

CLIMATE CHANGE, FORESTS, AND RECREATION IN NORTHERN MINNESOTA

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Outline of Talk

- ▣ Background
- ▣ Research Questions
- ▣ Findings from related work
- ▣ Data
- ▣ Methods
- ▣ Results
- ▣ Key Takeaways

Climate Change Impacts

- ▣ Climate change: Latest predictions suggest a 4–5° C rise in temperatures in northern boreal regions (Christensen et al., 2007)
- ▣ Vegetation change: changes in future forest composition
 - Northern species gradually replaced by temperate species such as oak, hickory and maplesMinnesota FEVAS, 2014
- ▣ Changes in ecosystem services: carbon sequestration, water quality, *recreation...wildlife watching, hunting, fishing*
- ▣ ...*Approach to value impact of climate induced vegetation change on forest-based recreation in Minnesota.*

Current Research Findings

VEGETATION CHANGE

- ▣ Handler et al, 2014: Pines, Aspen-Birch, Spruce-Fir replaced by Elm-Ash-Cottonwood, Oak-Hickory, Maple-Beech-Birch
- ▣ Models: Climate Change Tree Atlas, LANDIS-II, PnET-CN
- ▣ Problems
 - Static approach
 - Left out: wildlife impacts, invasive species, pathogens, extreme events, feedback effects from aquatic, humans and wildlife systems

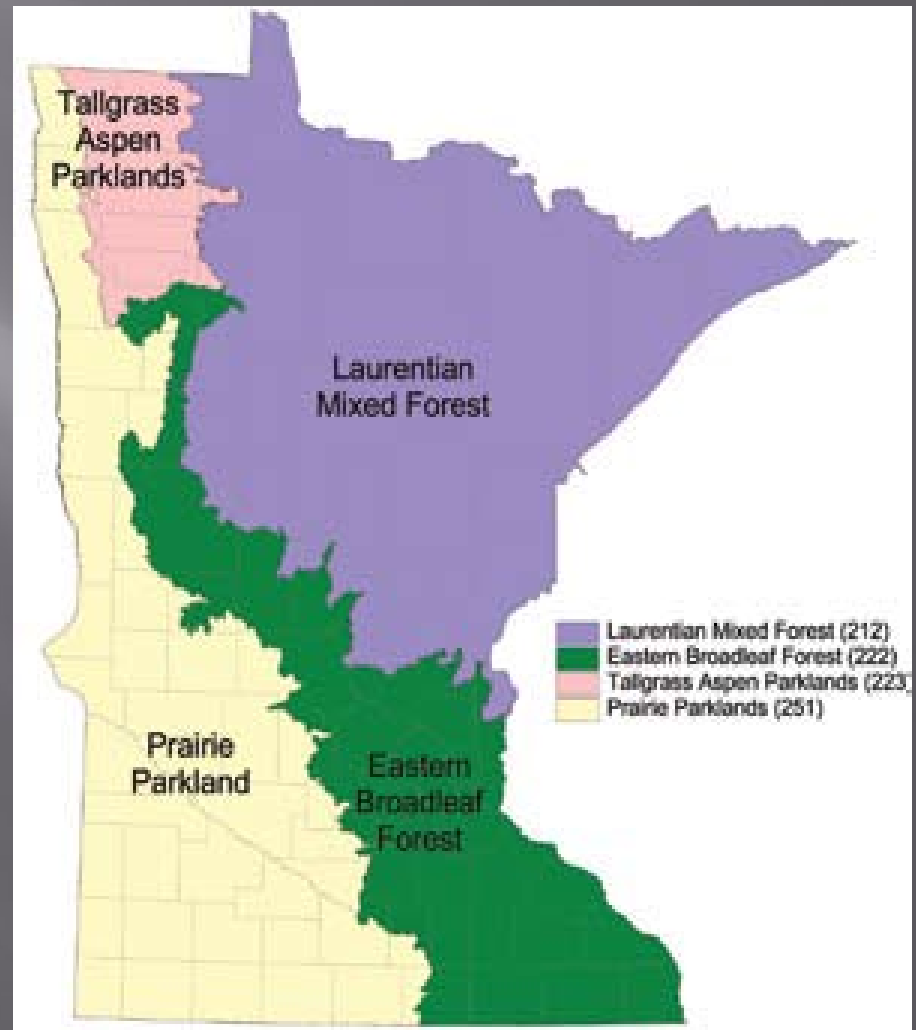
RELATION: RECREATION

- ▣ People prefer forested to barren areas for recreation (Pena et al., 2015)
- ▣ Mixed preferred to pure (Grilli et al. 2014)
- ▣ Broadleaved preferred to conifers (Edwards et al, 2010)
- ▣ Broadleaved and hunting: lack of consensus
- ▣ ...Gap in knowledge how forest composition affects recreation.

