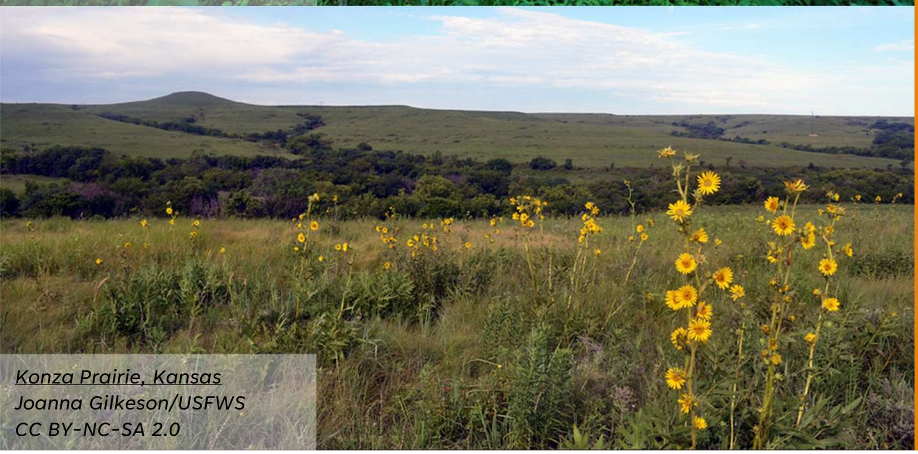
Virginia Mid-Atlantic Forest
Danielle Brigida
CC BY-NC-SA 2.0



Konza Prairie, Kansas
Joanna Gilkeson/USFWS
CC BY-NC-SA 2.0

Landscape Metrics as Predictors of Avian Species Richness in Grassland vs Forest Biomes

ANDREW CAMERON

VIRGINIA COMMONWEALTH UNIVERSITY

CENTER FOR ENVIRONMENTAL STUDIES

Background

- The loss of grassland and forest ecosystems poses the most serious threat to terrestrial biodiversity (Ceballos et al., 2010; Jaureguiberry et al., 2022)
- Land use change for agriculture, livestock, urbanization, and other forms of human development and its resultant habitat loss is primary driver of this trend, particularly for bird species (Jaureguiberry et al., 2022; Rosenberg et al., 2019)
- Eastern forest and grassland bird species have declined by 27% and 34% respectively since 1970 (NABCI, 2022)
- Among grassland birds, 74% of species have experienced population declines over that period (Lees et al., 2022)

Research Question

To what degree can class-level landscape metrics help explain variation in avian species richness in forest vs grassland biomes at a variety of spatial scales?

Hypothesis

Avian species richness will be significantly better explained by class-level landscape metrics in grassland rather than forest biomes.

THE DATA

AVIAN POINT COUNTS

LANDCOVER RASTERS

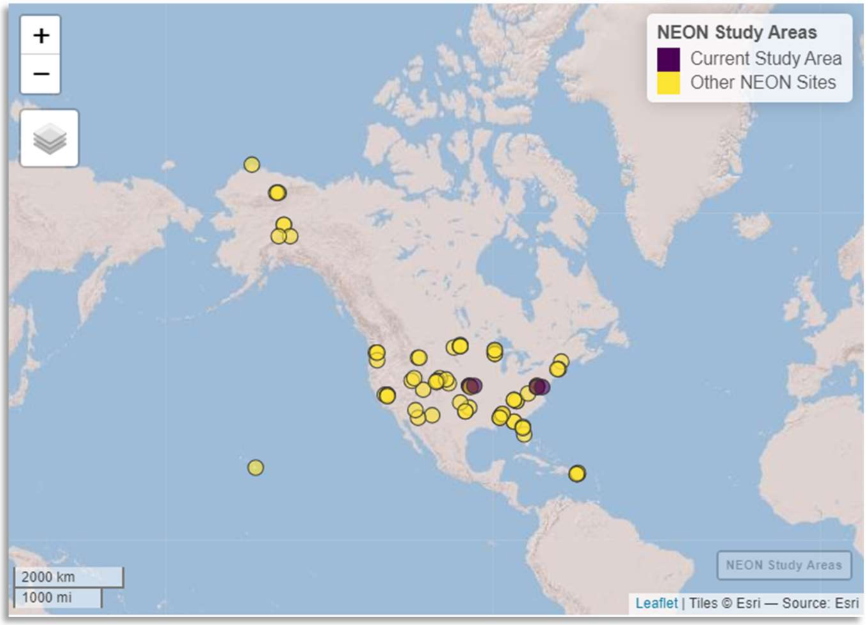
21	2019-06-11 09:17:00	BLAN_001.21.2019-06-11	88	Y	COYE	Geothlypis trichas	species	Common Yellowthroat	NA	singing
21	2019-06-11 09:17:00	BLAN_001.21.2019-06-11	1	Y	BGGN	Polioptila caerulea	species	Blue-gray Gnatcatcher	18	singing
21	2019-06-11 09:17:00	BLAN_001.21.2019-06-11	88	Y	ACFL	Empidonax virescens	species	Acadian Flycatcher	NA	singing
21	2019-06-11 09:17:00	BLAN_001.21.2019-06-11	88	Y	CHSP	Spizella passerina	species	Chipping Sparrow	NA	singing
21	2019-06-11 09:17:00	BLAN_001.21.2019-06-11	5	Y	DOWO	Picoides pubescens	species	Downy Woodpecker	23	singing
21	2019-06-11 09:17:00	BLAN_001.21.2019-06-11	3	Y	NOCA	Cardinalis cardinalis	species	Northern Cardinal	24	calling
21	2019-06-11 09:17:00	BLAN_001.21.2019-06-11	2	Y	CARW	Thryothorus ludovicianus	species	Carolina Wren	15	singing
21	2019-06-11 09:17:00	BLAN_001.21.2019-06-11	3	Y	INBU	Passerina cyanea	species	Indigo Bunting	33	singing
21	2019-06-11 09:17:00	BLAN_001.21.2019-06-11	88	Y	NOPA	Setophaga americana	species	Northern Parula	NA	singing
21	2019-06-11 09:17:00	BLAN_001.21.2019-06-11	6	Y	OROR	Icterus spurius	species	Orchard Oriole	29	calling
21	2019-06-11 09:17:00	BLAN_001.21.2019-06-11	4	N	NA	NA	NA	NA	NA	NA
21	2019-06-11 09:17:00	BLAN_001.21.2019-06-11	1	Y	REVI	Vireo olivaceus	species	Red-eyed Vireo	23	singing
21	2019-06-11 09:17:00	BLAN_001.21.2019-06-11	88	Y	EATO	Pipilo erythrophthalmus	species	Eastern Towhee	NA	singing
21	2019-06-11 09:17:00	BLAN_001.21.2019-06-11	88	Y	EAWP	Contopus virens	species	Eastern Wood-Pewee	NA	singing
21	2019-06-11 09:53:00	BLAN_004.21.2019-06-11	3	Y	BGGN	Polioptila caerulea	species	Blue-gray Gnatcatcher	23	calling
21	[illegible]	[illegible]	[illegible]	[illegible]	NA	NA	NA	NA	NA	NA
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Vireo gilvus	species	Warbling Vireo	61	singing
21	2019-06-11 09:53:00	BLAN_004.21.2019-06-11	3	Y	INBU	Passerina cyanea	species	Indigo Bunting	162	singing
21	2019-06-11 09:53:00	BLAN_004.21.2019-06-11	2	Y	WAVI	Vireo gilvus	species	Warbling Vireo	171	singing
21	2019-06-11 09:53:00	BLAN_004.21.2019-06-11	88	Y	OROR	Icterus spurius	species	Orchard Oriole	NA	singing
21	[illegible]	[illegible]	[illegible]	[illegible]	MODO	Zenaida macroura	species	Mourning Dove	61	singing
21	2019-06-11 09:53:00	BLAN_004.21.2019-06-11	88	Y	FISP	Spizella pusilla	species	Field Sparrow	NA	singing
21	[illegible]	[illegible]	[illegible]	[illegible]	INBU	Passerina cyanea	species	Indigo Bunting	57	singing
21	2019-06-11 09:53:00	BLAN_004.21.2019-06-11	2	Y	YBCU	Coccyzus americanus	species	Yellow-billed Cuckoo	17	singing
21	2019-06-11 09:53:00	BLAN_004.21.2019-06-11	4	Y	BHCO	Molothrus ater	species	Brown-headed Cowbird	173	singing
21	2019-06-11 09:53:00	BLAN_004.21.2019-06-11	3	Y	EABL	Sialia sialis	species	Eastern Bluebird	148	singing
21	2019-06-11 09:53:00	BLAN_004.21.2019-06-11	2	Y	INBU	Passerina cyanea	species	Indigo Bunting	34	singing

