Past, Current, and Future Forest Harvest and Regeneration Management in Interior Alaska Boreal Forest: Adaptation Under Rapid Climate Change

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Boreal Forest

- 30% of forest lands on the earth
- Ecosystem services
  - Biodiversity
  - Wildlife habitat
  - Subsistence use
  - Climate regulation
  - Wood products
  - Recreation etc…

Source: http://www.grida.no/

Source: http://alaska.usgs.gov/

Source: https://paulgreci.wordpress.com

Source: http://vilda.alaska.edu/

Source: http://www.adfg.alaska.gov/

Changes in the Boreal Forests

Large-scale clearcutting in world's boreal forests

Source: http://www.worldviewofglobalwarming.org/

Source: http://forestry.sfasu.edu/

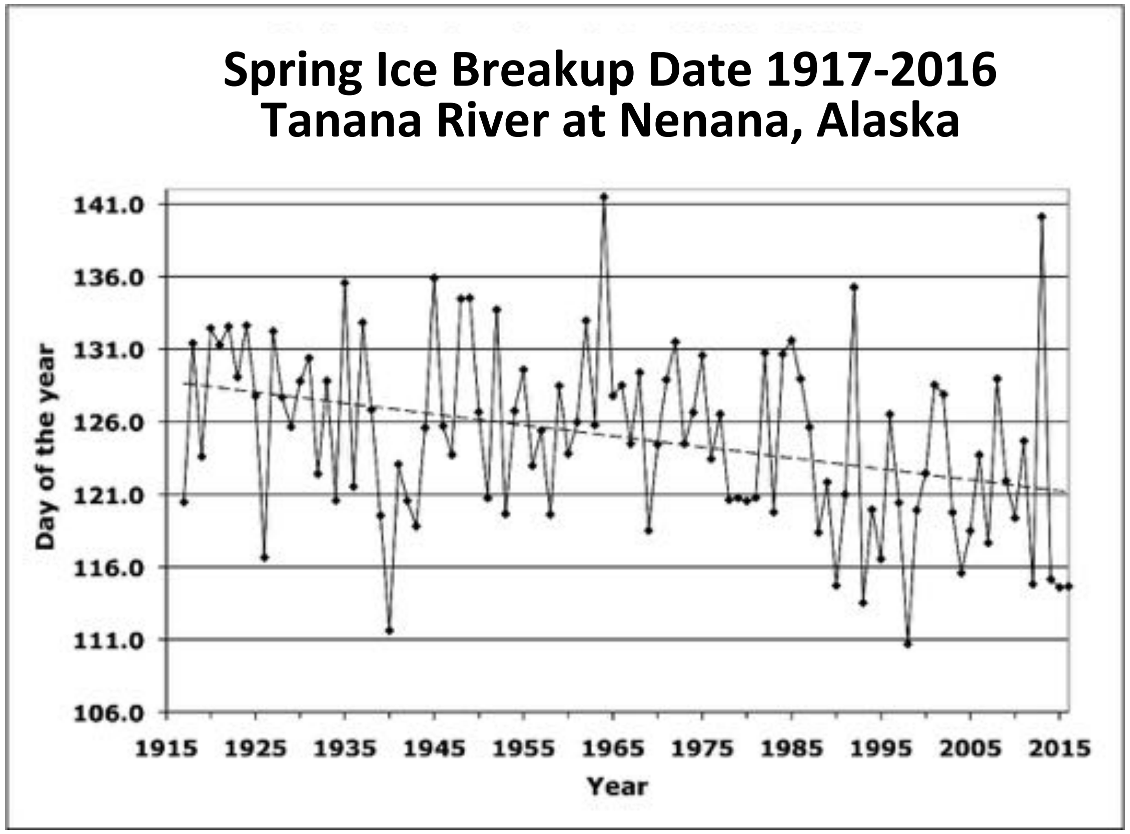
Increasing natural disturbances and demand for wood biomass in Alaska boreal forest