Study Area-LMF

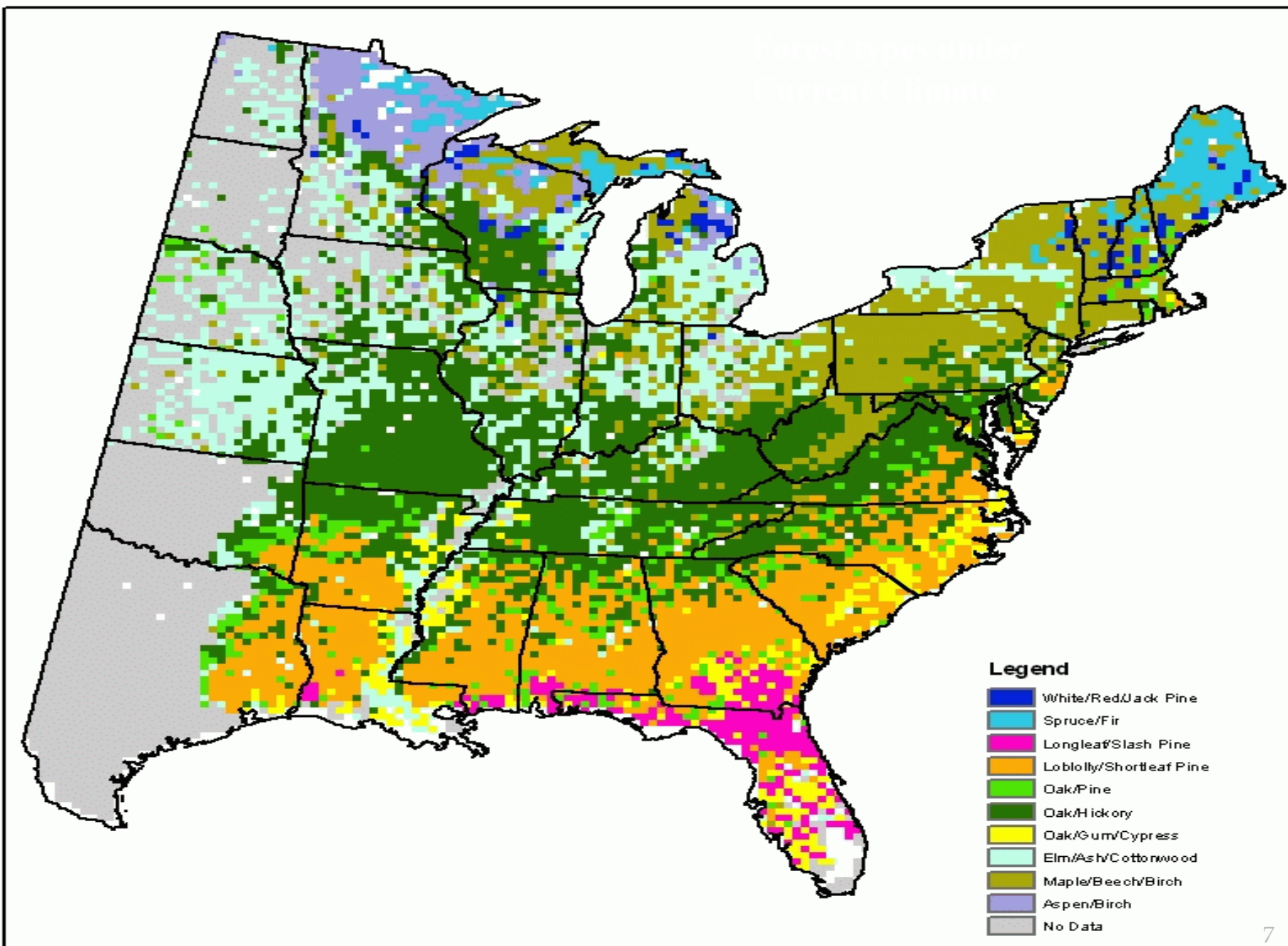
Laurentian Mixed Forest Province- LMF

- Significant climate change impact- Gonzalez, 2010
- Forestland: 63% forested, 100% federal and 92% state forest
- Haven for ecosystem services
- Nature-based recreation
 - Tourism: 11 bn
 - 69% participation
 - Hunting, wildlife-watching: >3 bn
 - 6.1 million jobs

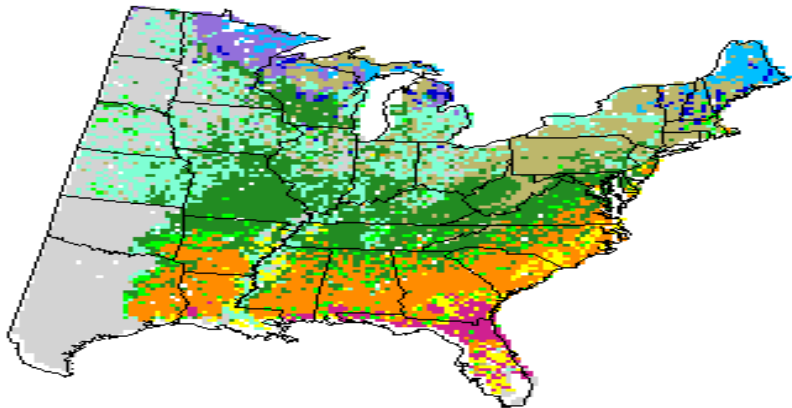


Research Questions

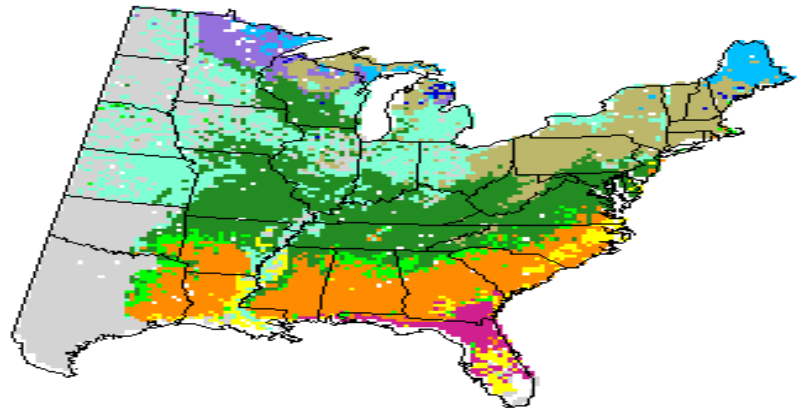
- ▣ 1: How is recreation related to forest composition?
- ▣ 2: What is the impact of future change in forest composition on recreation?