BIRD POINT COUNT DATA

Accessed through the **National Ecological Observatory Network** (NEON), a collection of field observation facilities across the United States providing long term ecological data.

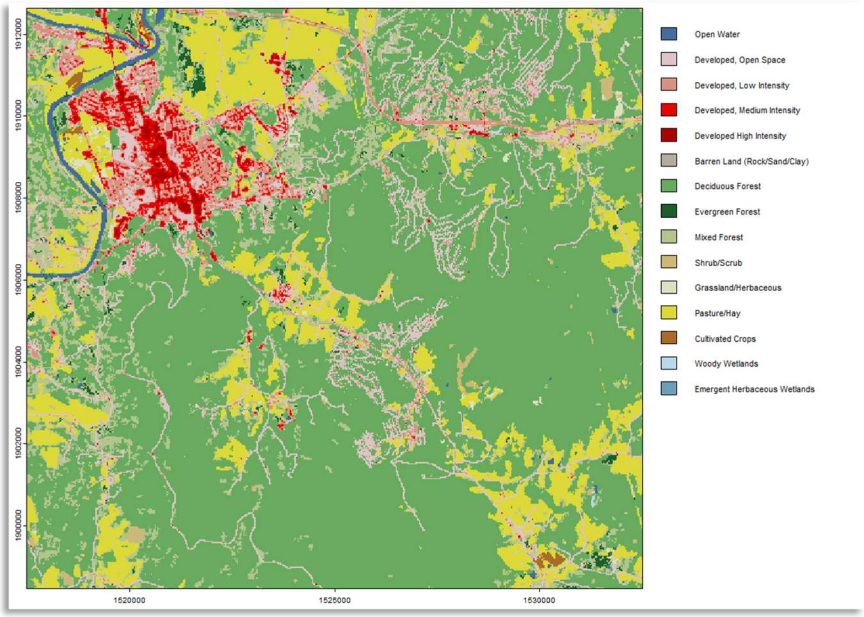
Bird count study areas have roughly 10-20 distinct plots within them. Each plot contains points arranged in a 3x3 point grid, with points separated by 250m.

This analysis uses **three years of data (2019-2021)** from three separate study areas in each of the two landscape types.



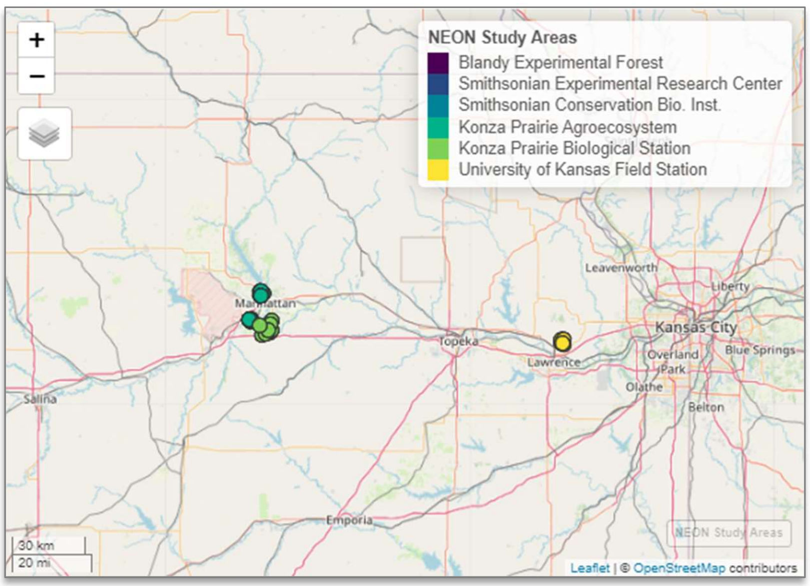
LAND COVER DATA

National Land Cover Database (NLCD) rasters with spatial resolution of 30m were accessed using the `FedData` package in R.