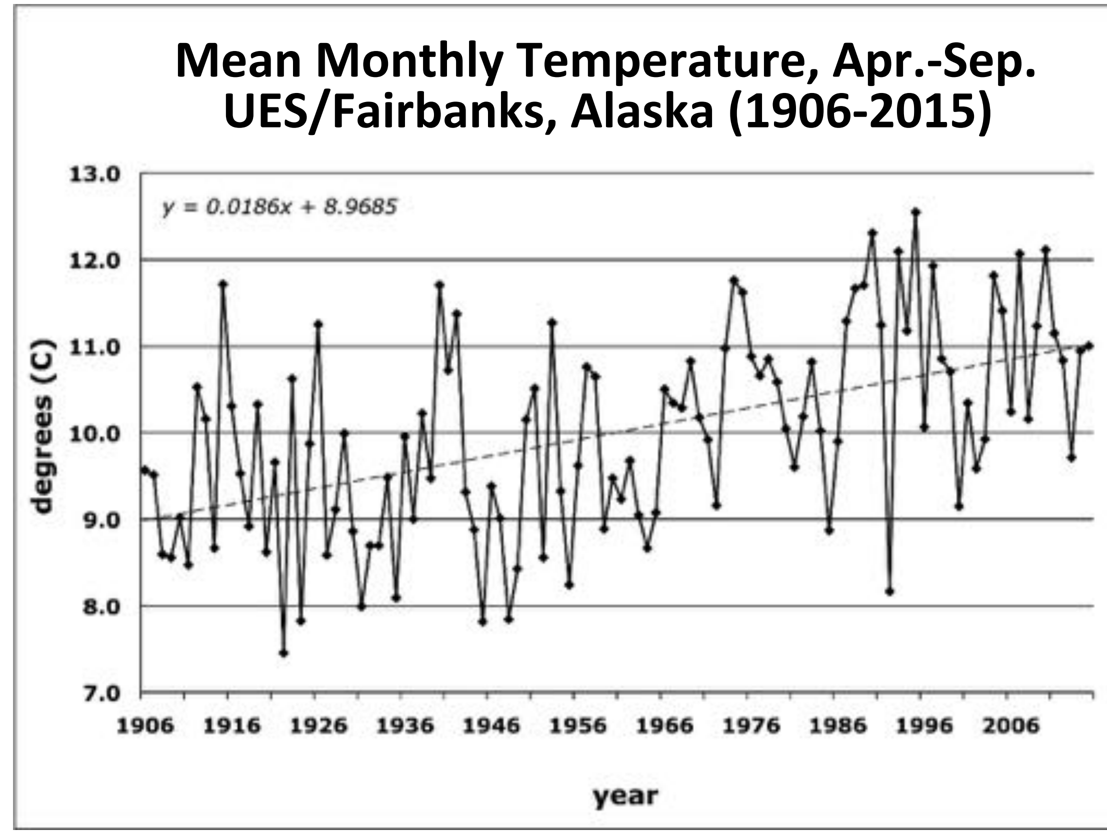
Source: AKDNR Division of Forestry

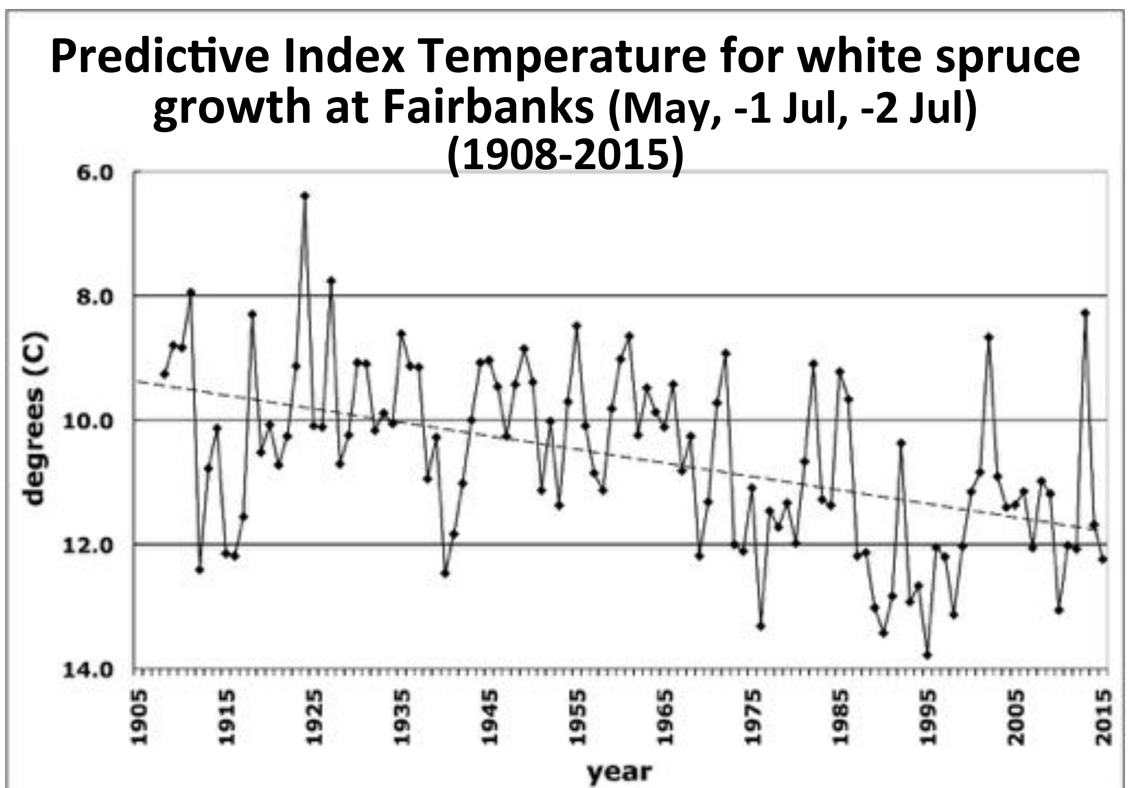
Source: http://www.fs.fed.us//

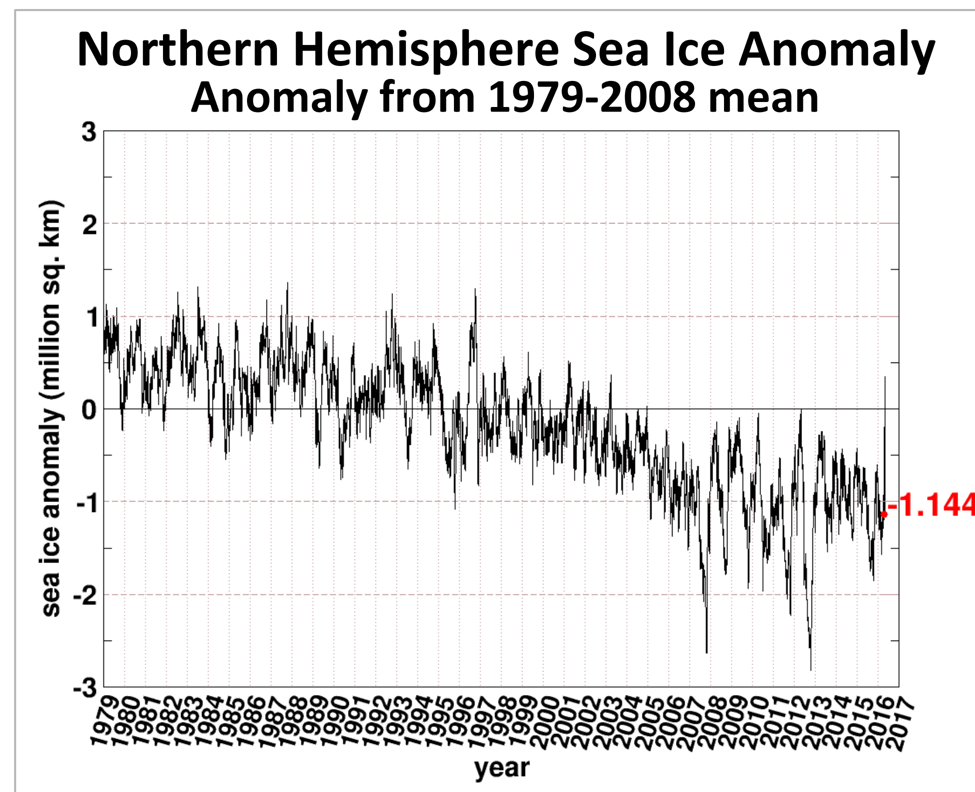
Source: http://biomassmagazine.com/

Strong evidence of warming in boreal Alaska





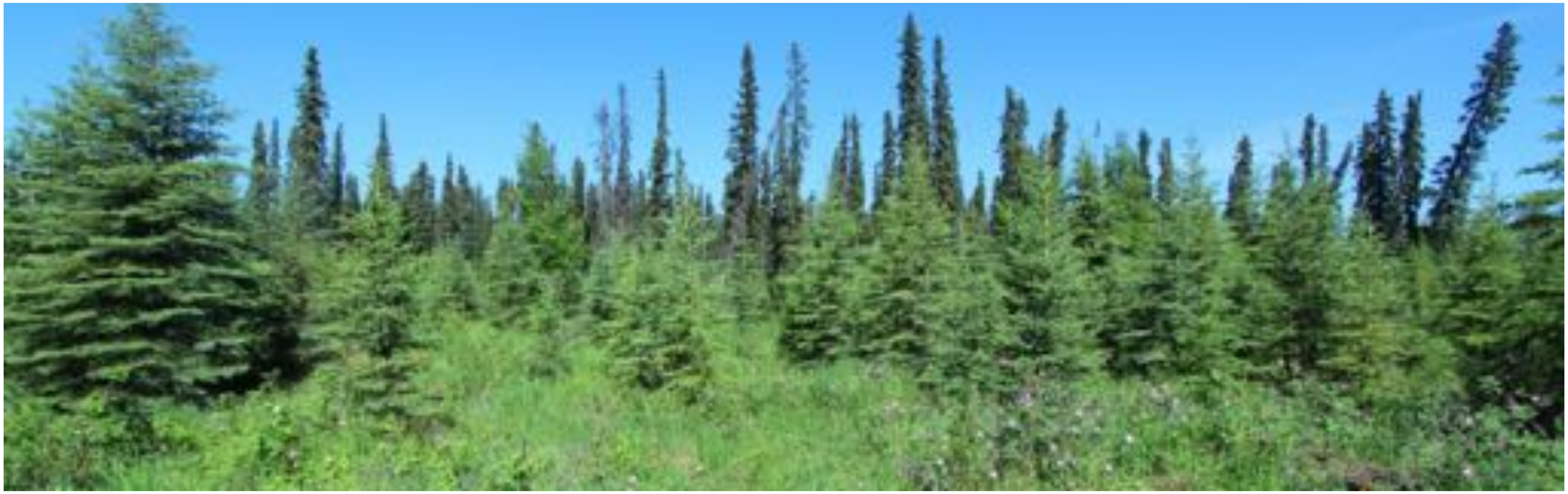




Source: Glenn P. Juday

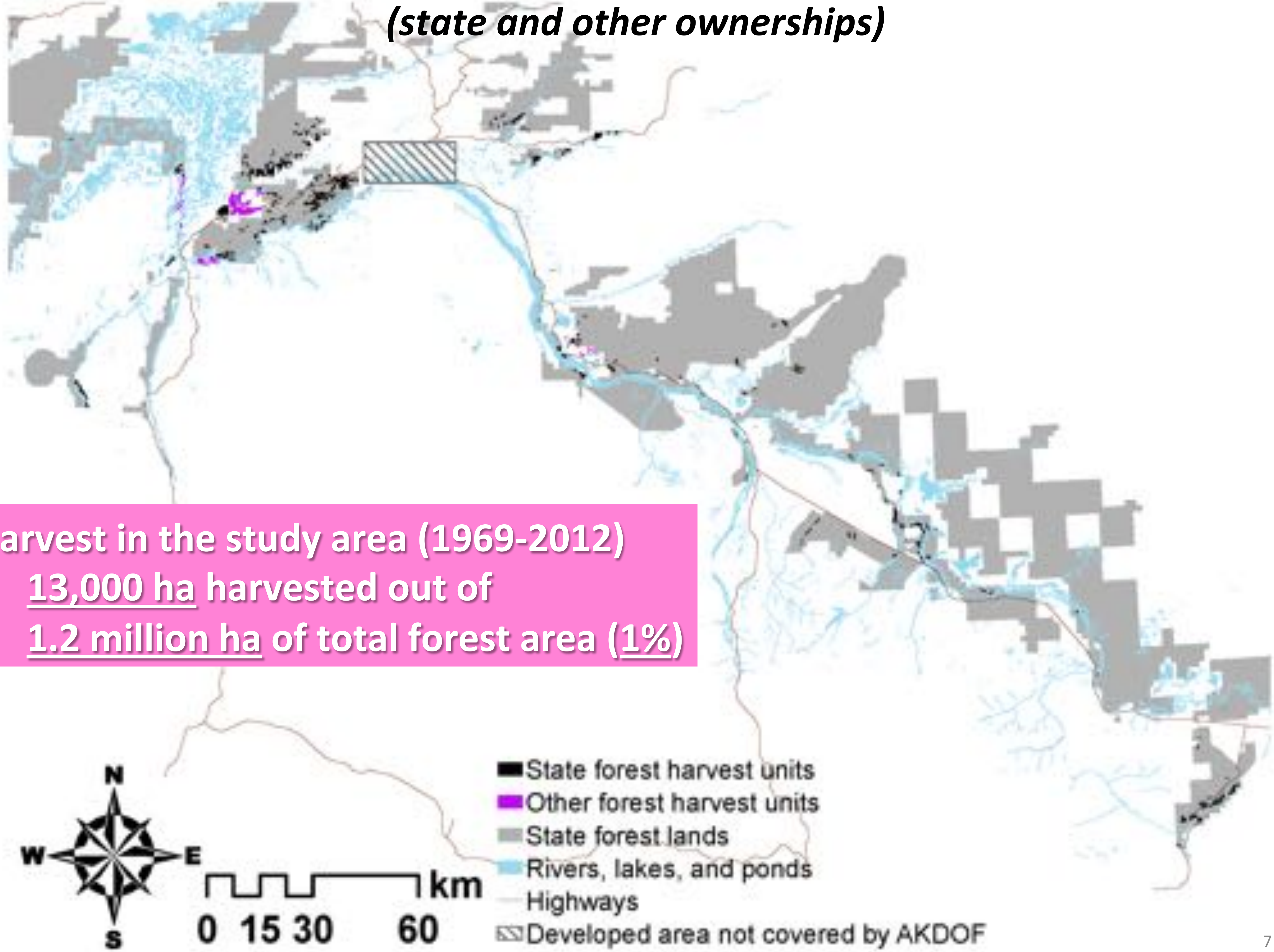
Topics

1. Overview of **historical harvest** and **regeneration** management
2. Lessons for **implementation** of post-harvest **regeneration** management
3. An **ecosystem approach to climate change** and post-harvest regeneration



Study Area in Interior Alaska and Tanana Valley

Historical Timber Harvest in Interior Alaska
(state and other ownerships)



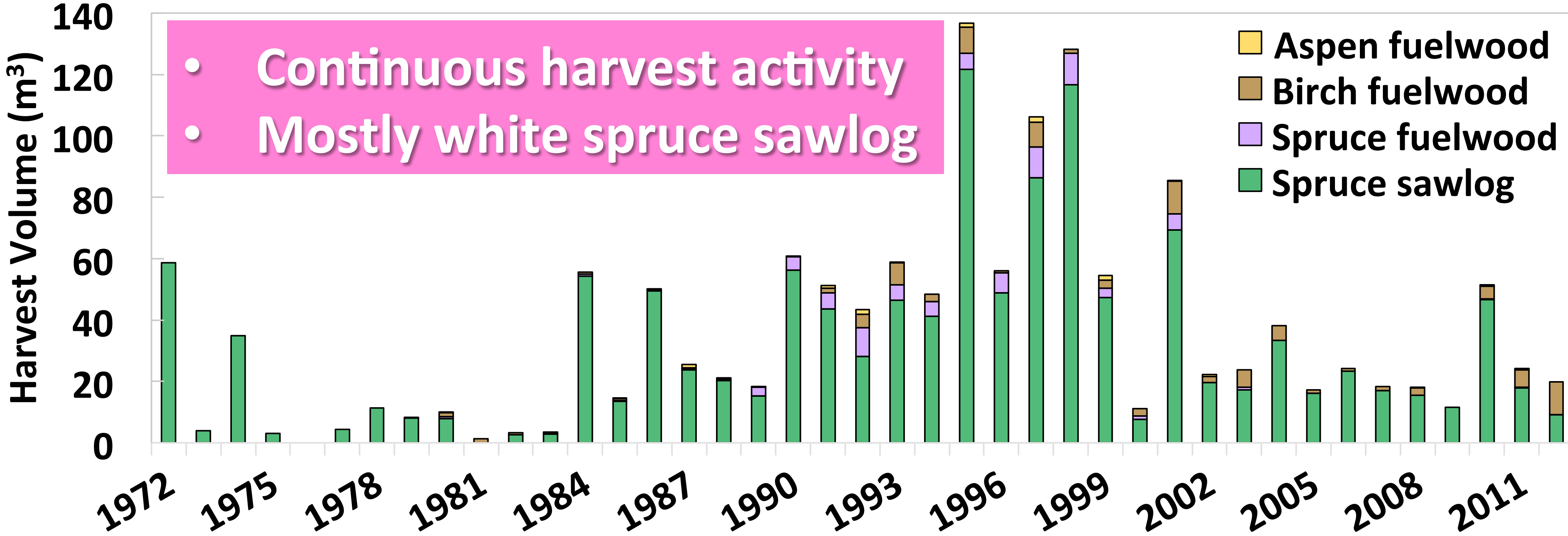
Harvest in the study area (1969-2012)

13,000 ha harvested out of

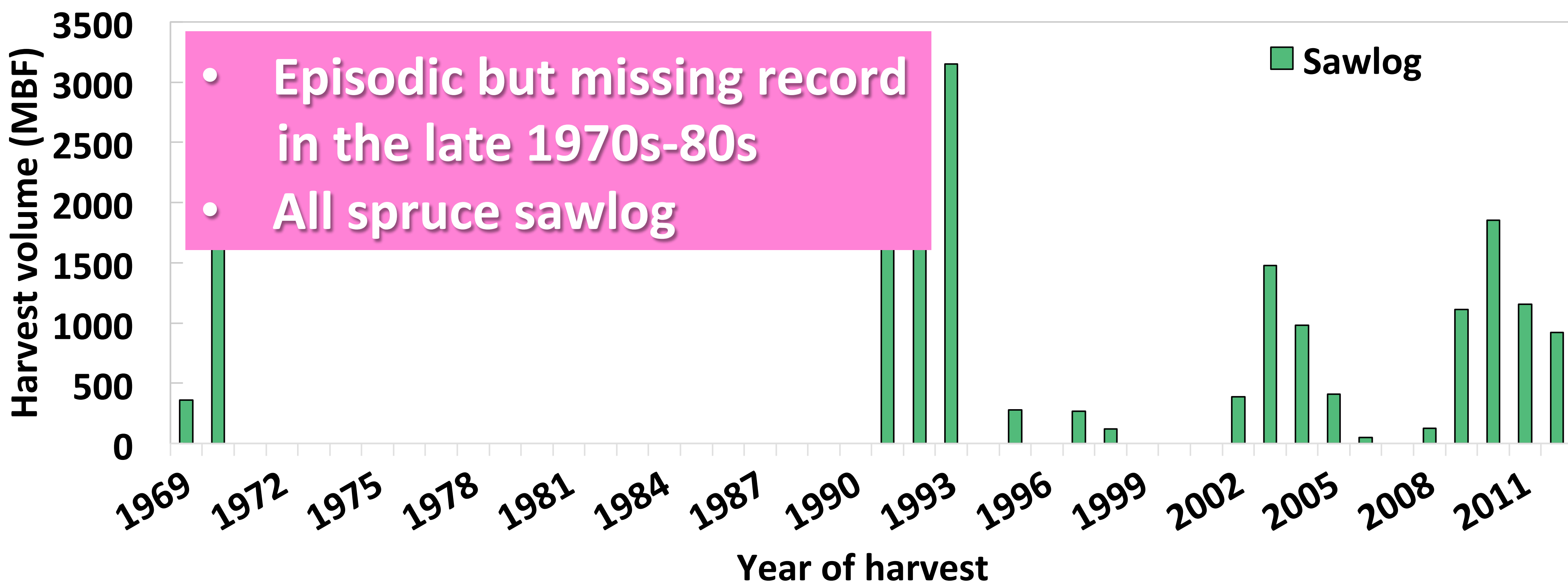
1.2 million ha of total forest area (1%)

