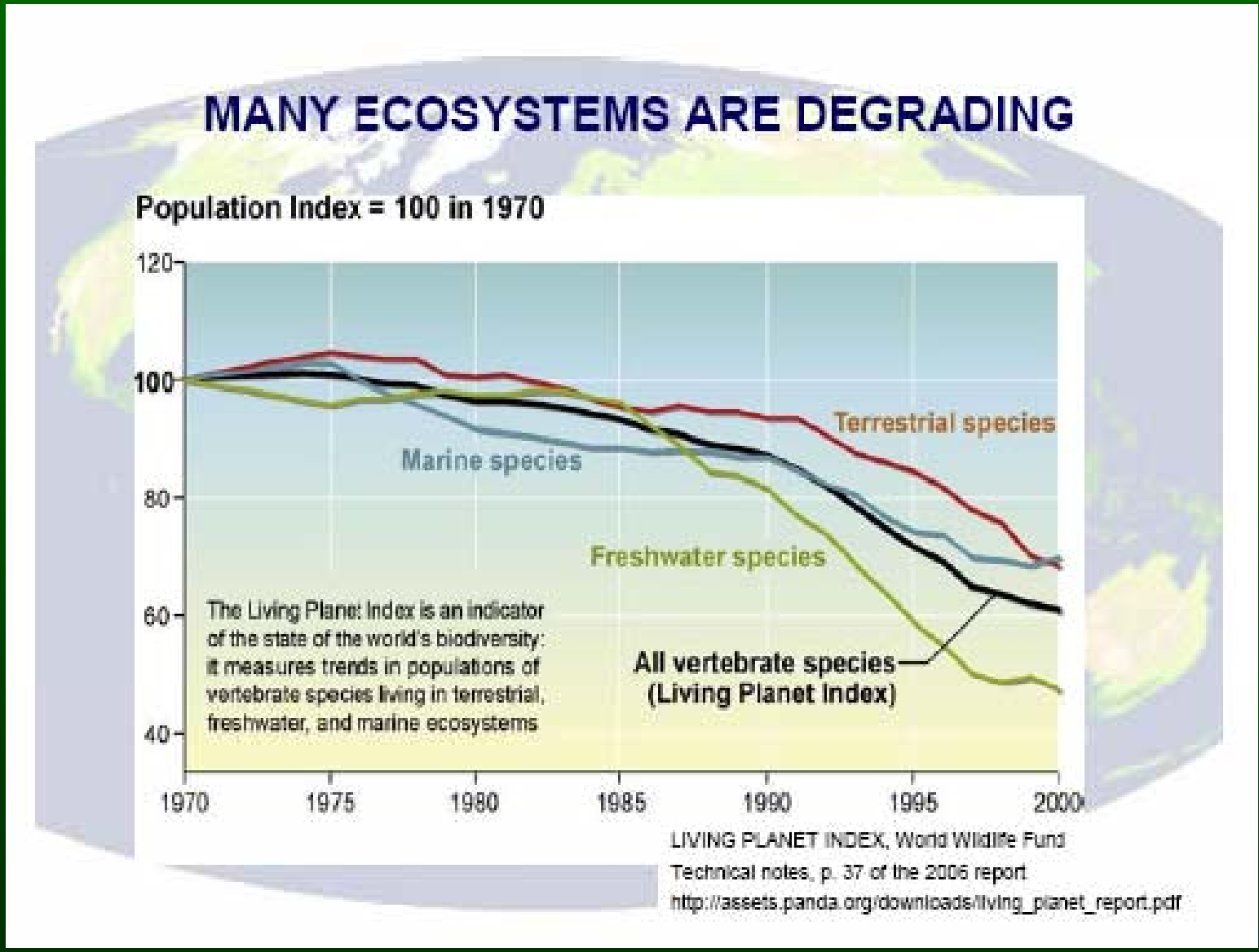
Importance: Needs for Veg3D for Biodiversity

- Management must be informed by science on ecosystems & biodiversity
- *Land-cover change* is altering habitats and biodiversity at increased rates
  - Loss of habitat and habitat diversity
  - Degraded habitat, e.g. less vertical complexity, loss of large trees, fragmentation
  - Species extinctions, may be linked to habitat loss & degradation
- *Invasive species* are increasing and more pervasive
- *Climate change*
  - already altering habitat & disturbance regimes
  - modifying ecosystem structure






Importance: Needs for Veg3D for Biodiversity



J. Ranson, data from WWF 2006

Importance: Seeking Solutions

- Importance to science and management - from presented examples:
  - Bergen et al 2007 (with USFS Hiawatha National Forest, MI)
  - Goetz et al 2007 (with USGS Breeding Bird Survey, Patuxent Wildlife Refuge)
  - Hyde, Dubayah et al 2005 (with Sierra National Forest, CA)

Importance: Seeking Solutions

- Convention on Biological Diversity
  - 2010 Target “significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth.”

- GTOS Biodiversity Initiative (B-GTOS)

  - GTOS is contributing to the CBD effort
  - Products and services that will assist in determining progress toward CBD goals
  - GOFC/GOLD

Importance: Solutions

- With Veg3D data and information:
  - Better understanding of vegetation structure as a control on biodiversity
  - ..and of vegetation structure habitat requirements of species or guilds
    - Poorly known even for charismatic megafauna
  - Better parameterized biodiversity & habitat models
    - Provides more realistic description of habitat
  - Policy and management can rely on quality state-of-the-art data
    - Veg 3d structure is difficult and inefficient to measure on ground
  - Rapid assessment of potential problems (i.e. invasives, LCLUC)
  - Identification of suitable habitat / critical areas
    - Provides much more information than vegetation type alone (age surrogate, density, complexity, heterogeneity, etc.)
  - Design of reserves
    - Provides ability to base decision-making on full multi-dimensional characteristics of vegetation diversity and habitat

Veg3D Workshop

- Document our most important needs and variables, i.e. requirements
  - Matching science needs with variables & parameters
    - a main focus of our Breakout I
  - Matching science needs with sensors technologies
    - a main focus of our Breakout III
- Challenges (i.e. bring your expertise to the table)
  - Consider documented results & requirements to date
  - Consider different
    - spatial scales of study
    - taxa, i.e. not just birds
    - temporal scales of change and disturbance

Veg3D Workshop

How are biodiversity and species habitats distributed over the Earth surface, how are they changing, and what Veg3d information is critical for biodiversity and habitat science and management?