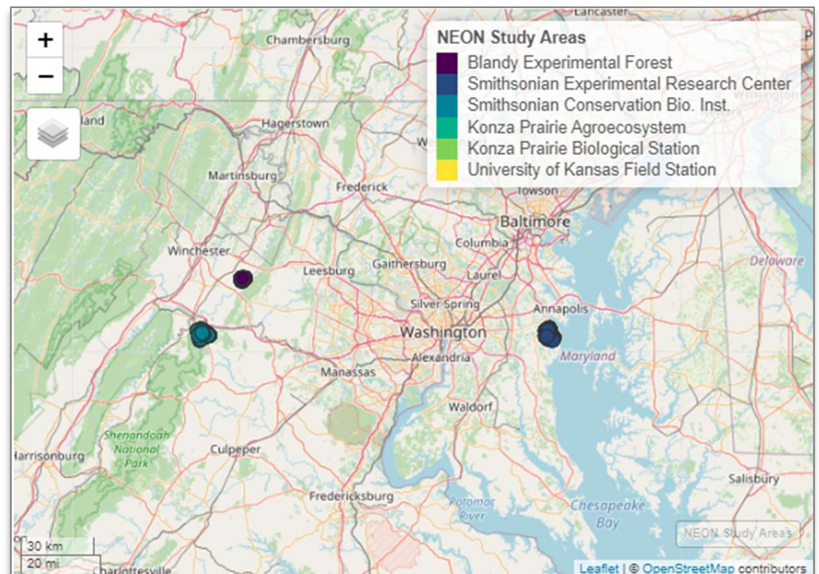


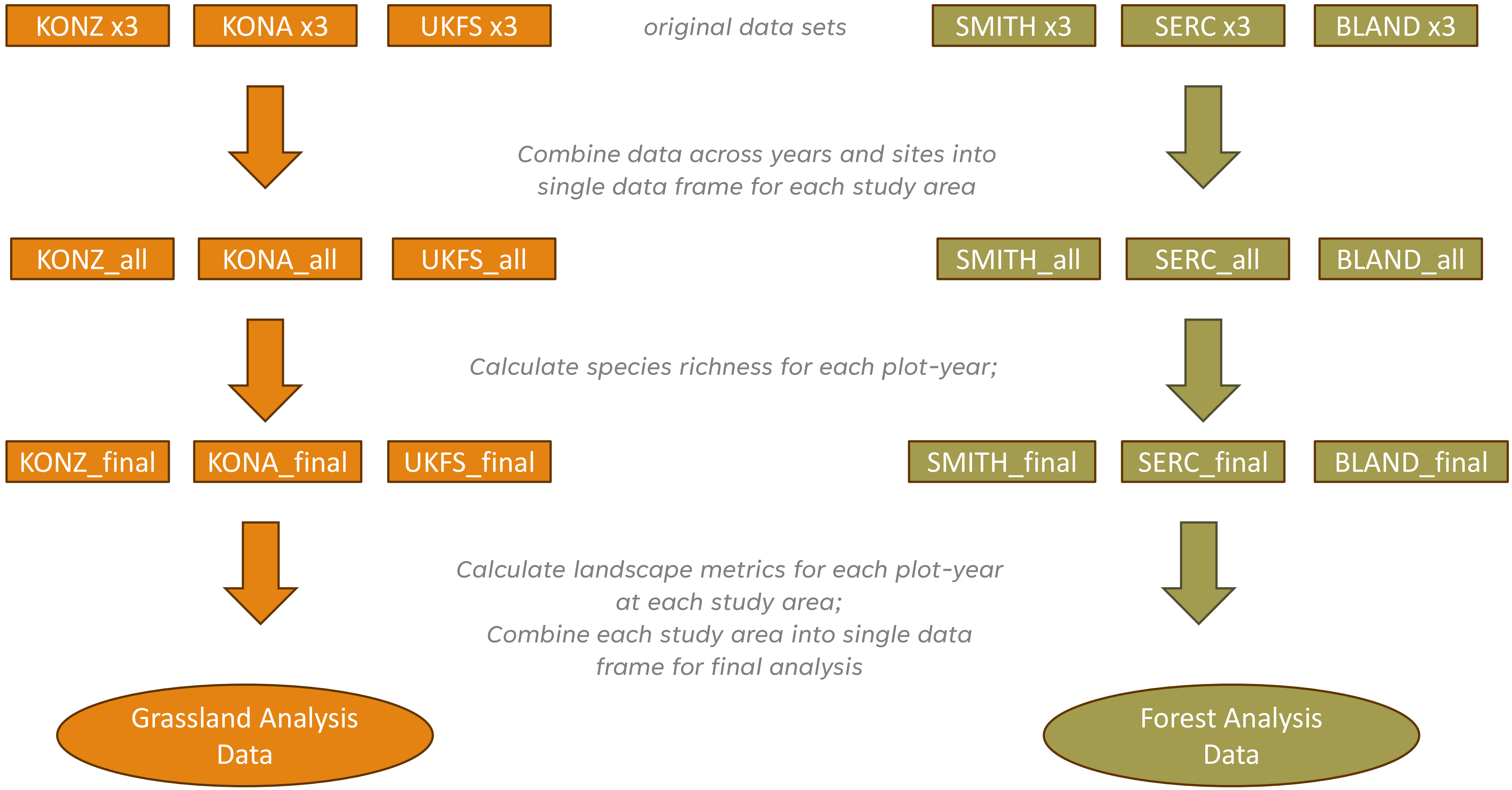
Study Area Locations

GRASSLAND SITES



MID-ATLANTIC FOREST SITES




KONZ x3
KONA x3
UKFS x3
original data sets
SMITH x3
SERC x3
BLAND x3
Combine data across years and sites into single data frame for each study area
KONZ_all
KONA_all
UKFS_all
SMITH_all
SERC_all
BLAND_all
Calculate species richness for each plot-year;
KONZ_final
KONA_final
UKFS_final
SMITH_final
SERC_final
BLAND_final
Calculate landscape metrics for each plot-year at each study area;
Combine each study area into single data frame for final analysis
Grassland Analysis Data
Forest Analysis Data

