USING LIDAR TO ASSESS THE ROLES OF CLIMATE AND LAND-COVER DYNAMICS AS DRIVERS OF CHANGES IN BIODIVERSITY

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Motivation

NY State Breeding Bird Atlas:
• From 129 bird species, 57.4% experienced a northward shift in the mean latitude of their distribution.
• Southern range limits of 43 northerly species have shifted northward an average of 11.4 km.

What are the drivers behind this change?
Approach

3D LULC Changes 2010-1991

Climate Changes 2005-1985

Biodiversity Predictor

BBA Changes 1985-2005

NY State BBA 1980-1985

NY State BBA 2000-2005

Carolina Wren (Thryothorus ludovicianus)
Remote Sensing

Model Development

LVIS: Laser Vegetation Imaging Sensor, LULC: Land Use Land Cover
NLCD: National Land Cover Data, BBA: Breeding Bird Atlas

Historical Data
NLCD1991
NLCD2001

Landsat 2010
LVIS 2010

Multi-source Classifier

3D LULC 2010

Forest Succession

3D LULC Changes 2010-1991

Biodiversity Predictor

3D LULC 1991

backcast

PRISM 1985
PRISM 2005

Climate Changes 2005-1985

BBA Changes 1985-2005

Legend:
- Models
- Original Data
- Produced Data
Leaf Off/On Scenes (19 in total)

Remote Sensing

Vegetation Model

Biodiversity Model
Shrubs: Important for avian biodiversity

NLCD 2006 accuracy <30%
Multi-temporal Landsat: ~49%
Shrubs: Important for avian biodiversity

NLCD 2006 accuracy <30%
Multi-temporal Landsat: ~49%
Landsat + PALSAR: ~53%*
Shrubs: Important for avian biodiversity

LiDAR LVIS: Large-footprint waveform sensor
Remote Sensing
Ground detection using LiDAR LVIS

Video
Remote Sensing

Ground detection using LiDAR LVIS

![Bar chart showing RMSE in meters for different vegetation types: Deciduous, Coniferous, Shrub, Grass, Developed Area. The chart compares ZC, GD, and FICA methods.](chart-url)
<table>
<thead>
<tr>
<th></th>
<th>PCF</th>
<th>GD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bias</td>
<td>0.5</td>
<td>2.84</td>
</tr>
<tr>
<td>MAE (m)</td>
<td>1.41</td>
<td>2.84</td>
</tr>
<tr>
<td>RMSE (m)</td>
<td>1.92</td>
<td>3.36</td>
</tr>
</tbody>
</table>

PCF (Partial Curve Fitting) = Our method
GD (Gaussian Decomposition) = Existing benchmark method

Remote Sensing
Ground detection using LiDAR LVIS + Landsat fusion specifically for shrubs
Forest Succession Model

Model Development

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Legend:
- Models
- Original Data
- Produced Data
Methods

• State-based Markov transition model of land cover change
• ~2600 points classified
Forest Succession Results

1985

2005
Biodiversity Model
Community turnover
METHODS

Response:
• Temporal Turnover (BBA 1980s-2000s): \( \text{TURN} = \frac{(E+C)}{(E+C+P)} \)
• Extinction (BBA 1980s-2000s): \( \text{EXT} = \frac{E}{(E+P)} \)
• Colonization (BBA 1980s-2000s): \( \text{COL} = \frac{C}{(E+C+P)} \)

Covariates:
• Temporal (1980-2005) trends in climatic covariates: Maximum Temp (TMAX, °C/25 years), Minimum Temp (TMIN, °C/25 years), Precipitation (PRECIP, mm/25 years).
• Landscape fragmentation: Edge density (ED, m/ha), Percent Developed Land (DEVEL, %)
• Change in Survey Effort (EFF)
CHANGE IN AVIAN ASSEMBLAGE

TEMPORAL TURNOVER

EXTINCTION

COLONIZATION

97.5 percentile
50 percentile (mean)
2.5 percentile

ALL SPECIES: N = 256
LONG-DISTANCE: N = 110
RESIDENT: N = 79

SHORT-DISTANCE: N = 67
CHANGE IN AVIAN ASSEMBLY

TEMPORAL TURNOVER

RESIDENT

ALL  LONG  SHORT

TURNOVER

0.50
0.45
0.40
0.35
0.30

LD

SD

RES
METHODS

Statistical models:
Binomial distribution
Space-varying intercept models in spBayes package (accounting for spatial autocorrelation)

Competing models:
Dependent variables: TURN, EXT, COL
Model 1: TMAX, TMIN, PRECIP, EFF
Model 2: TMAX, TMIN, PRECIP, ED, EFF
Model 3: TMAX*ED, TMIN*ED, PRECIP*ED, EFF
Model 4: TMAX, TMIN, PRECIP, ED, DEVEL, EFF
Model 5: TMAX*ED, TMIN*ED, PRECIP*ED, DEVEL, EFF
RESULTS

Best models (DIC) for Temporal Turnover

Climate-land cover interactions are important

No clear differences between different migratory groupings for any of the community change metrics

**ALL BIRDS**: TMAX*ED, TMIN*ED, PRECIP*ED, DEVEL, EFF ($R^2 = 0.3$)

**LONG**: TMAX*ED, TMIN*ED, PRECIP*ED, DEVEL, EFF ($R^2 = 0.22$)

**SHORT**: TMAX, TMIN, PRECIP, DEVEL, EFF ($R^2 = 0.18$)

**RESIDENT**: TMAX*ED, TMIN*ED, PRECIP*ED, DEVEL, EFF ($R^2 = 0.37$)
RESULTS

What do these significant interactions mean? How do climate and land cover interact to shape changes in community structure?

Stronger associations between community change and \textit{TEMP} in regions with unfragmented habitats.

Negative associations between community change and \textit{PRECIP} in regions with unfragmented habitats, but positive in fragmented regions.
BIG PICTURE

Significant improvements in LiDAR data processing.

RADAR integration still in progress.

Interactions between avian community and climate dynamics may be different based on fragmentation level.

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