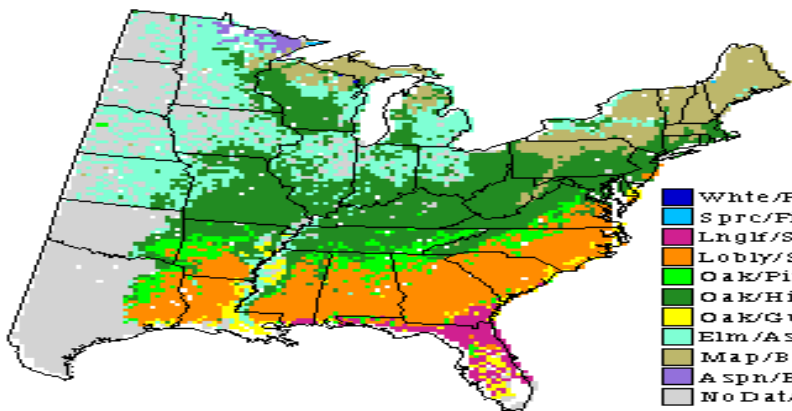
Forest Type Maps



FIA-Current

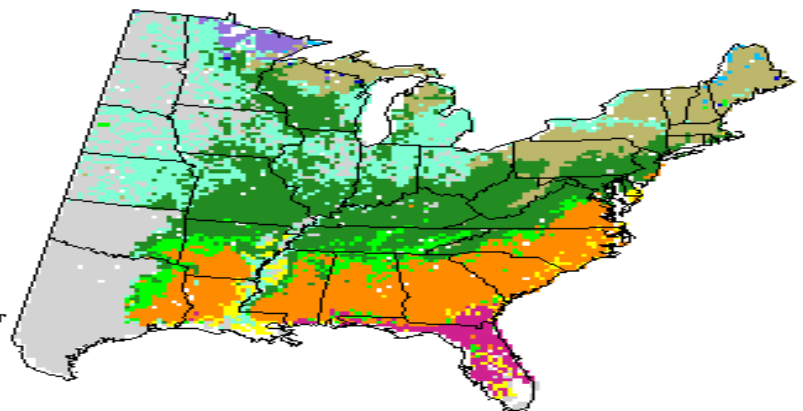


RF-Current

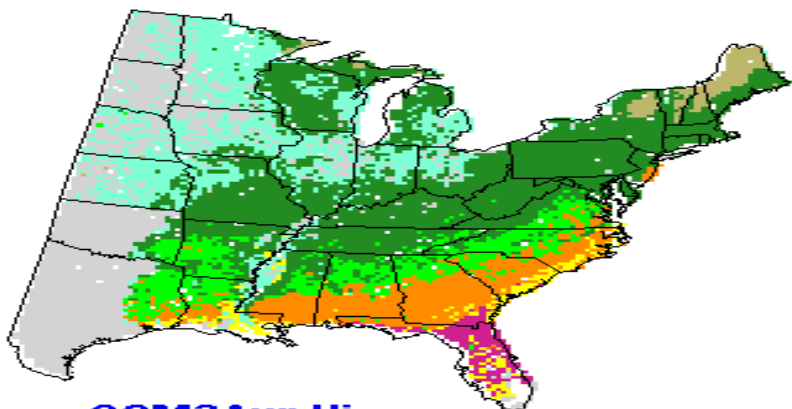


GCM3Avg Lo

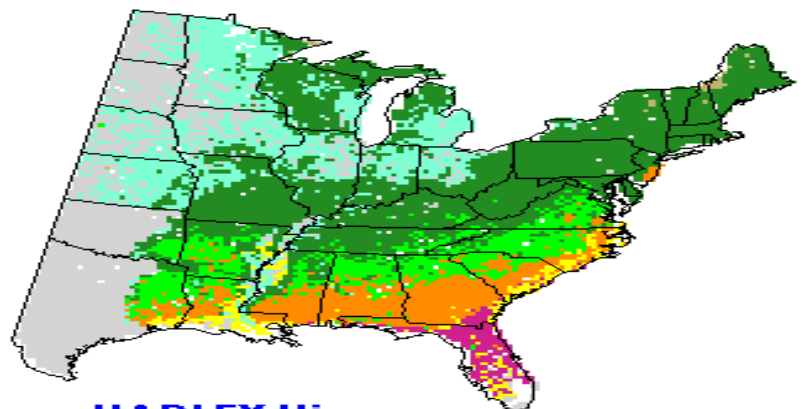
- White/Red/J ck
- Sprc/Fir
- Lnglf/Slsh
- Lobly/Shrtlf
- Oak/Pine
- Oak/Hikry
- Oak/Gum/Cypr
- Elm/Ash/Ctnw
- Map/Bch/Brch
- AspN/Brch
- NoDat/NoFor