Land Cover Categories Following Reclassification

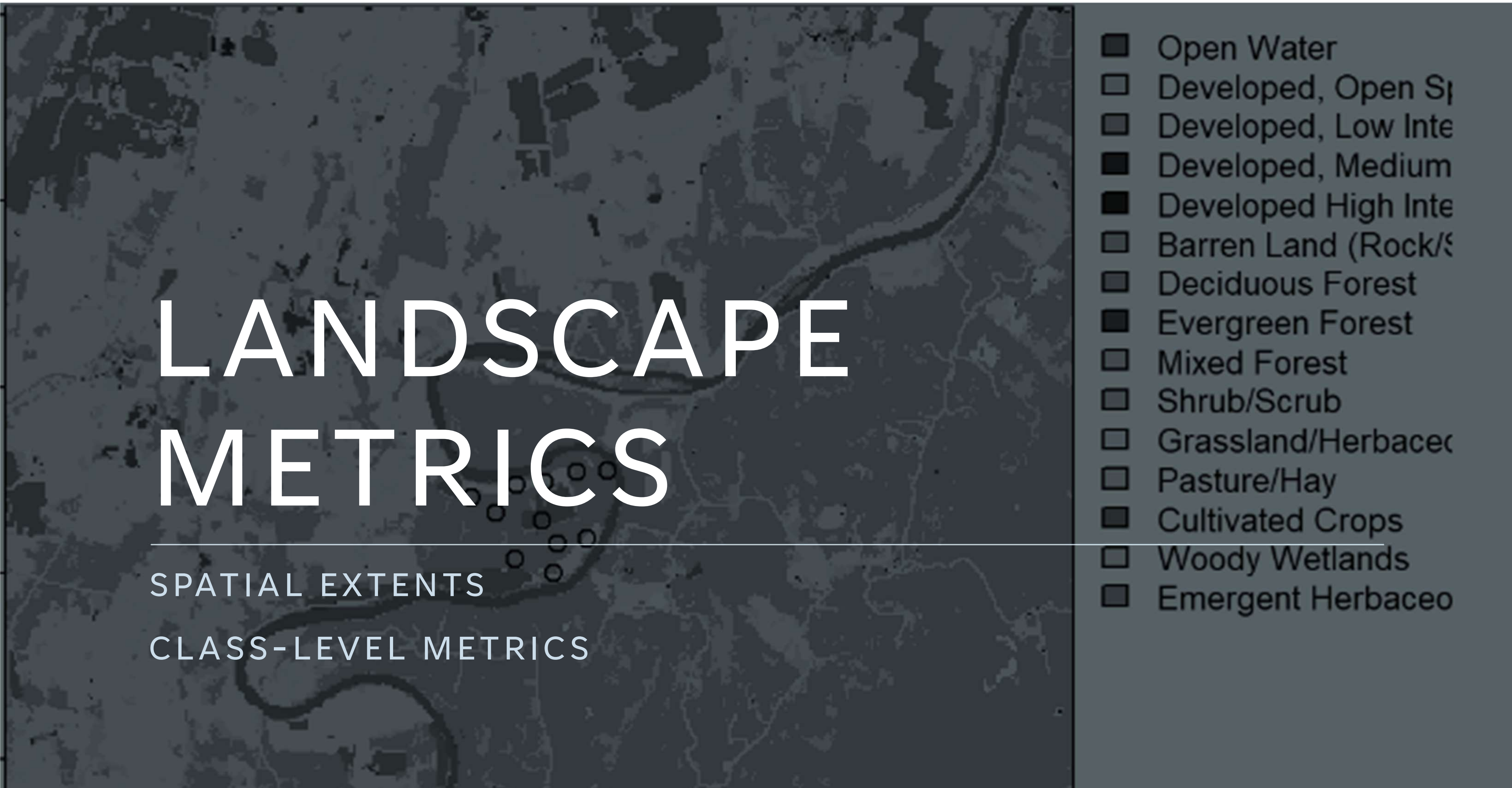
GRASSLAND	FOREST
• **GRASSLAND** ← Grassland/Herbaceous • **AGRICULTURAL** ← "Pasture/Hay", "Cultivated Crops" • **FOREST** ← "Deciduous Forest", "Evergreen Forest", "Mixed Forest"	• **FOREST** ← "Deciduous Forest", "Evergreen Forest", "Mixed Forest" • **AGRICULTURAL** ← "Pasture/Hay", "Cultivated Crops • (**SUB**)**URBAN** ← "Developed Medium", "Developed High