History of total annual volume harvested

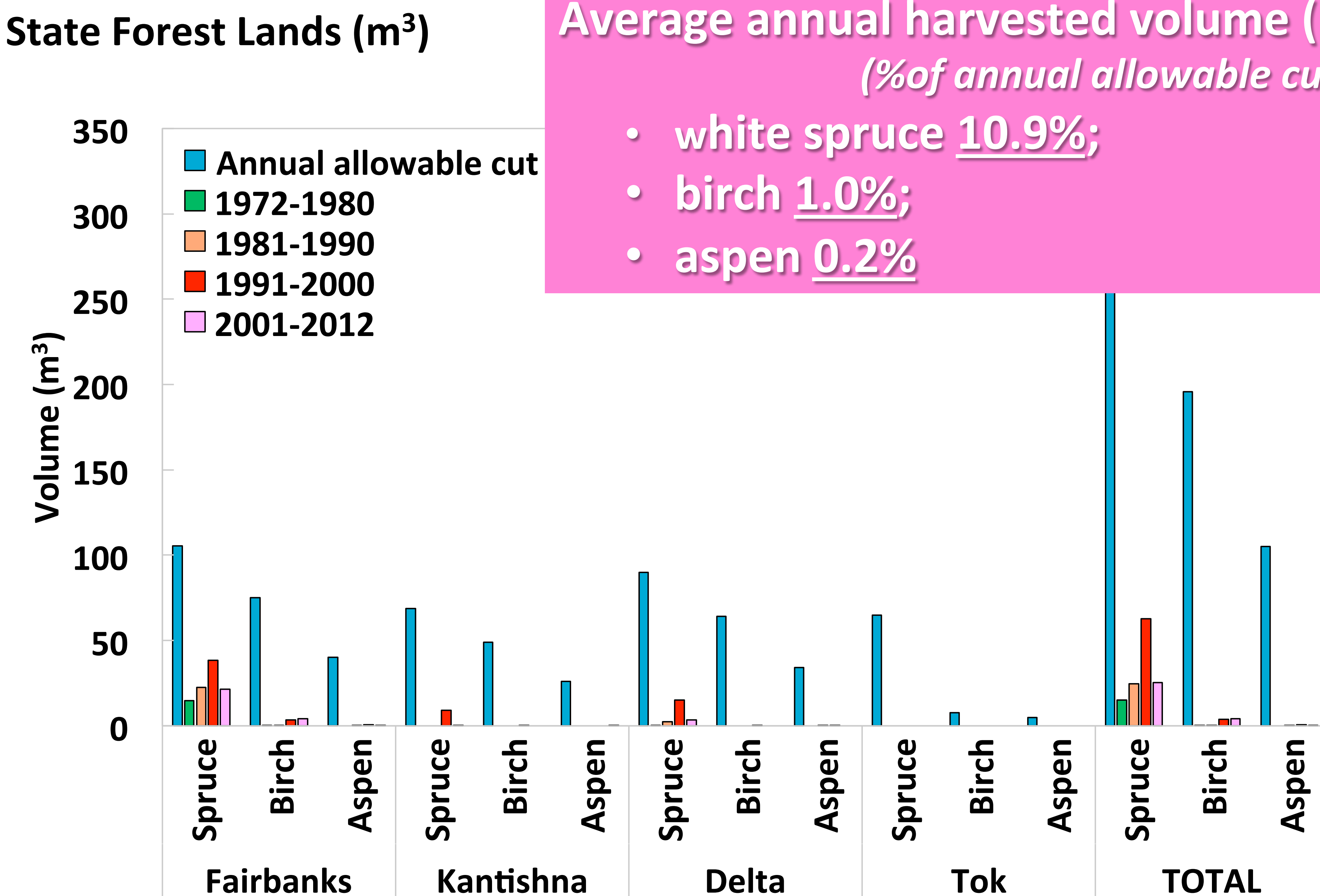
State Forest Lands



Other Forest Lands (MBF = 1000 board feet) *board foot is not compatible with metric



Annual allowable cut* and average annual harvested volume by species on lands set aside for timber harvest

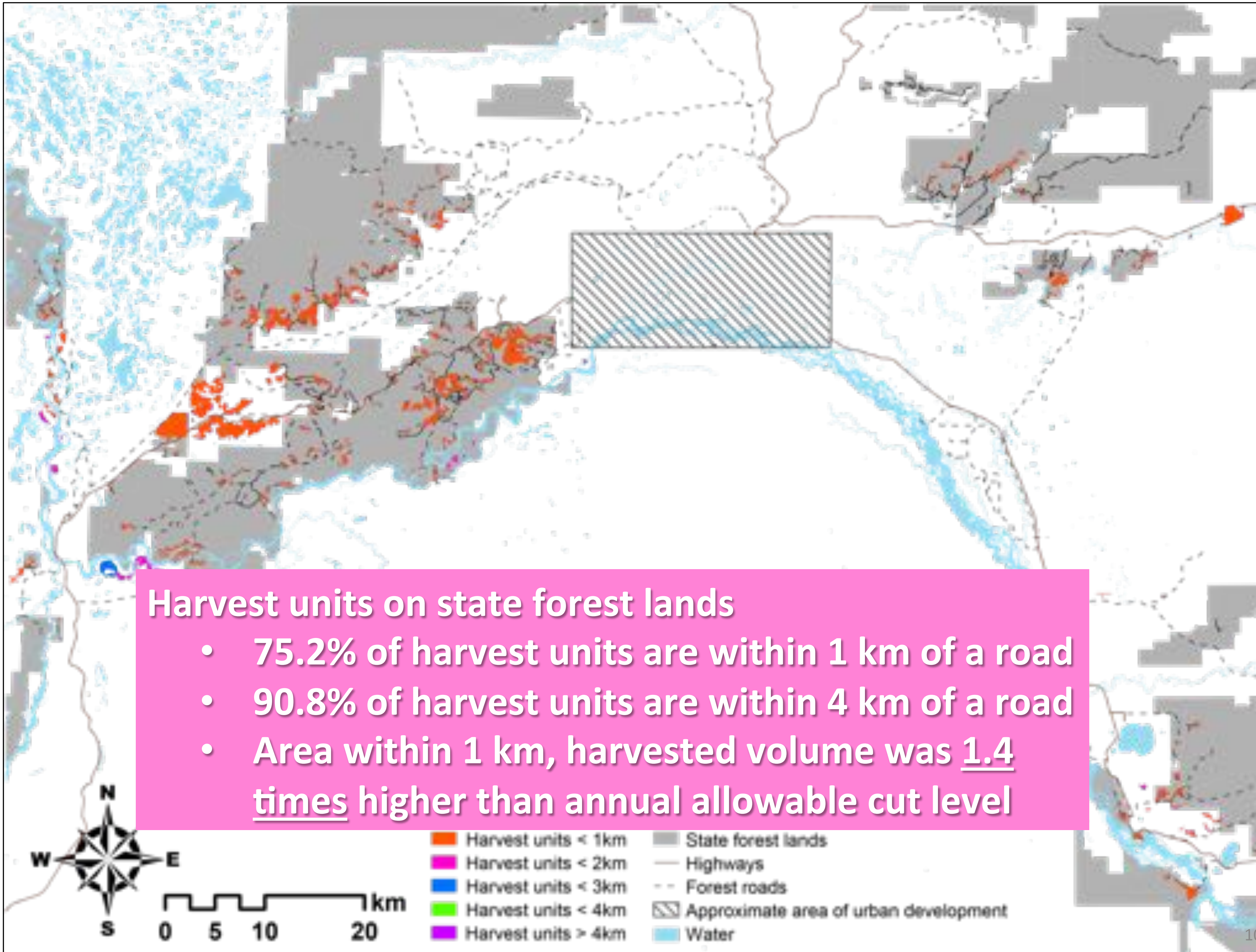


Average annual harvested volume (1972-2012)
(%of annual allowable cut)

- white spruce 10.9%;
- birch 1.0%;
- aspen 0.2%

***Allowable cut: the volume of timber that may be harvested during a given period (usually a year) that is specified by a sustained-yield forest plan (Society of American Foresters, Dictionary of Forestry)**

Distribution of historical harvest units and roads



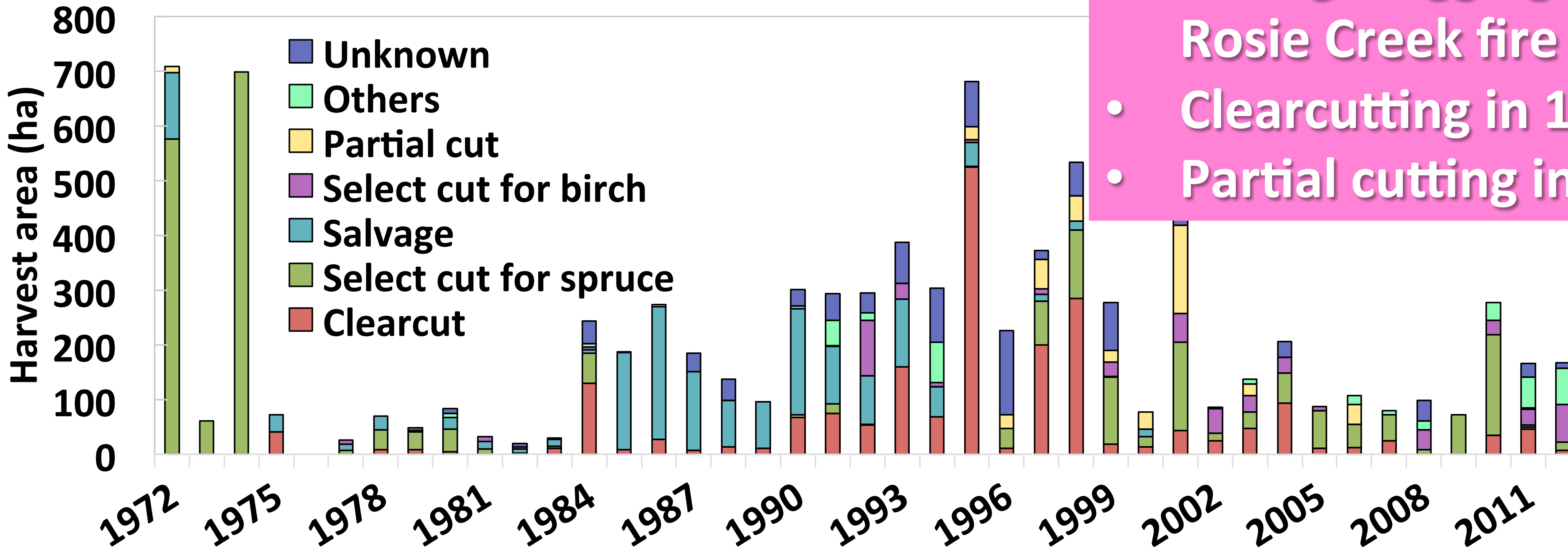
Harvest units on state forest lands

- 75.2% of harvest units are within 1 km of a road
- 90.8% of harvest units are within 4 km of a road
- Area within 1 km, harvested volume was 1.4 times higher than annual allowable cut level

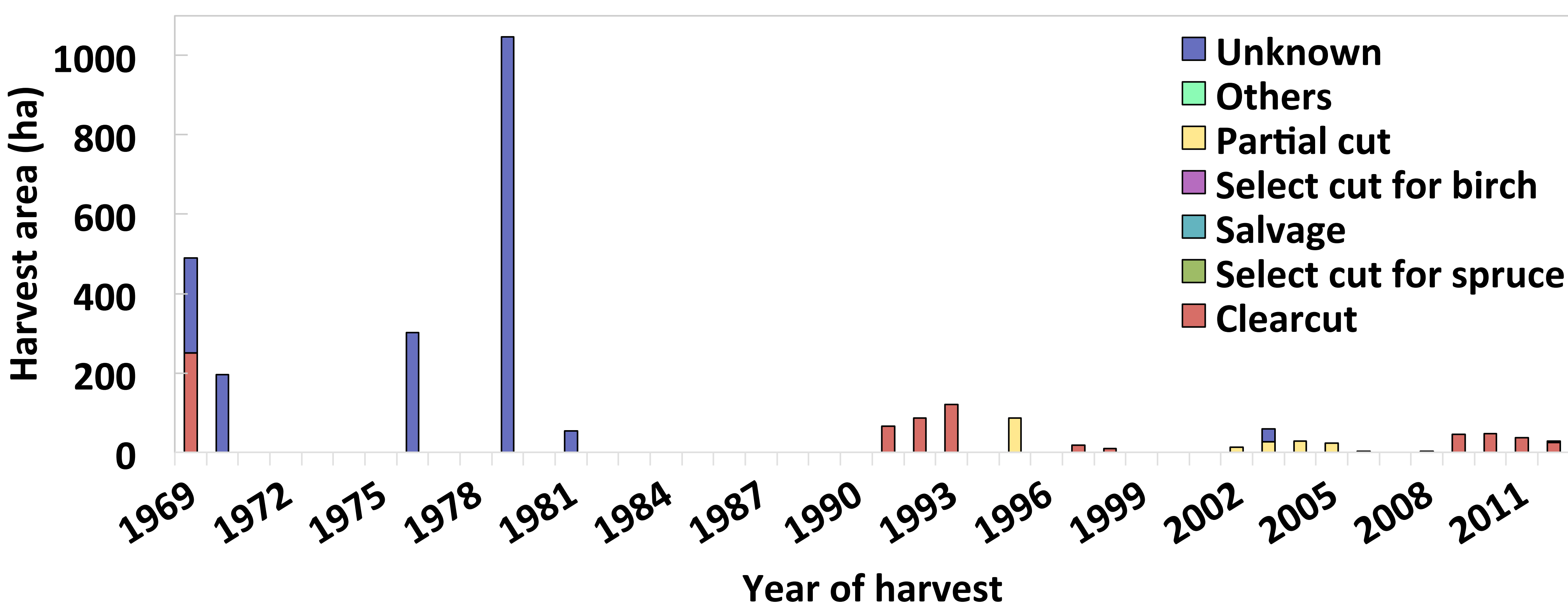
History of annual area harvested by harvest type