PCM Lo



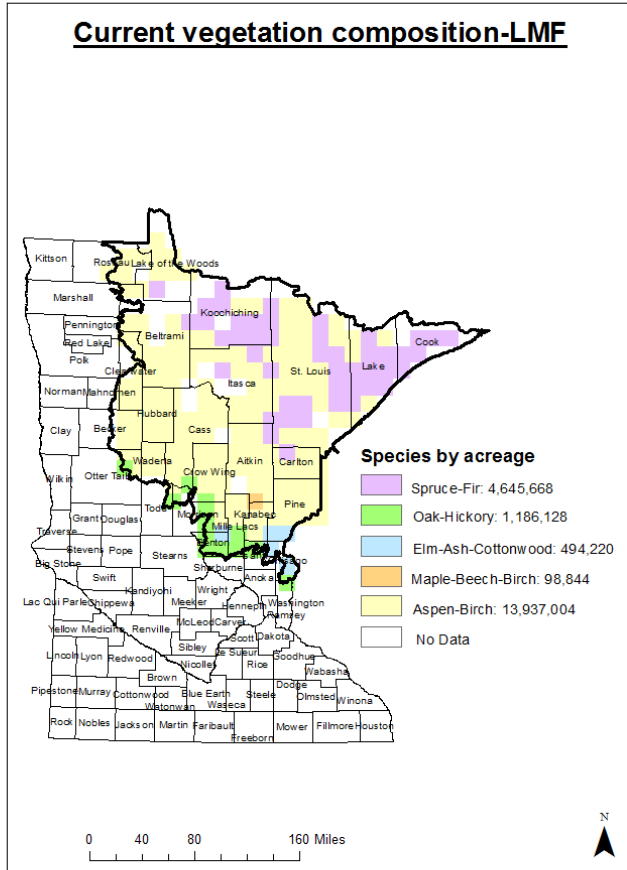
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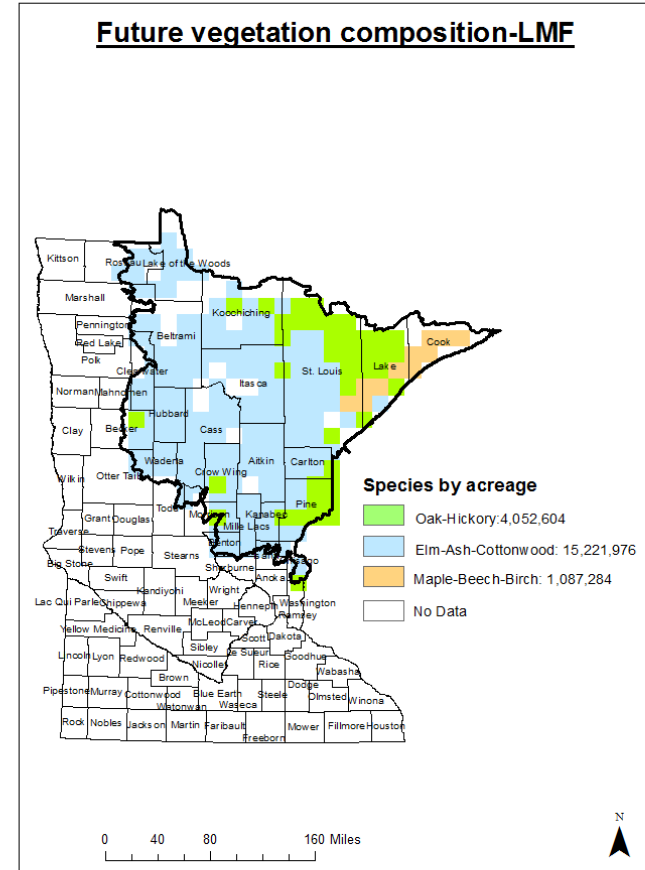
HADLEY Hi

Minnesota Vegetation: Recent Research

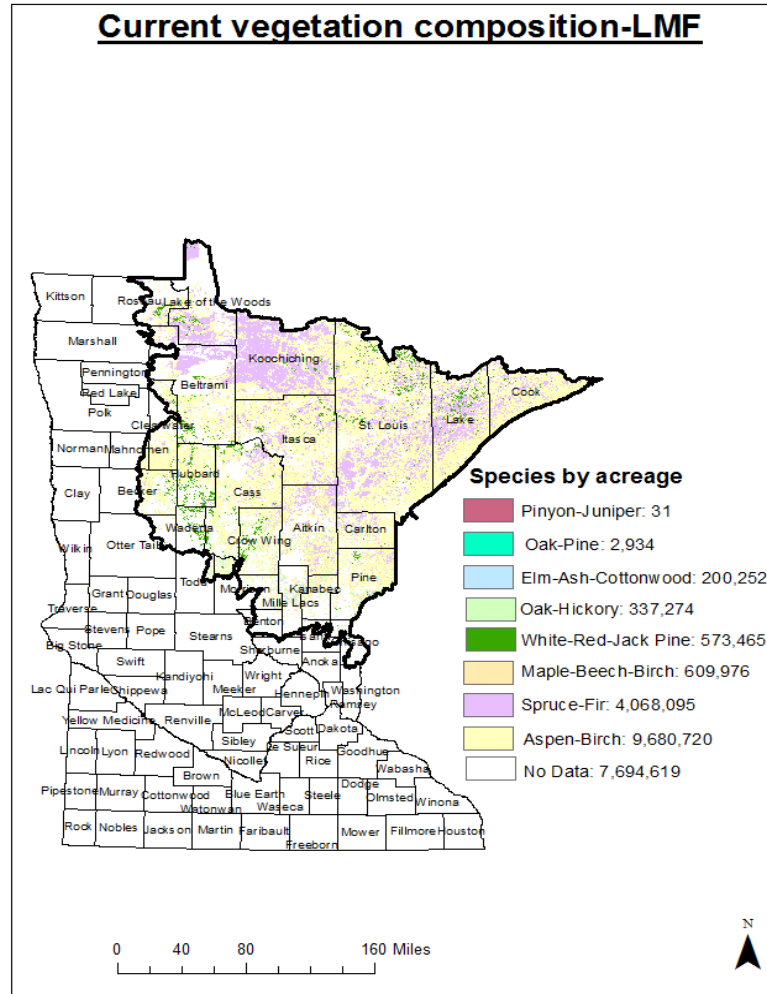
Current vegetation composition-LMF



Future vegetation composition-LMF



Current vegetation map from data



Data

VEGETATION-ACRES

- ▣ Aspen-Birch
- ▣ Spruce-Fir
- ▣ Oak-Hickory
- ▣ Oak-Pine
- ▣ Elm-Ash-Cottonwood
- ▣ Maple-Beech-Birch
- ▣ White-Red-Jack Pine

RECREATION-LICENSES

- ▣ Big Game
- ▣ Small Game
- ▣ Deer
- ▣ Stamps
- ▣ Angling
- ▣ Sports
- ▣ Ski

Log-normal panel data model

- ▣ For each of the 7 recreation categories, Y_i , the expectation of each satisfies:
- ▣ $Exp(Y_i) \sim \text{Lognormal}(\mu_i, \sigma^2_i); \quad i=1, \dots, n$, where μ and σ^2 are mean and variance parameters, and n is sample size.
- ▣ Then $\log(Exp(Y_i)) = \mathbf{x}_i^T \boldsymbol{\beta} + \varepsilon_i \sim N(\mu_i, \sigma^2_i)$, where \mathbf{x}_i denotes a vector of predictors; $\boldsymbol{\beta}$ is a vector of unknown parameters; \mathbf{x}_i^T is the transpose of \mathbf{x}_i , and ε_i denotes the error term.