NA ← All other land cover classes

LANDSCAPE METRICS

SPATIAL EXTENTS

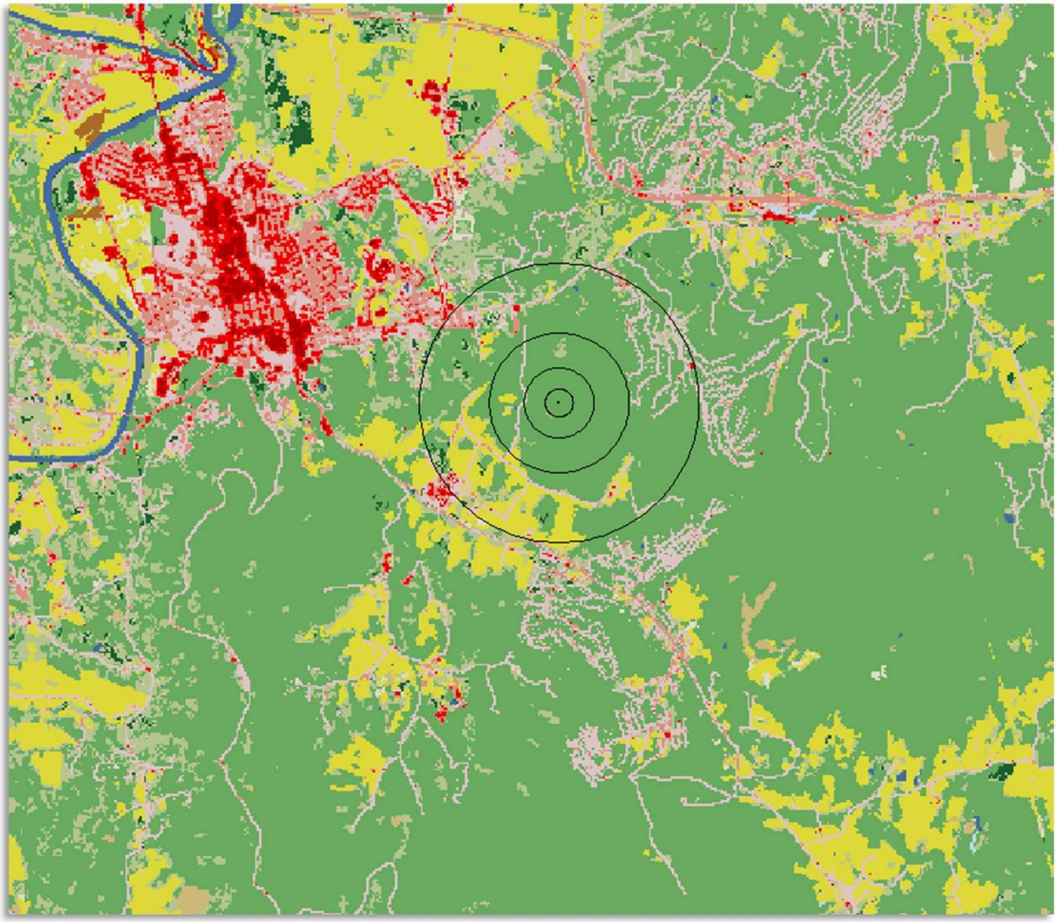
CLASS-LEVEL METRICS



SPATIAL SCALES

Landscape metrics were calculated for each study area plot-year at four spatial scales.

- 200m
- 500m
- 1000m
- 2000m



Smithsonian Conservation Biology Institute plot 002 with its four buffers.

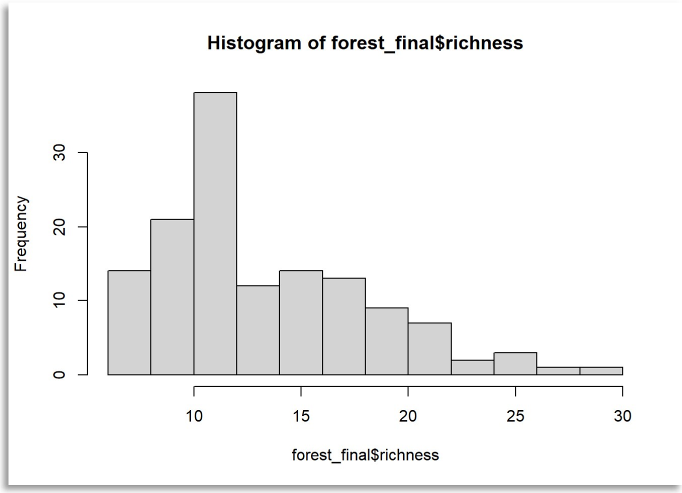
CLASS-LEVEL LANDSCAPE METRICS

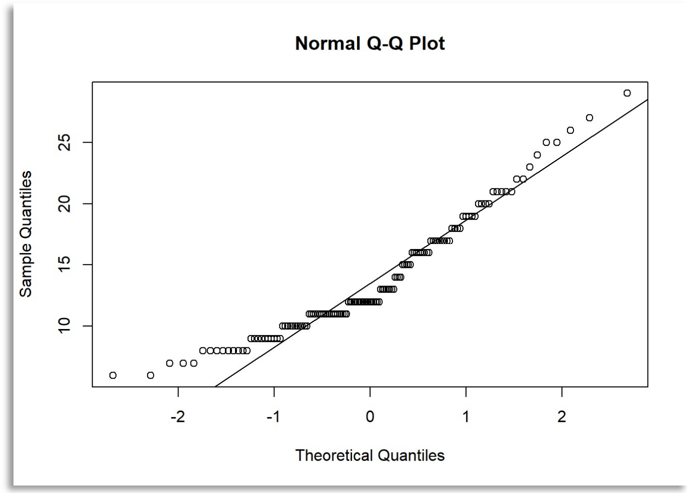
A total of five metrics were selected and calculated for each plot-year at each of the four spatial scales.

- **Proportion of Landscape (PLAND):** Measures the percentage of the landscape covered by a specific land cover class.
- **Largest Patch Index (LPI):** Measures the dominance of the largest patch of a particular land cover class.
- **Aggregation Index (AI):** Measures the degree to which a land cover class is aggregated or dispersed in the landscape.
- **Mean Patch Size:** Represents the average size of patches for a given land cover type.
- **Mean Core Area Size:** Represents the average size of the core areas (interior parts of patches, excluding edges) of land cover class for given cover type.