1. Importance: why is biodiversity and habitat mapping and modeling using Veg3D important
   - General needs
   - Specific programs
2. What Veg3D variables are needed and why are they important:
   - For mapping and quantification of biodiversity and habitat
   - For use in models (e.g. statistical, ecological niche models, species range/distribution models)
3. Record the Veg3D variables requirements: What are the required…
   - spatial resolutions for important structural variables
   - accuracies for important structural variables
   - geographic extents
   - temporal frequencies

Let’s Have Something to Celebrate for:

Convention on Biodiversity

The International Day for Biological Diversity:
2008 Theme: Biodiversity and Agriculture
22 May 2008

What is Needed: Science

- Studies on spatial scales
  - To date we have used the limited existing & available data
  - How would precision/accuracy of habitat or biodiversity WRT birds improve or degrade depending on spatial resolution of data?
  - Need studies relating spatial resolution to scales of habitat/diversity
- Studies on a wider range of taxonomic groups (i.e. mammals, reptiles, amphibians, insects)
  - Habitat/biodiversity patterns will have different scales than birds
  - Need partnerships for ground data for other taxa
- Studies on temporal scales:
  - Consideration of the temporal *change* of biodiversity and habitat:
  - what temporal resolutions are needed?

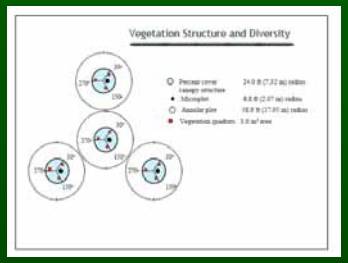
Importance: Seeking Solutions

- Convention on Biological Diversity
  - 2010 Target “significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth.”
- GTOS Biodiversity Project

GTOS GLOBAL TERRESTRIAL OBSERVING SYSTEM

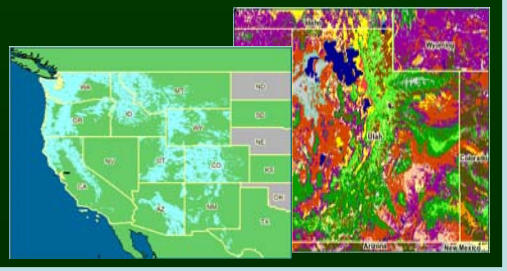
  - GTOS is contributing to the CBD effort
  - Products and services that will assist in determining progress toward CBD goals
  - GOFC/GOLD

- USFS: FHM Vegetation Indicator
  - Vegetation structure & diversity
  - Susceptibility to invasive species
  - Which ecoregions and forest types are most diverse?



USDA

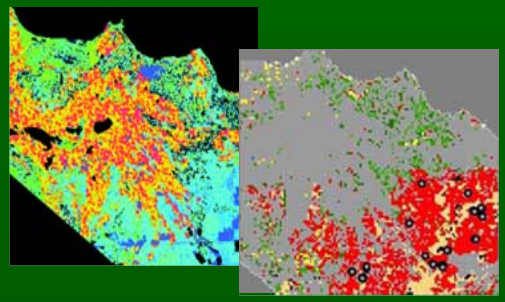
- USGS: GAP Analysis Program
  - “Keep Common Species Common”
  - Method used combination of
    1) satellite-derived land-cover &
    2) wildlife habitat models



What We Have Learned to Date

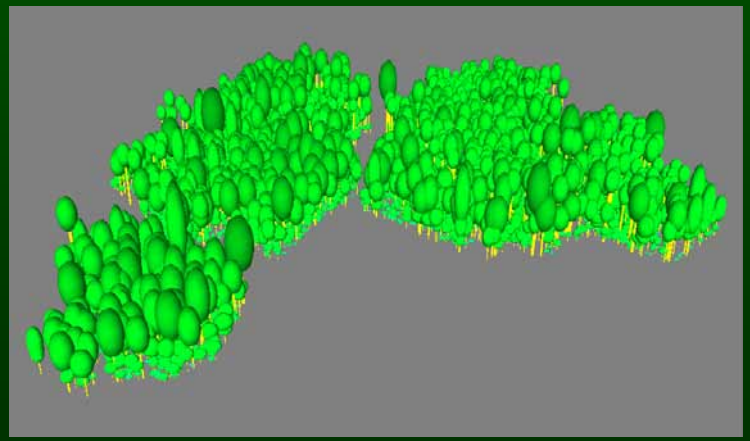
Modeling: variables and resolutions needed:

- at local landscape scales
  - See reported studies
  - Landscape scale (i.e. better than 30m)
  - Change
- at regional to continental scales
  - Which are ‘generalizable” at coarser resolutions?
  - Biomass is example
  - Change



Regional Biodiversity Modeling with Biomass Data

University of Michigan ESALab , Bergen et al



Tree & Canopy Modeling

Jim Clark Lab, Duke University

Forest Structure and Biodiversity Modeling

Weishampel, University of Central FL and UMD/NASA GSFC (Blair, Knox, Dubayah et al)