RESULTS FOR SELECTED RECREATION CATEGORIES

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

BIG GAME HUNTING; R²: 0.9693	Estimate	Std. Error	t value	p value
Intercept	5.74	1.26	4.555	1.02e-05 ***
Becker-Beltrami-Clearwater-Koochiching	-0.35	0.10	-3.596	0.000428 ***
Cass	-1.28	0.22	-5.857	2.55e-08 ***
Hubbard	-1.11	0.30	-3.698	0.000297 ***
Lake-Cook	-1.61	0.39	-4.103	6.44e-05 ***
Carlton-Pine-St. Louis	-0.37	0.18	-2.075	0.039546 *
Chisago-Isanti-Mille Lacs	-0.19	0.13	-1.467	0.144437
WRJ-Pine	6.29	2.01	3.125	0.002110 **
Spruce-Fir	0.08	0.26	0.291	0.771641
Oak-Pine	4.13	3.24	1.275	0.204170
Oak-Hickory	1.09	1.36	0.803	0.422984
Elm-Ash-Cottonwood	5.02	1.16	4.346	2.44e-05 ***
Maple-Beech-Birch	0.53	0.98	0.547	0.585322
Aspen-Birch	-2.38	0.36	-6.620	5.01e-10 ***
Pop	6.59	3.10	2.127	0.034948 *
Number of WMAs	-0.03	0.01	-5.826	2.98e-08 ***
WMA acres	0.00	0.00	3.102	0.002267 **
Number of Parks	0.03	0.01	3.914	0.000133 ***
Park acres	0.00	0.00	4.196	4.46e-05 ***

SMALL GAME HUNTING; R²: 0.9707	Estimate	Std. Error	t value	p value
Intercept	4.45	1.42	3.135	0.002042 **
Becker-Beltrami-Clearwater-Koochiching	-0.49	0.10	-4.710	5.29e-06 ***
Cass	-1.05	0.25	-4.198	4.42e-05 ***
Hubbard	-1.39	0.32	-4.292	3.04e-05 ***
Lake-Cook	-2.73	0.40	-6.877	1.26e-10 ***
Carlton-Pine-St. Louis	-1.05	0.18	-5.854	2.58e-08 ***
Chisago-Isanti-Mille Lacs	-0.51	0.13	-3.820	0.000190 ***
WRJ-Pine	1.76	2.26	0.780	0.436592
Spruce-Fir	1.36	0.27	5.117	8.70e-07 ***
Oak-Pine	4.27	3.54	1.204	0.230460
Oak-Hickory	-3.04	1.47	-2.070	0.039993 *
Elm-Ash-Cottonwood	1.09	1.33	0.821	0.412723
Maple-Beech-Birch	-0.93	1.07	-0.870	0.385413
Aspen-Birch	-0.82	0.44	-1.866	0.063909 .
Pop	1.25	3.43	0.363	0.717275
Number of WMAs	-0.03	0.01	-5.261	4.49e-07 ***
WMA acres	0.00	0.00	2.532	0.012282 *
Number of Parks	0.01	0.01	1.508	0.133542
Park acres	0.00	0.00	4.390	2.04e-05 ***

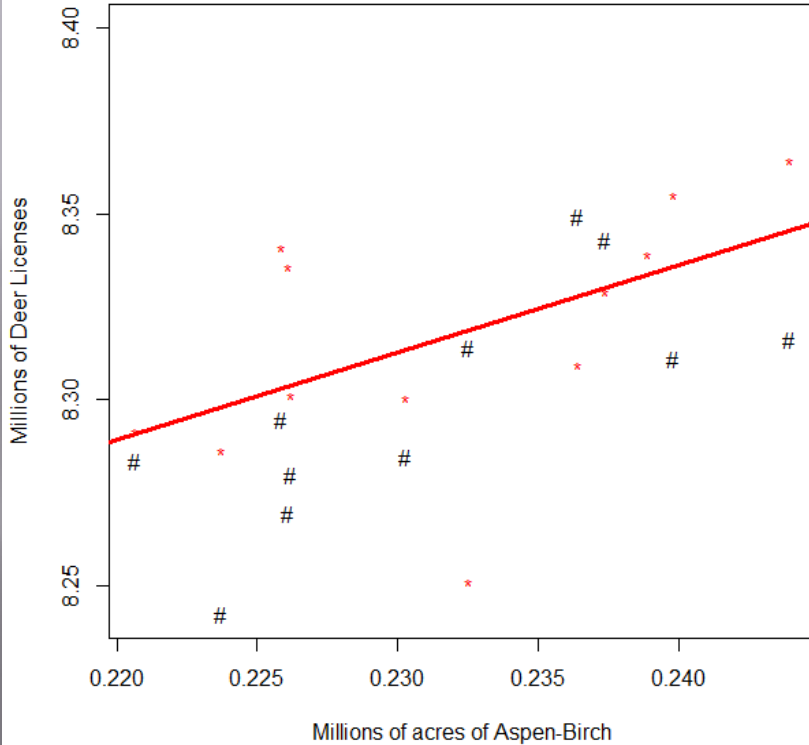
SKIING; R²: 0.9955	Estimate	Std. Error	t value	p value
Intercept	1.57	1.70	0.922	0.358671
Becker-Beltrami-Clearwater-Koochiching	0.11	0.11	1.029	0.305804
Cass	0.62	0.31	1.977	0.050526 .
Hubbard	-0.46	0.24	-1.935	0.055488 .
Lake-Cook	4.59	2.18	2.108	0.037252 *
Carlton-Pine-St. Louis	2.41	1.23	1.960	0.052493 .
Chisago-Isanti-Mille Lacs	2.62	1.31	1.999	0.048056 *
WRJ-Pine	-0.66	1.15	-0.568	0.571212
Spruce-Fir	0.73	0.36	2.018	0.045988 *
Oak-Pine	-0.37	1.90	-0.195	0.845869
Oak-Hickory	-2.86	0.79	-3.595	0.000484 ***
Elm-Ash-Cottonwood	-0.58	0.58	-1.011	0.314286
Maple-Beech-Birch	0.07	0.75	0.099	0.921178
Aspen-Birch	1.04	0.46	2.271	0.025044 *
Pop	-3.73	3.15	-1.184	0.239001
Number of Ski Miles	0.01	0.01	1.980	0.050199 .
Number of Lakes	0.00	0.00	2.329	0.021640 *
Lake acres	0.00	0.00	2.304	0.023058 *
Number of Parks	-1.94	0.83	-2.336	0.021277 *
Park Acres	0.00	0.00	-2.418	0.017215 *