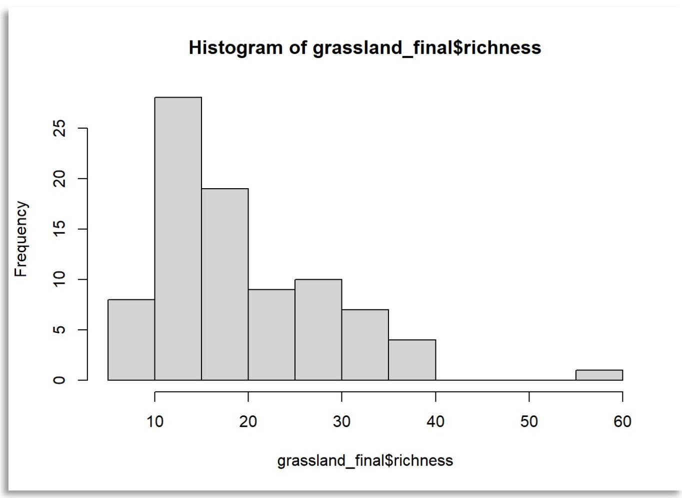
MODEL SELECTION

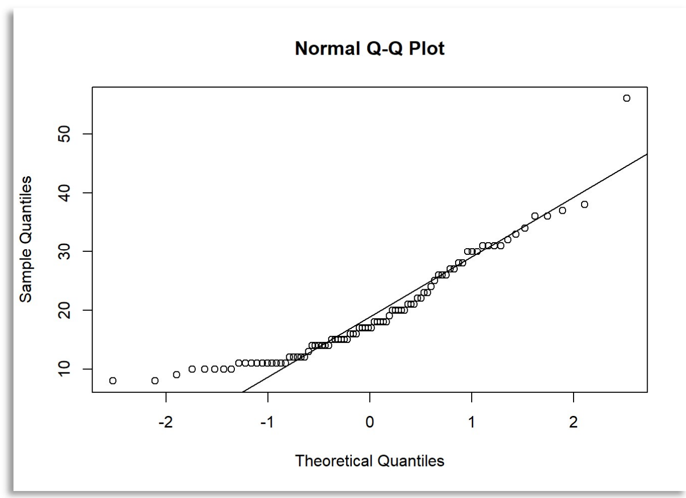
FOREST DATA





GRASSLAND DATA



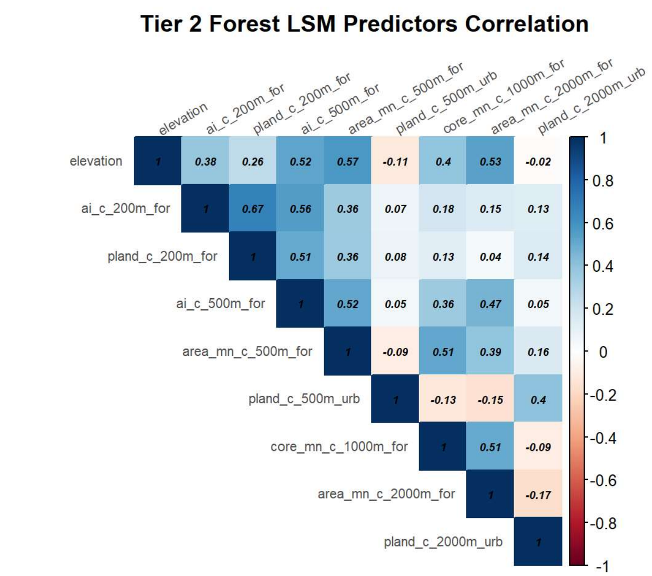


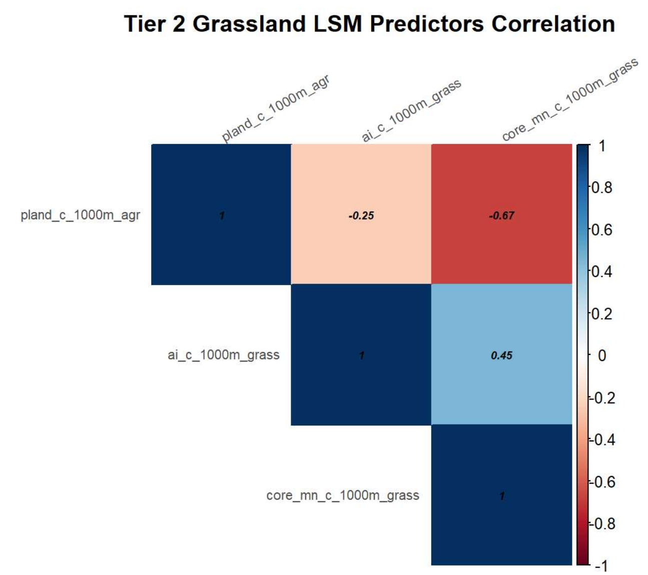
HIERARCHICAL VARIABLE SELECTION

Step 1 Select minimally correlated variables at each spatial extent ($R < 0.7$)

Step 2 Group all remaining variables and again select variables with correlation coefficients < 0.7

Step 3 Repeat process, lowering threshold to 0.6





Correlograms following step two of the variable selection process for both forest (top) and grassland (bottom) data

FINAL VARIABLE SELECTION

GRASSLAND	FOREST
% Agricultural (1000m)	Elevation
Grassland Aggregation Index	% Forest (200m)
	% Urban (500m)
	Forest Mean Core Area (1000m)
	% Urban (2000m)