- Salvage logging after Rosie Creek fire in 1983
- Clearcutting in 1990s
- Partial cutting in 2000s

State Forest Lands (ha)

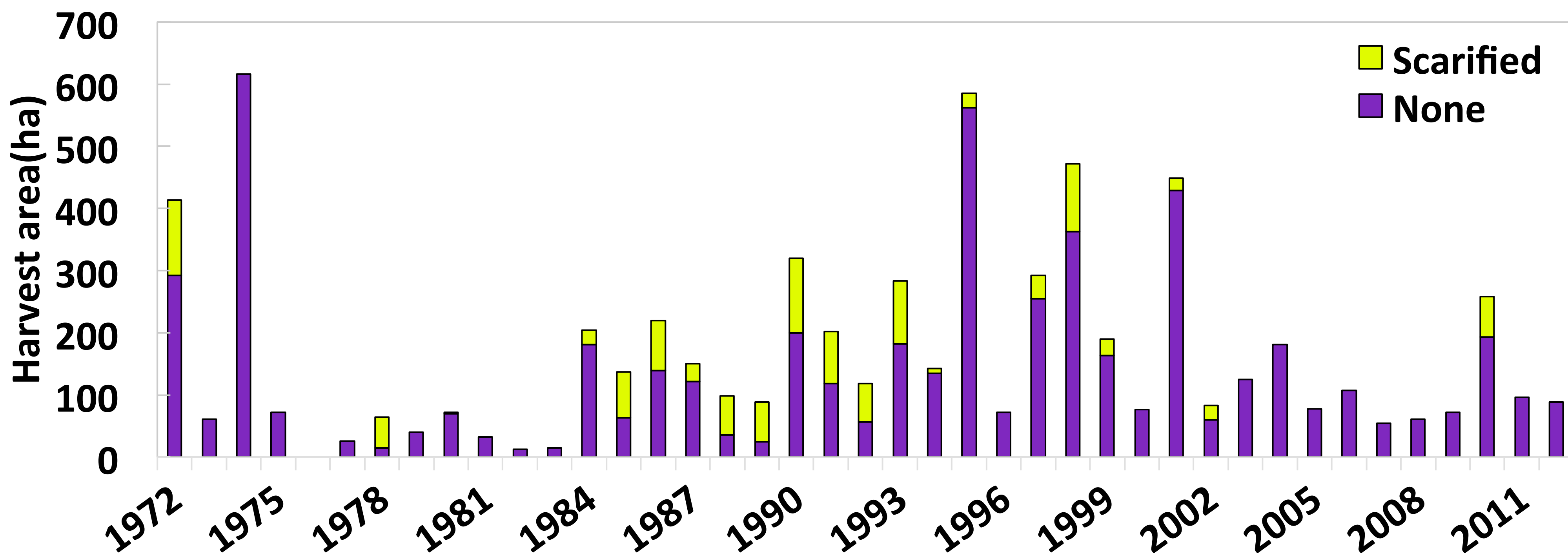


Other Forest Lands (ha)



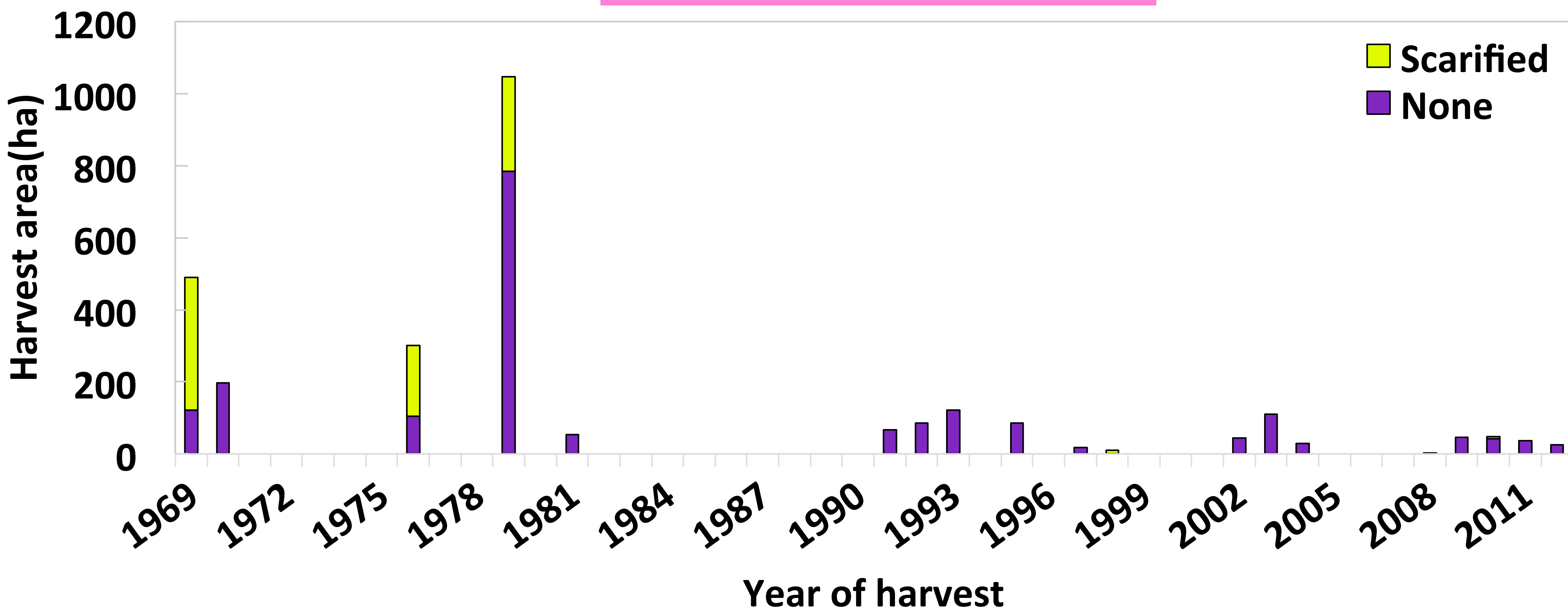
History of site preparation and harvest (annual area)

State Forest Lands (ha)



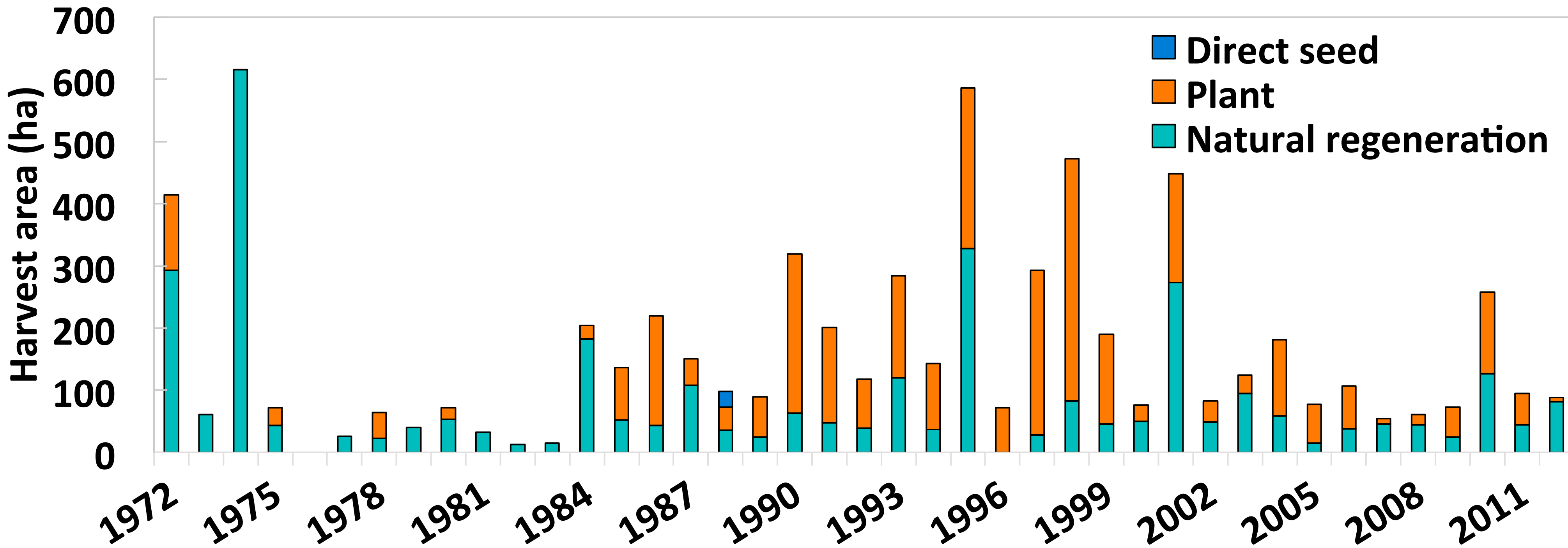
Other Forest Lands (ha)

Less than 20% of area



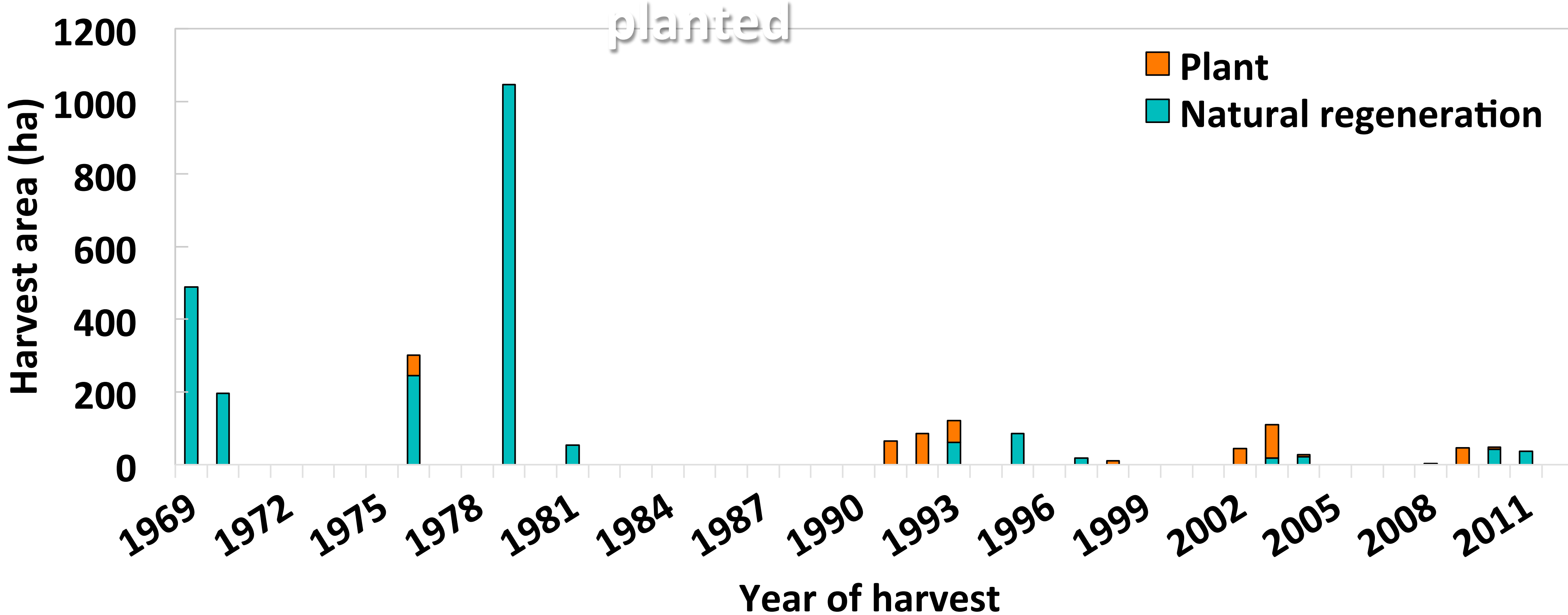
History of reforestation method of area harvested (annual total)

State Forest Lands (ha)