DEER HUNTING; R²: 0.9879	Estimate	Std. Error	t value	p value
Intercept	0.68	0.82	0.833	0.40629
Becker-Beltrami-Clearwater-Koochiching	-0.18	0.06	-2.960	0.00354 **
Cass	-0.61	0.14	-4.319	2.72e-05 ***
Hubbard	-0.09	0.19	-0.459	0.64673
Lake-Cook	-0.80	0.25	-3.260	0.00136 **
Carlton-Pine-St. Louis	0.18	0.11	1.651	0.10064
Chisago-Isanti-Mille Lacs	-0.05	0.08	-0.672	0.50266
WRJ-Pine	2.26	1.26	1.788	0.07559 .
Spruce-Fir	0.66	0.15	4.312	2.80e-05 ***
Oak-Pine	4.85	1.97	2.466	0.01472 *
Oak-Hickory	2.49	0.81	3.068	0.00253 **
Elm-Ash-Cottonwood	-0.87	0.75	-1.168	0.24449
Maple-Beech-Birch	1.40	0.59	2.372	0.01887 *
Aspen-Birch	-0.13	0.25	-0.530	0.59685
Pop	-8.59	1.81	-4.750	4.45e-06 ***
Number of WMAs	-0.01	0.00	-2.628	0.00942 **
WMA acres	0.00	0.00	4.054	7.79e-05 ***
Number of Parks	0.02	0.00	4.094	6.69e-05 ***
Park acres	0.00	0.00	-1.492	0.13769