MODEL RUNS

- All combinations of variables used within each data set

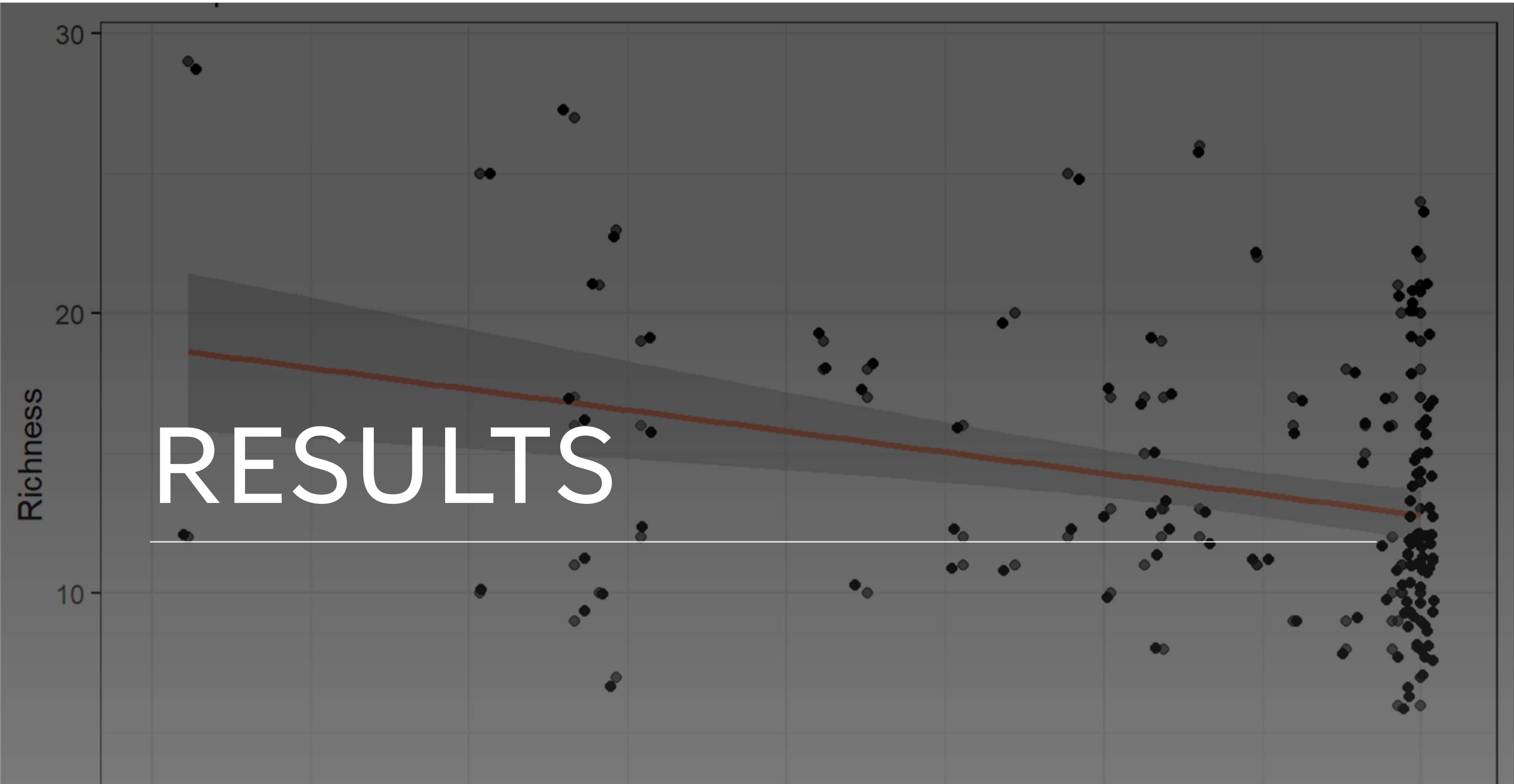
  4 grassland model runs

  22 forest model runs

- Models were then evaluated for goodness of fit using Akaike Information Criterion

```r
## 2 VARIABLE MODELS
two_var_combos <- combn(as.character(final_vars_f$var.names), 2, simplify = TRUE)
l <- ncol(two_var_combos)
for (i in 1:ncol(two_var_combos)) {
    formula <- as.formula(paste("richness ~ ",
                                paste(two_var_combos[, i], collapse = " + "))  )

  model <-
    lm(formula = formula,
          data = forest_final,
          na.action = na.omit)

      all_models_f[[i + l]] <- model
}


## 3 VARIABLE MODELS
three_var_combos <- combn(as.character(final_vars_f$var.names), 3, simplify = TRUE)
l <- ncol(three_var_combos)
for (i in 1:ncol(three_var_combos)) {
    formula <- as.formula(paste("richness ~ ",
                                paste(three_var_combos[, i], collapse = " + "))  )

  model <-
    lm(formula = formula,
          data = forest_final,
          na.action = na.omit)

      all_models_f[[i + l]] <- model
}
```

RESULTS



AIC Results for All Grassland Candidate Models

predictors	K	AICc	Delta_AICc	ModelLik	AICcWt	model.num
pland_c_1000m_agr | ai_c_1000m_grass	4	576.9533	0.000000	1.0000000	0.9702911	3
pland_c_1000m_agr	3	583.9256	6.972299	0.0306185	0.0297089	1
NA | (Intercept)	2	622.3568	45.403550	0.0000000	0.0000000	4
ai_c_1000m_grass	3	623.7691	46.815825	0.0000000	0.0000000	2

AIC Results for All Forest Candidate Models

predictors	K	AICc	Delta_AICc	ModelLik	AICcWt	model.num
elevation | pland_c_200m_for | pland_c_500m_urb	5	794.6300	0.0000000	1.0000000	0.2409743	11
elevation | pland_c_200m_for | pland_c_2000m_urb	5	795.5767	0.9467038	0.6229108	0.1501055	13
elevation | pland_c_200m_for | core_mn_c_1000m_for	5	795.6959	1.0658368	0.5868897	0.1414253	12
elevation | pland_c_200m_for | pland_c_500m_urb | pland_c_2000m_urb	6	795.7279	1.0979093	0.5775532	0.1391755	7
elevation | pland_c_200m_for | pland_c_500m_urb | core_mn_c_1000m_for	6	796.5699	1.9398539	0.3791107	0.0913559	6
elevation | pland_c_200m_for | core_mn_c_1000m_for | pland_c_2000m_urb	6	797.6506	3.0206030	0.2208434	0.0532176	8
elevation | pland_c_200m_for | pland_c_500m_urb | core_mn_c_1000m_for | pland_c_2000m_urb	7	797.7636	3.1336082	0.2087111	0.0502940	21
pland_c_200m_for	3	798.0716	3.4415609	0.1789265	0.0431167	2
						17
						1
						19
						18
pland_c						10
						15
						14

Frequency of Predictor Variables Among Top Candidate Forest Models

Predictor	Freq	Ecosystem
elevation	4	Mid Atlantic Forest
pland_c_200m_for	4	Mid Atlantic Forest
pland_c_2000m_urb	2	Mid Atlantic Forest
pland_c_500m_urb	2	Mid Atlantic Forest
core_mn_c_1000m_for	1	Mid Atlantic Forest