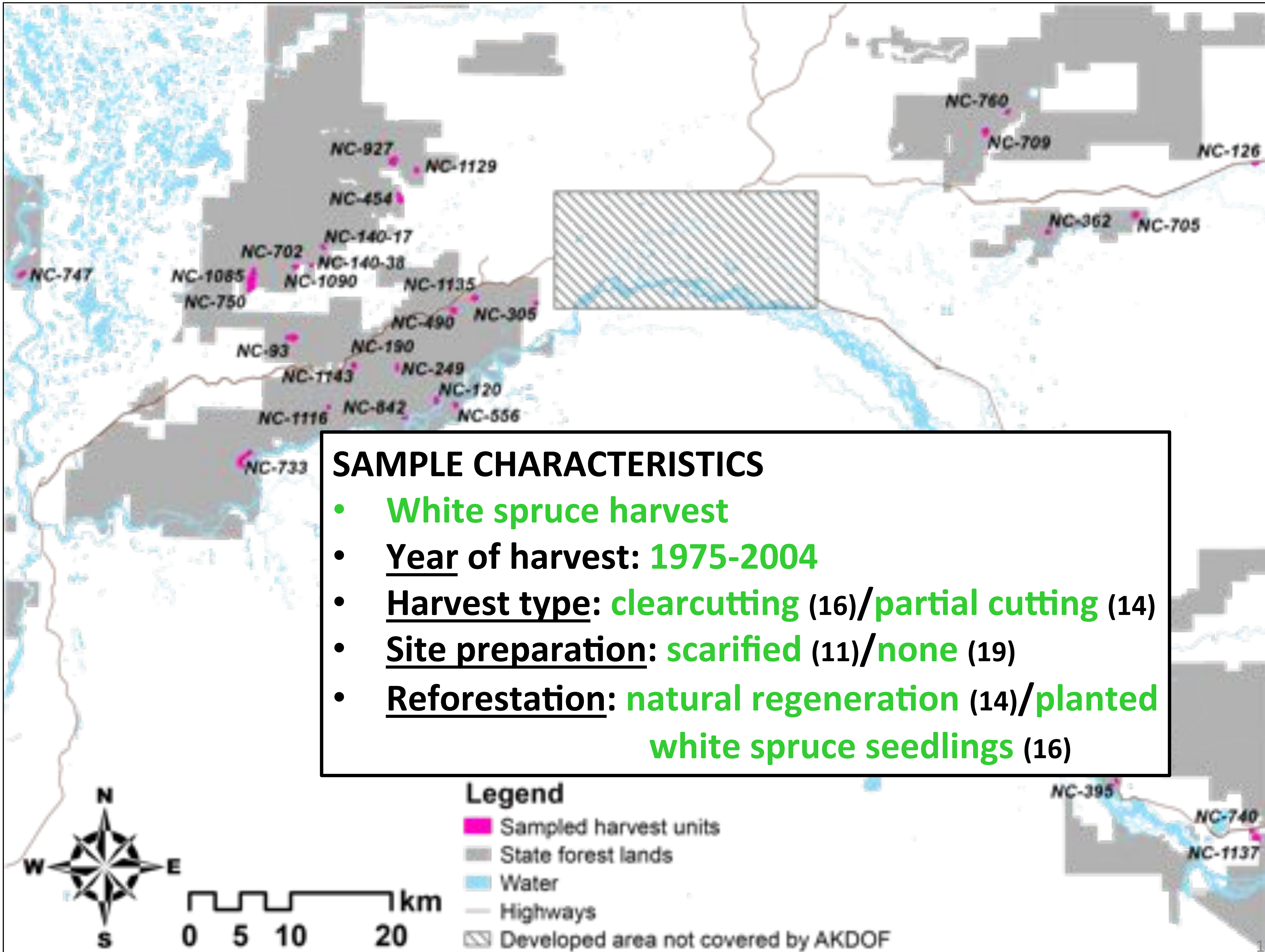


About ½ area was planted

Other Forest Lands (ha)



Harvest units sampled for regeneration (n = 30)

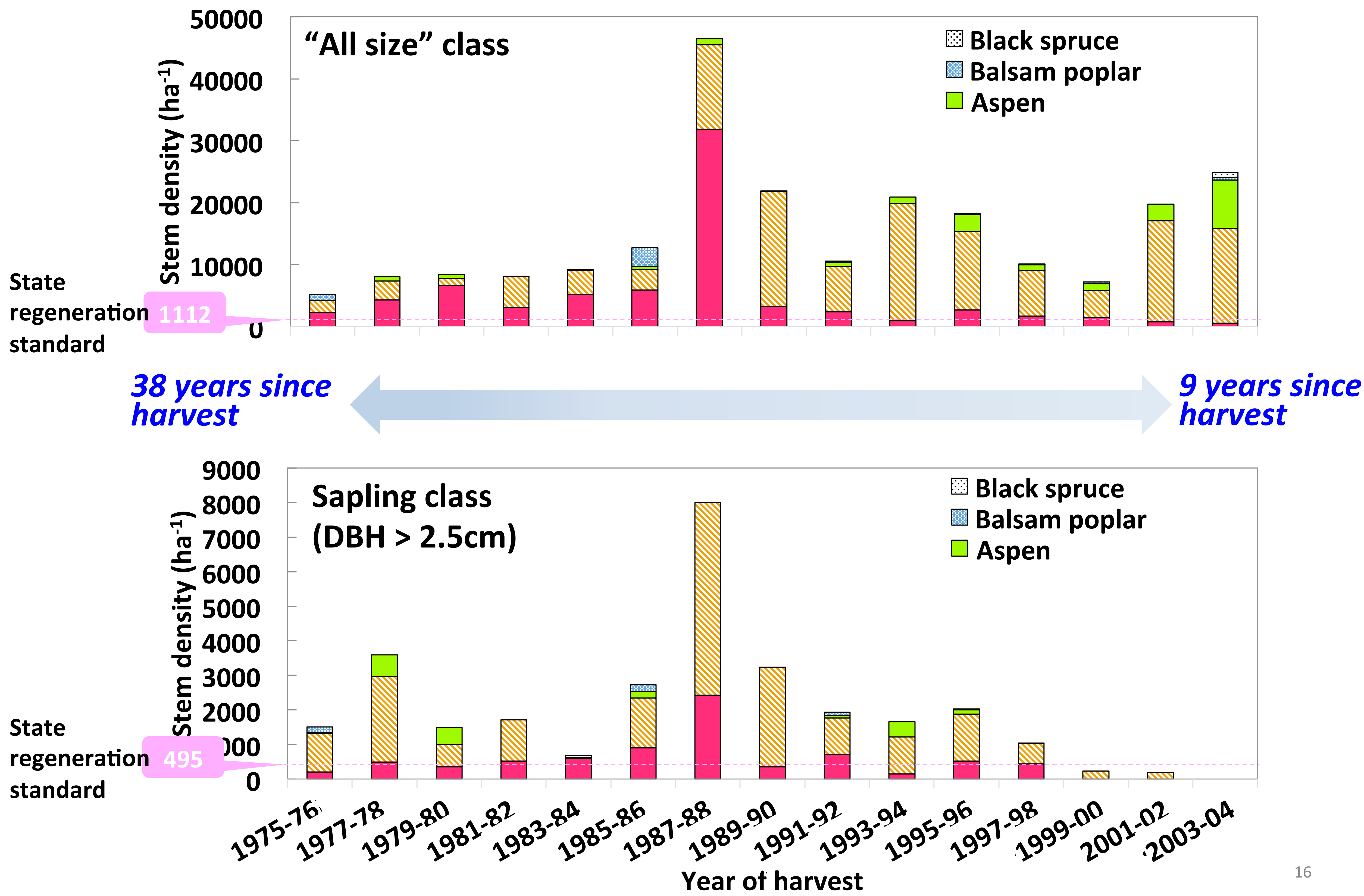


SAMPLE CHARACTERISTICS

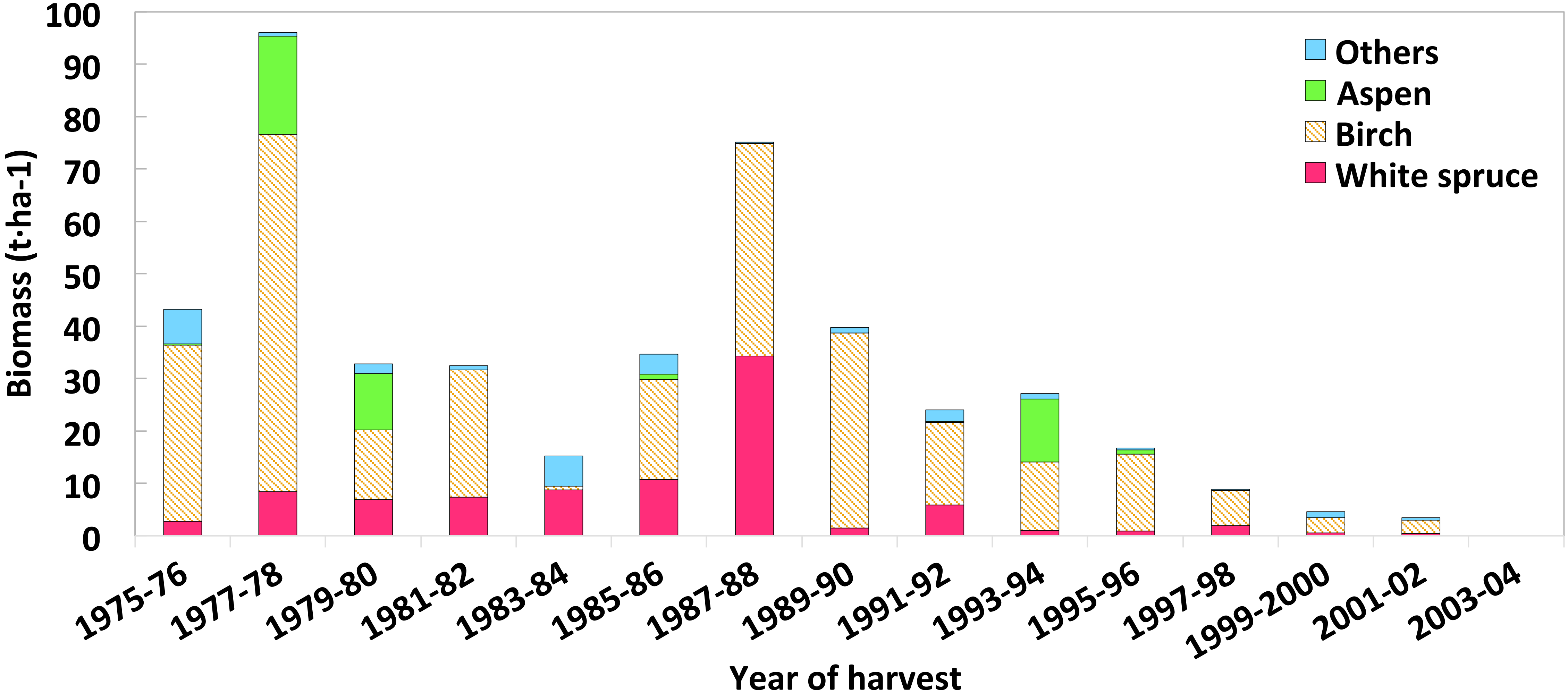
- White spruce harvest
- Year of harvest: 1975-2004
- Harvest type: clearcutting (16)/partial cutting (14)
- Site preparation: scarified (11)/none (19)
- Reforestation: natural regeneration (14)/planted white spruce seedlings (16)

Did the stands regenerate adequately?