Deer and Aspen-Birch

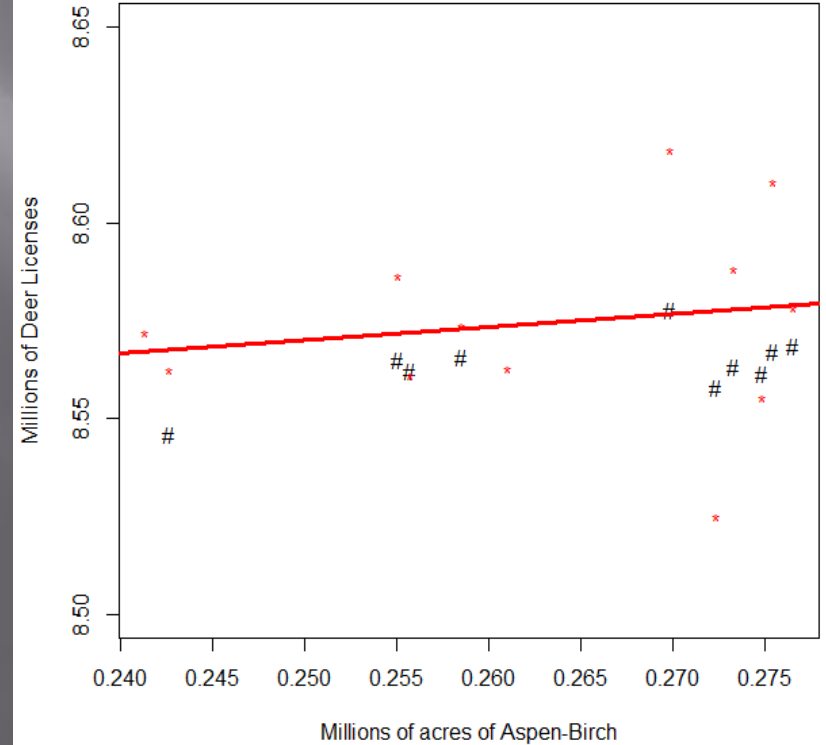
AITKIN COUNTY

Aspen-Birch : DeerF in Aitkin



PINE COUNTY

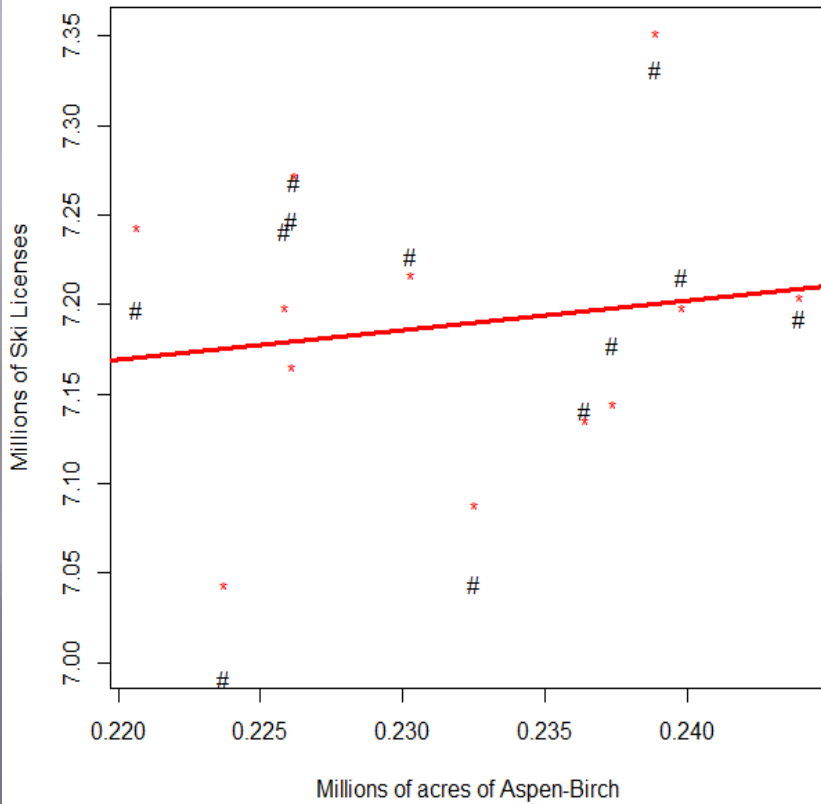
Aspen-Birch : DeerF in Pine



Ski and Aspen-Birch

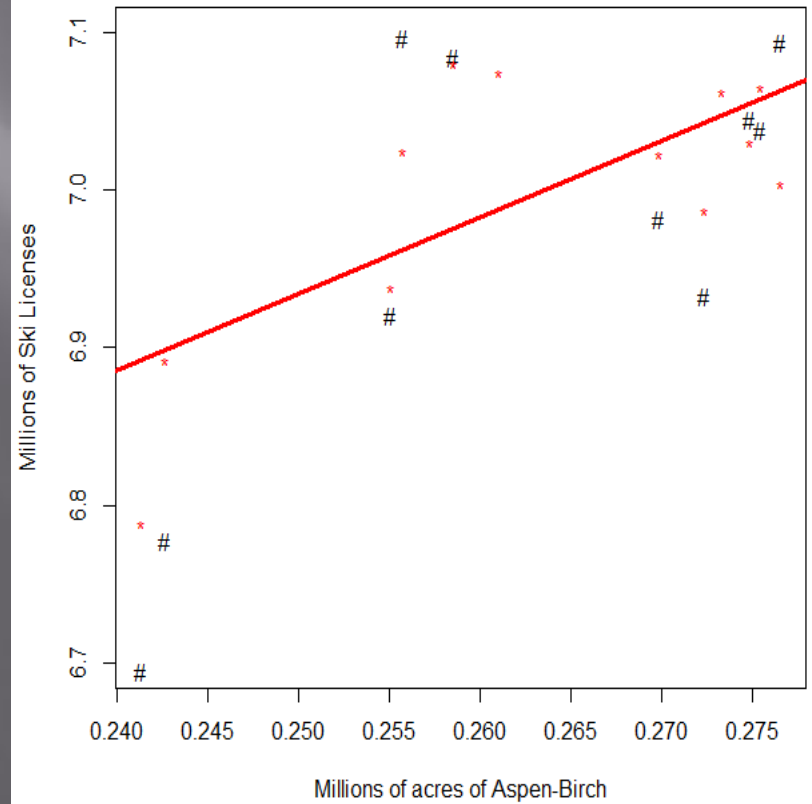
AITKIN COUNTY

Aspen-Birch : Ski in Aitkin



PINE COUNTY

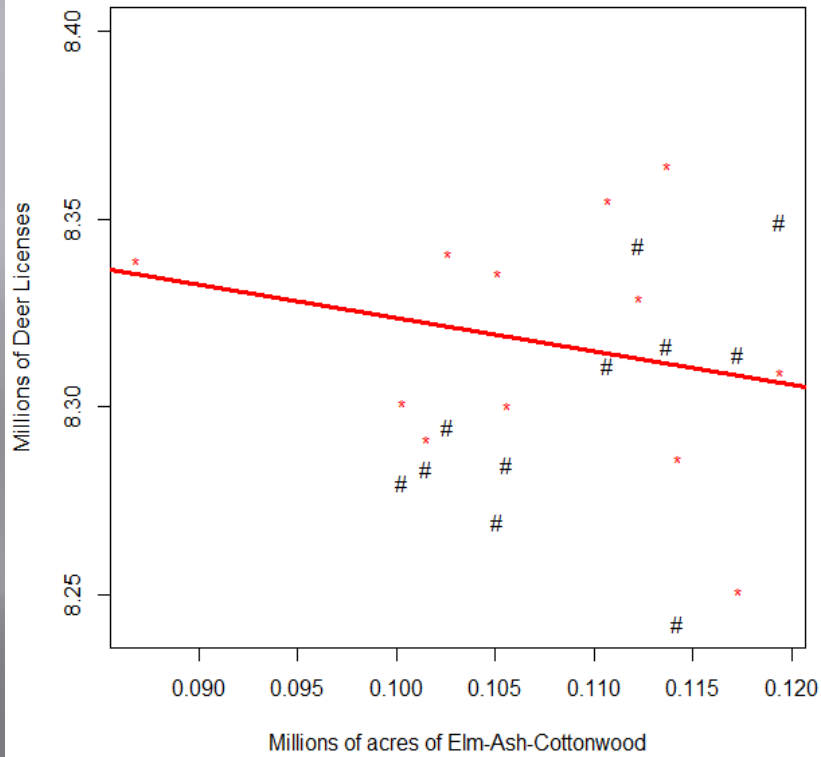
Aspen-Birch : Ski in Pine



Deer and Elm-Ash-Cottonwood

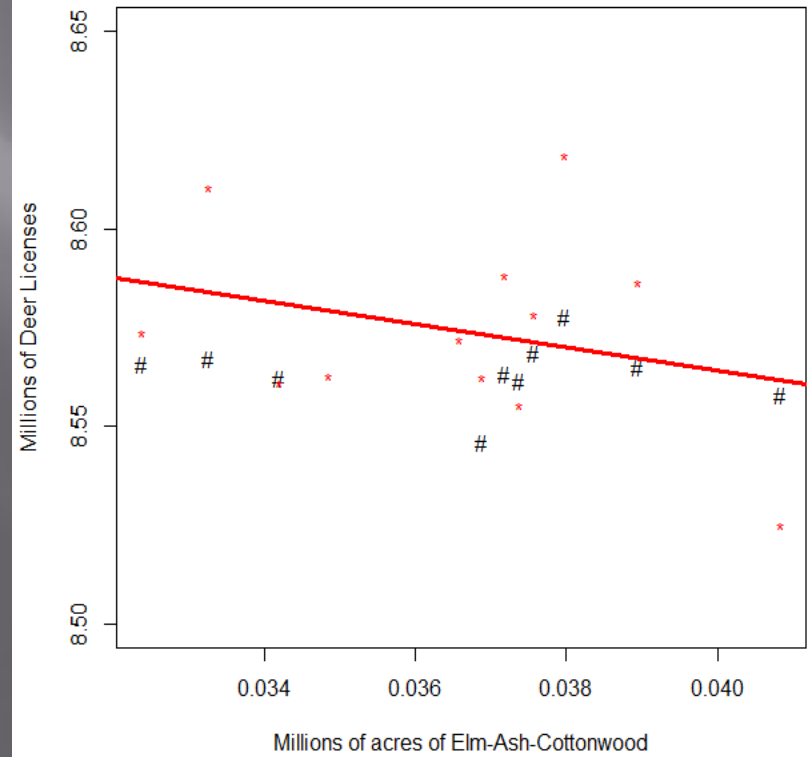
AITKIN COUNTY

Elm-Ash-Cottonwood : DeerF in Aitkin



PINE COUNTY

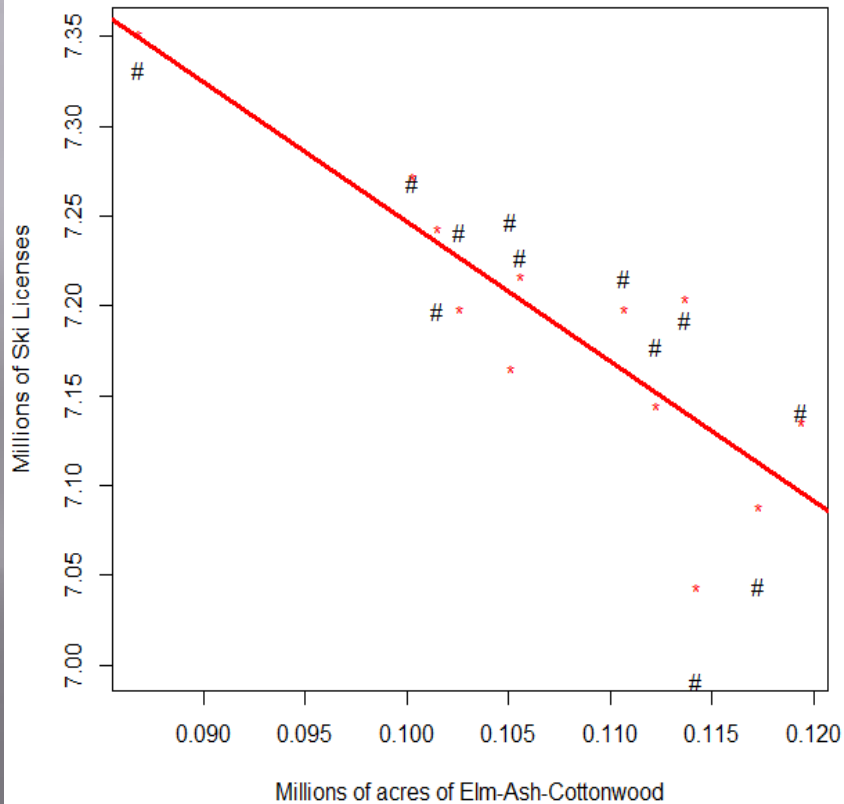