Top Forest Model Results

Predictor	Coefficient	Standard_Error	Rsq.adj	P_Value	Model_rank
Top Ranked					
(Intercept)	18.9253069	1.4444609	0.1199760	0.0000000	1
elevation	-0.0065671	0.0024503	0.1199760	0.0083052	1
pland_c_200m_for	-0.0467381	0.0170303	0.1199760	0.0069130	1
pland_c_500m_urb	-0.3260762	0.2991487	0.1199760	0.2777079	1
Second Ranked					
(Intercept)	18.9349004	1.4495889	0.1137830	0.0000000	2
elevation	-0.0061266	0.0024396	0.1137830	0.0132457	2
pland_c_200m_for	-0.0502426	0.0171679	0.1137830	0.0040418	2
pland_c_2000m_urb	0.1103858	0.2146804	0.1137830	0.6079877	2
Third Ranked					
(Intercept)	18.9991982	1.4563324	0.1130006	0.0000000	3
elevation	-0.0058119	0.0026359	0.1130006	0.0292065	3
pland_c_200m_for	-0.0487403	0.0169858	0.1130006	0.0047950	3
core_mn_c_1000m_for	-0.0060333	0.0156510	0.1130006	0.7004994	3

Only two of five predictors significant

- **Elevation**
- **% Forest, 200m**

Both show a *negative* relationship with species richness.

Very similar R^2 values in all three models, with < 12% of species richness variation explained.

Top Grassland Model Results

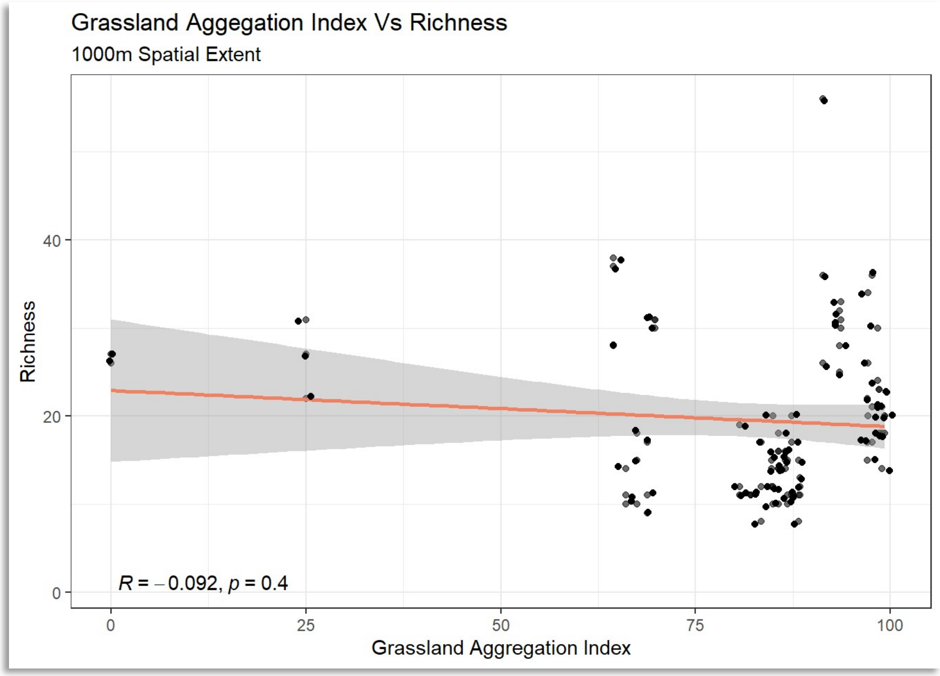
Predictor	Coefficient	Standard_Error	Rsq.adj	P_Value
(Intercept)	36.2584481	3.5124299	0.4257614	0.0000000
pland_c_1000m_agr	-0.1733121	0.0217046	0.4257614	0.0000000
ai_c_1000m_grass	-0.1154353	0.0377658	0.4257614	0.0030111

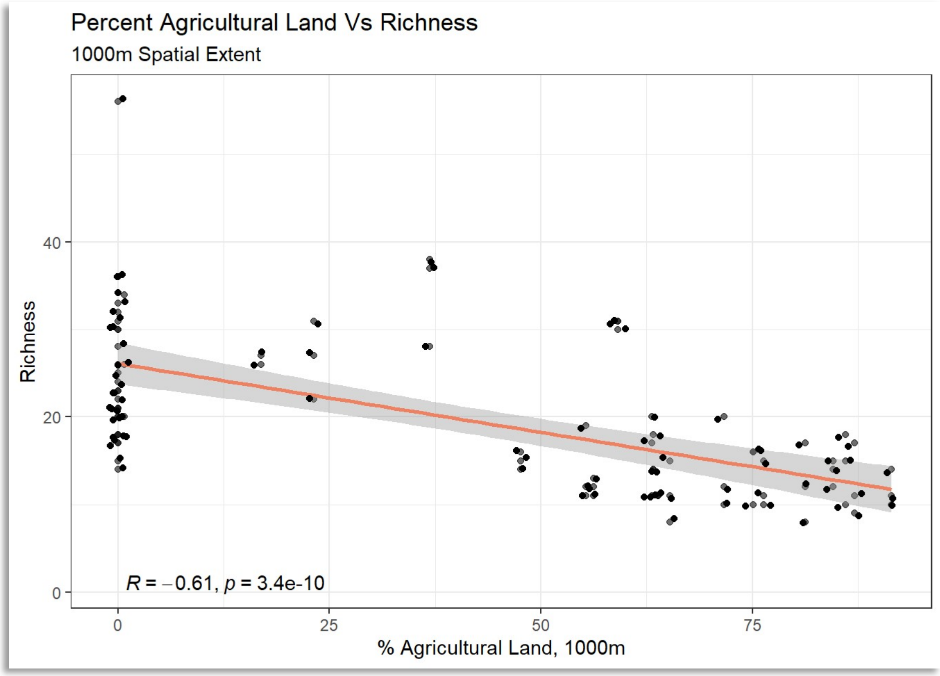
Both predictors significant

Significantly higher amount of variation in avian species richness explained by grassland model (42.6%) than forest models (<12%).

Increased grassland aggregation has a *negative* relationship with richness

Significant Grassland Variable Relationships





Significant Forest Variable Relationships