Post-Harvest Tree Regeneration Density (2-yr. categories)



Post-Harvest Woody Biomass Accumulation



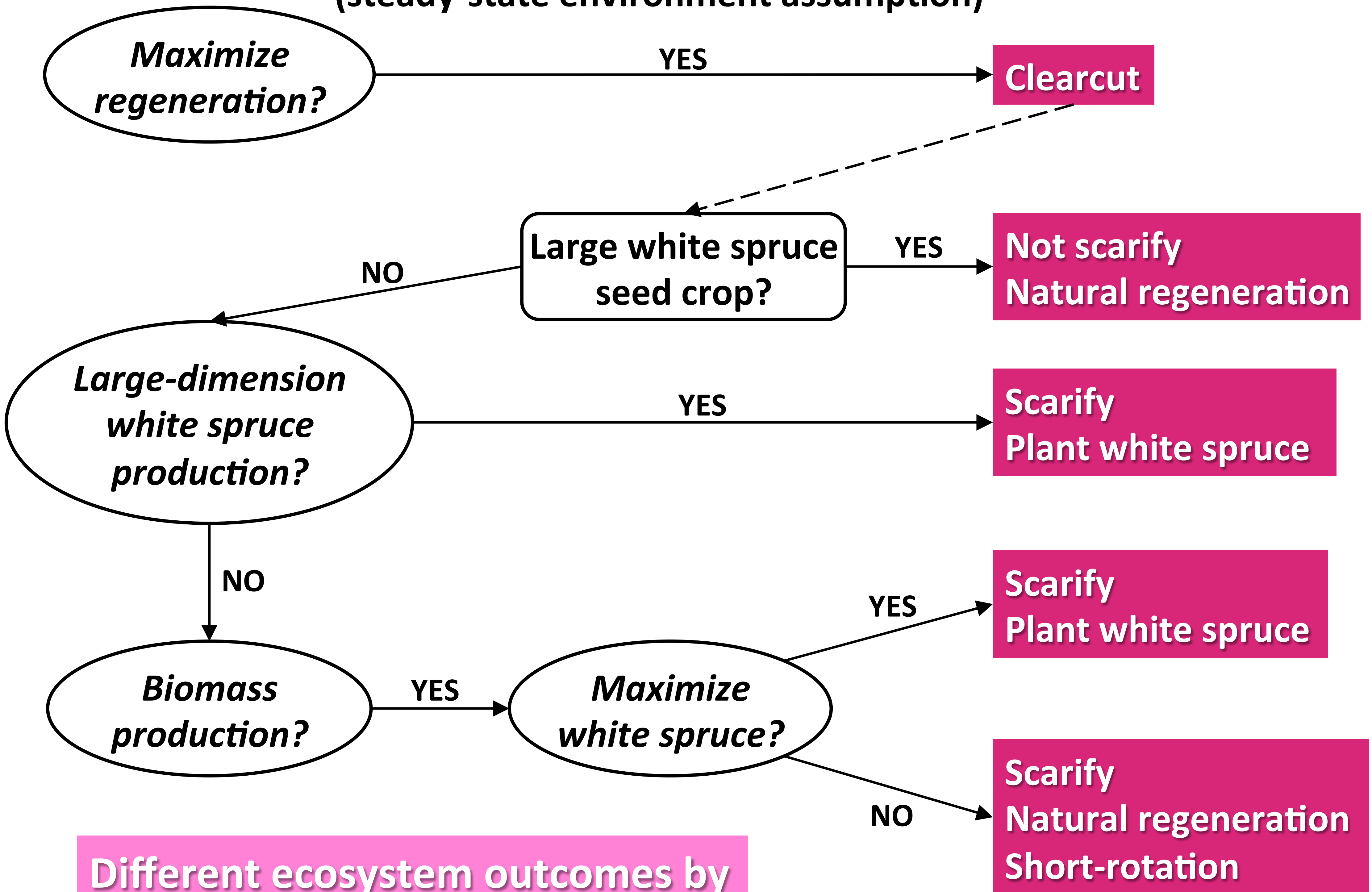
38 years since harvest ⟷ ***9 years since harvest***

Main demand might be biomass energy:

Regeneration is largely composed of hardwood (requires a change in species used)

Ecosystem Approach to Implementation of Management Goals

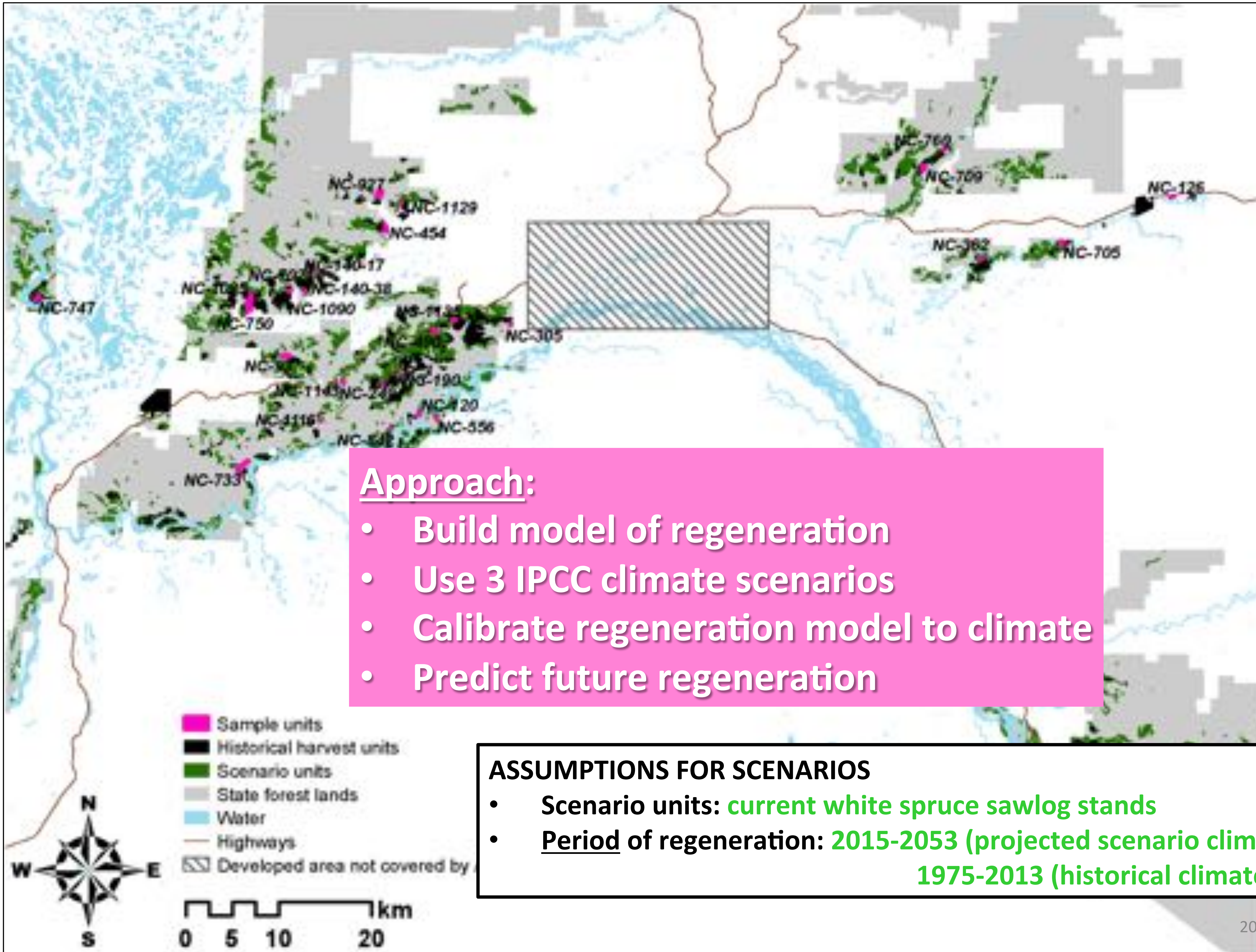
(steady-state environment assumption)



Different ecosystem outcomes by applying different management actions in different circumstances

How will climate change affect these results in the future?

Distribution of sampled units and scenario units

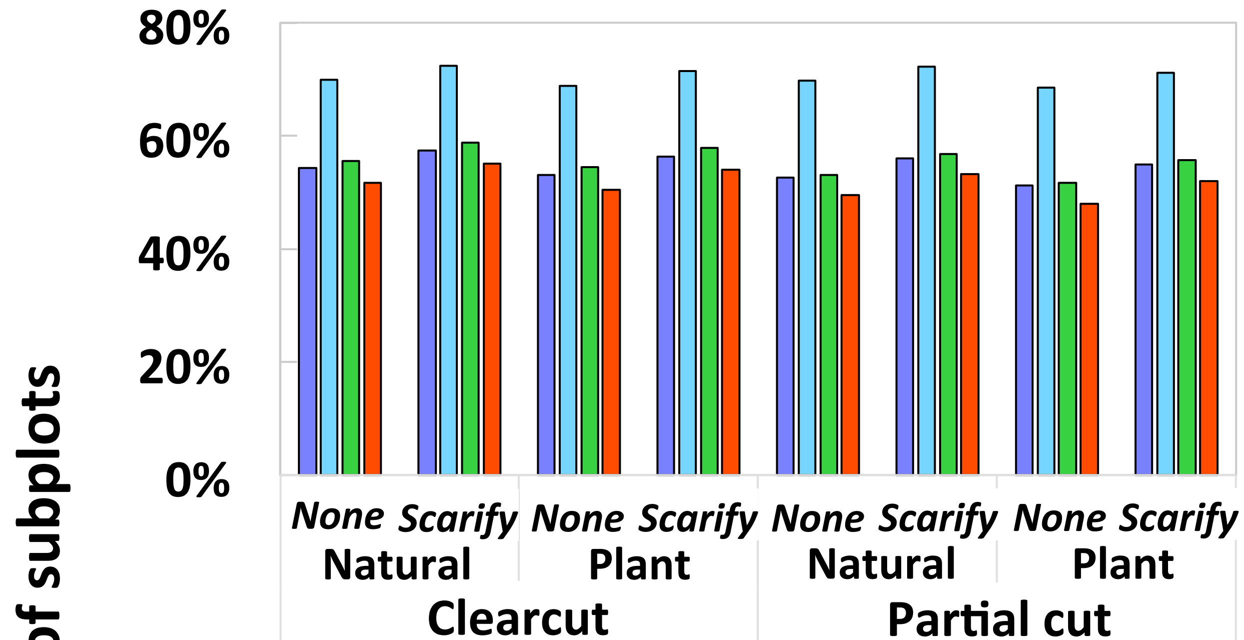


Approach:
- Build model of regeneration
- Use 3 IPCC climate scenarios
- Calibrate regeneration model to climate
- Predict future regeneration

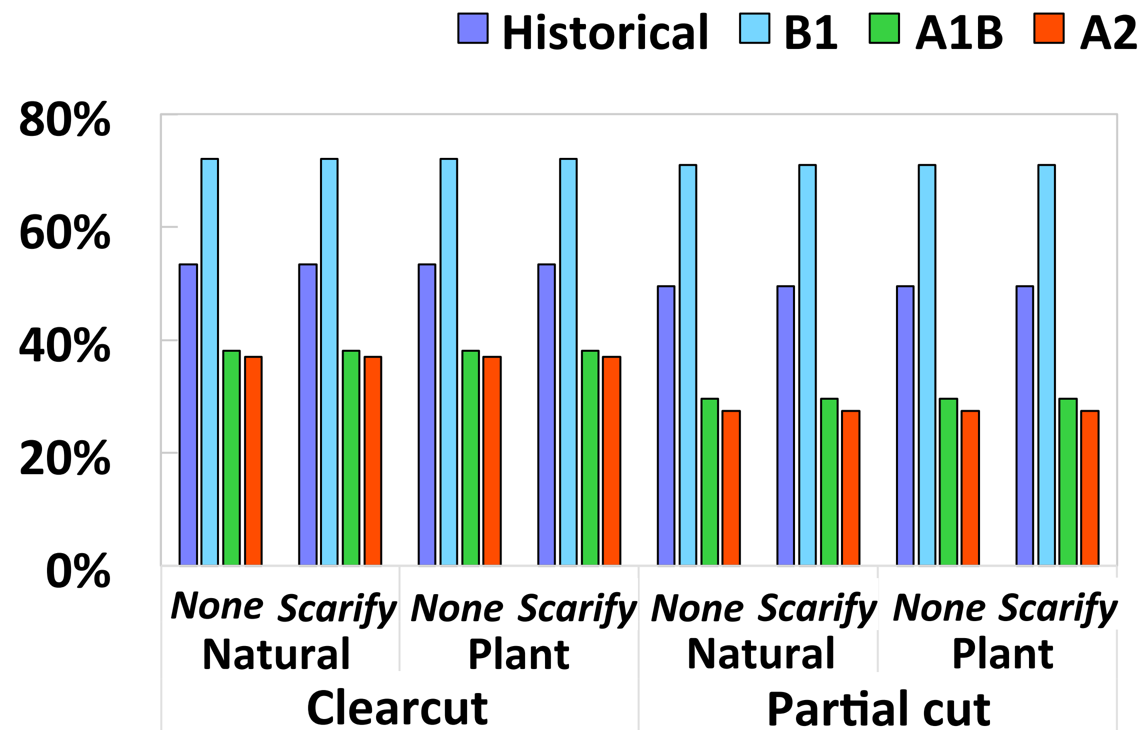
ASSUMPTIONS FOR SCENARIOS
- **Scenario units:** current white spruce sawlog stands
- **Period of regeneration:** 2015-2053 (projected scenario climate)
  1975-2013 (historical climate)