Elm-Ash-Cottonwood : DeerF in Pine



Ski and Elm-Ash-Cottonwood

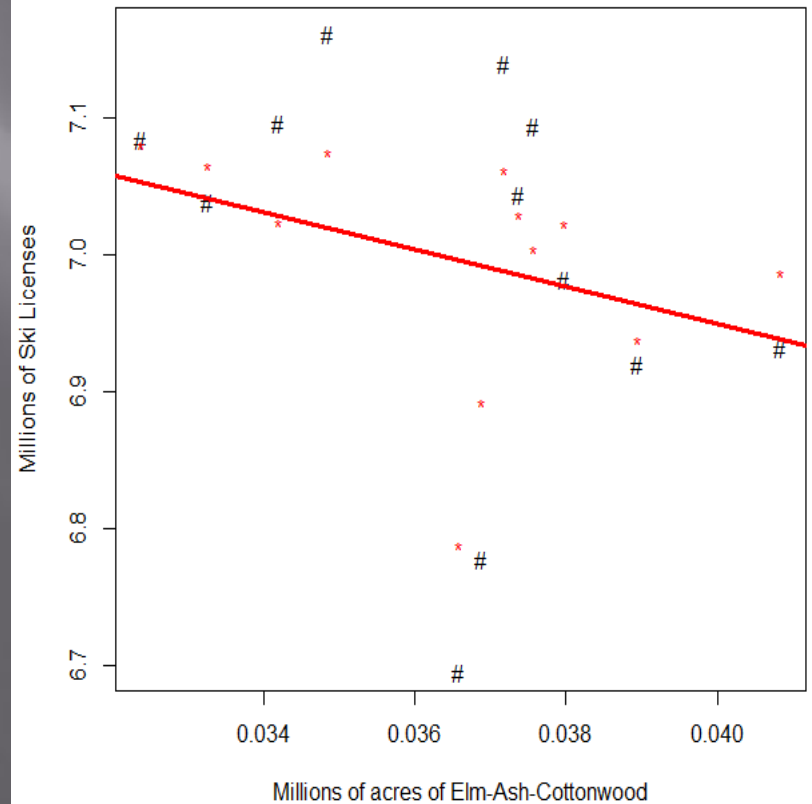
AITKIN COUNTY

Elm-Ash-Cottonwood : Ski in Aitkin



PINE COUNTY

Elm-Ash-Cottonwood : Ski in Pine



Key Takeways

- ▣ Forest composition and recreation are related
- ▣ Results vary across recreation and forest categories
 - Recreation can have positive association with conifers; conifers and broadleaved together
- ▣ Influence of other covariates
 - Public land, wildlife habitat, lakes, ski-miles
- ▣ Future decline in key recreation categories
 - Small game, deer hunting and skiing