Percentage of occurrence of natural regeneration under climate change scenario

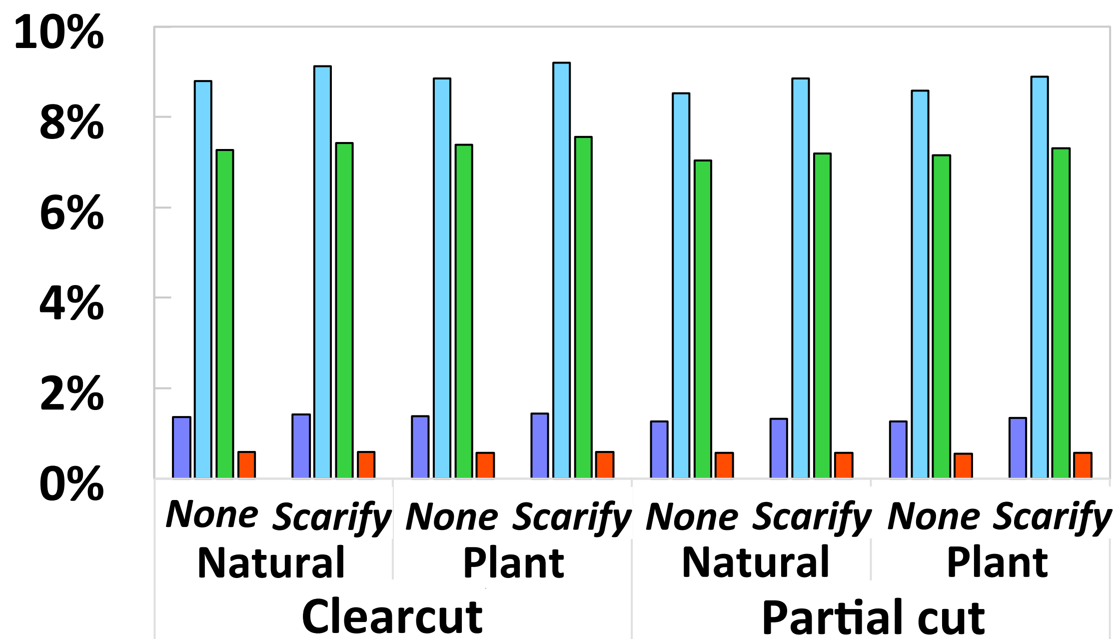
White spruce



Birch



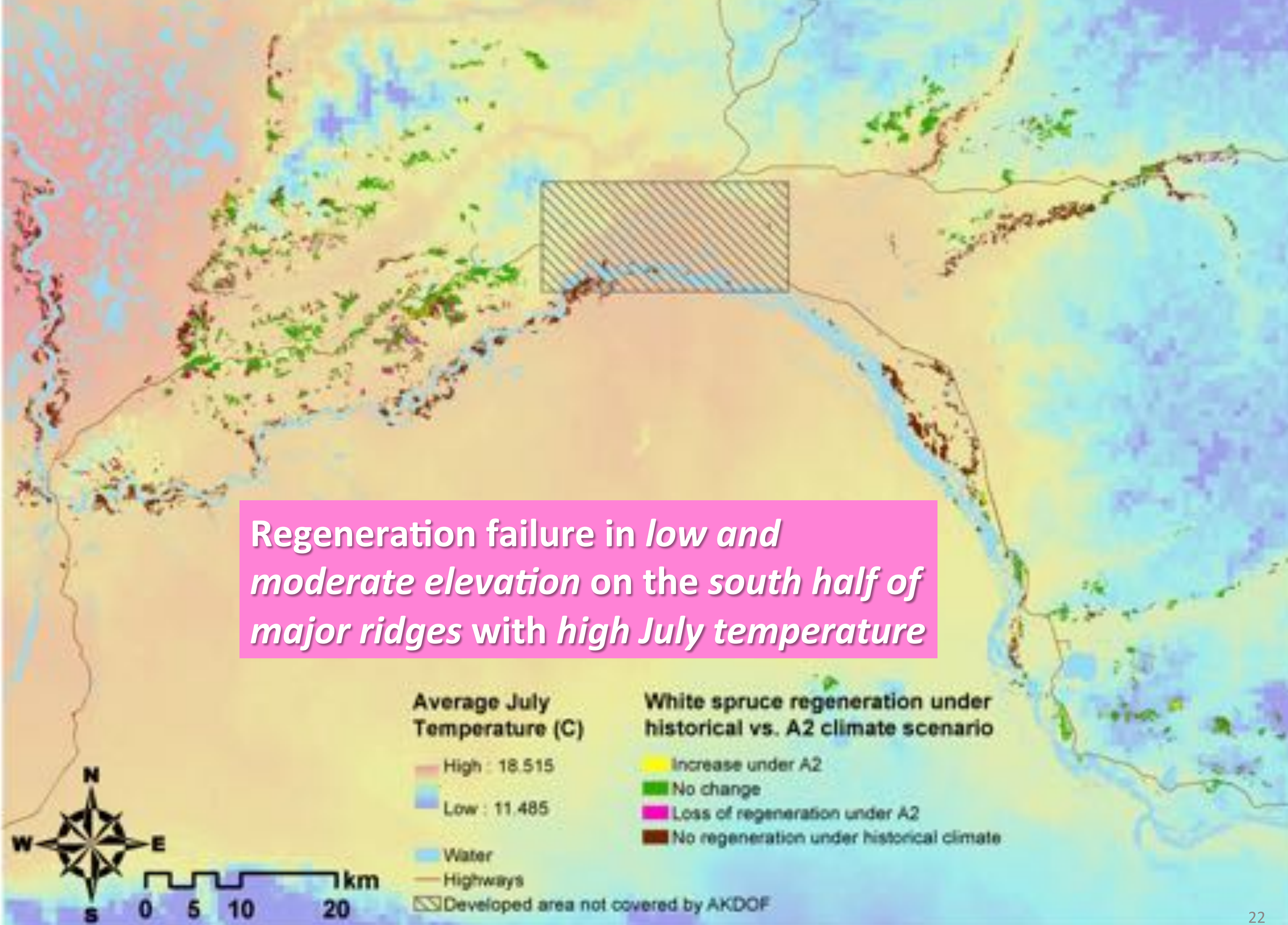
Aspen



PROJECTIONS:

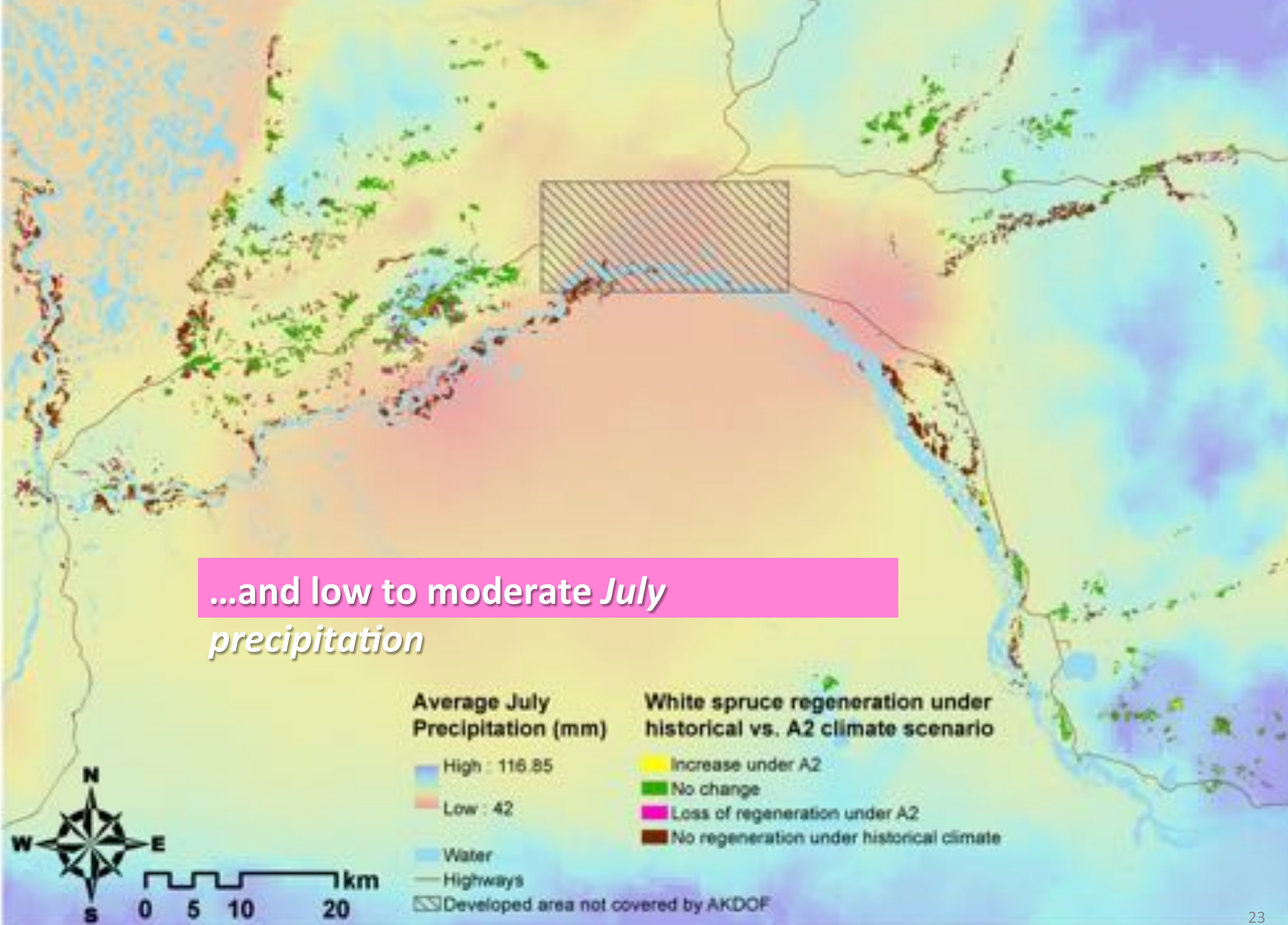
- Increase in regeneration under modest warming (B1, A1B)
- Substantial reduction of regeneration under A2

Failure of white spruce natural regeneration under A2 scenario



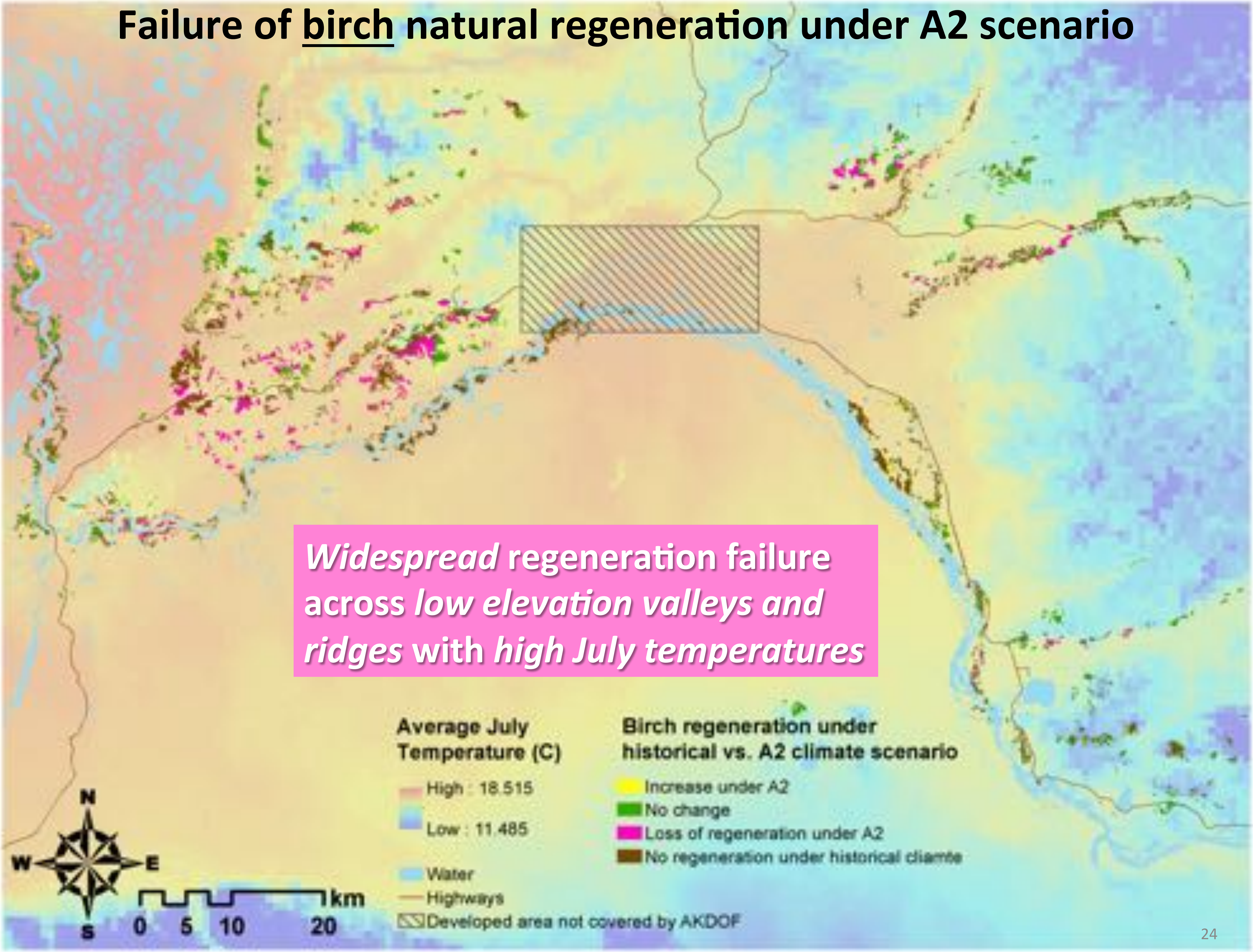
Regeneration failure in *low and moderate elevation* on the *south half of major ridges* with *high July temperature*

Failure of white spruce natural regeneration under A2 scenario

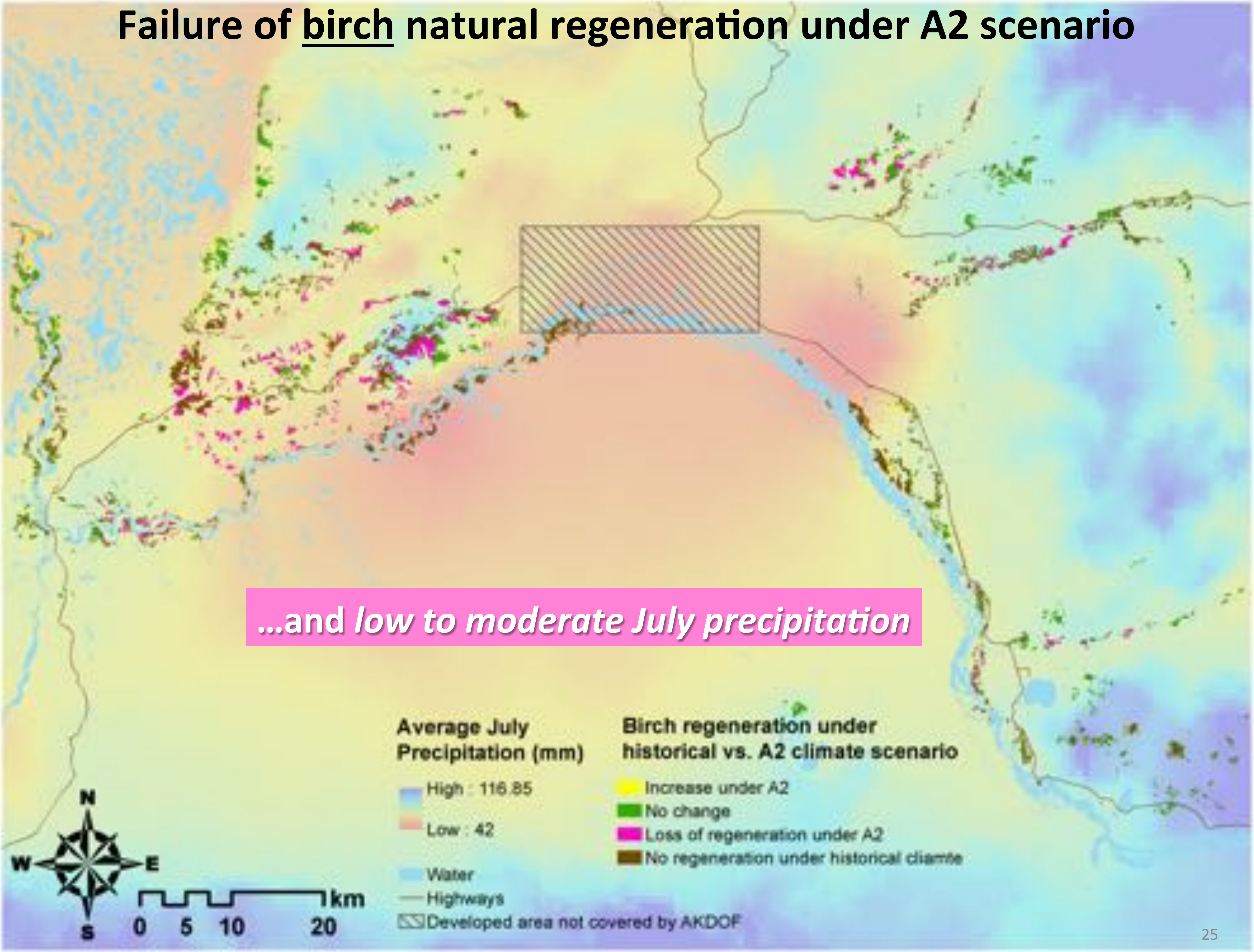


…and low to moderate *July precipitation*

Failure of birch natural regeneration under A2 scenario

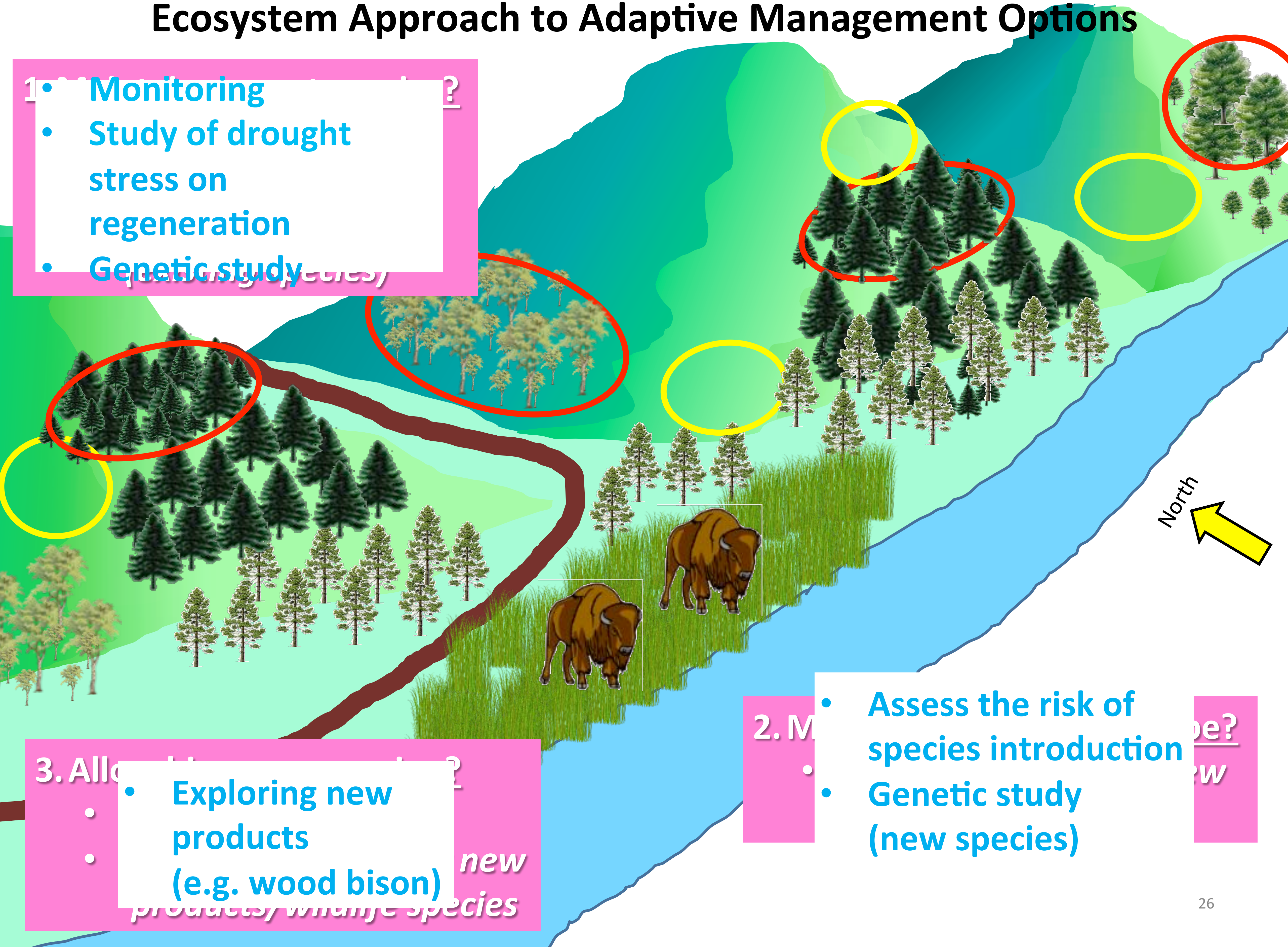


Failure of birch natural regeneration under A2 scenario



…and *low to moderate July precipitation*

Ecosystem Approach to Adaptive Management Options



- Monitoring
- Study of drought stress on regeneration
- Genetic study

- Assess the risk of species introduction
- Genetic study (new species)

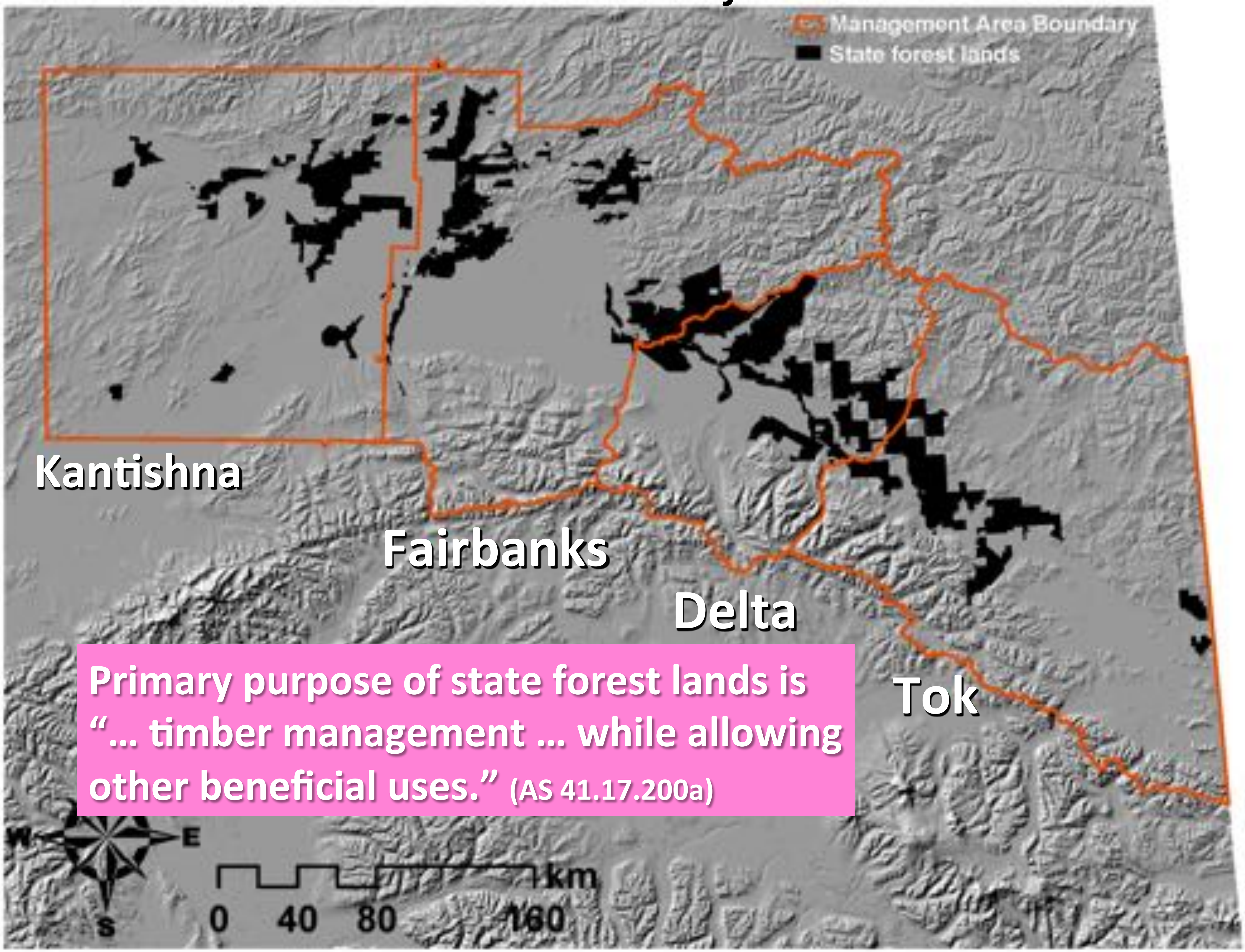
- Exploring new products (e.g. wood bison)

Acknowledgement

- Major advisor: Glenn Juday
- Graduate Committee: David Valentine, Falk Huettmann, John Yarie, and Valerie Barber
- BAK LAP supported by appropriation to the Alaska Department of Natural Resources Division of Forestry, the McIntire Stennis Cooperative Forestry Research Program (ALK13-04), and the Bonanza Creek Long-Term Ecological Research program funded by the National Science Foundation (DEB-1026415)
- Alaska Department of Natural Resources, Division of Forestry, especially Brian Young and Doug Hanson, for databases, equipment, transportation, advises, reviews
- Tanana Chiefs Conference for databases
- People who helped me with fieldwork, especially Ryan Jess and Mary Guisa
- Friends and family who have supported and encouraged me

State of Alaska Management Areas

- *Tanana Valley State Forest,* plus
- *State "Forest Classified" Land*

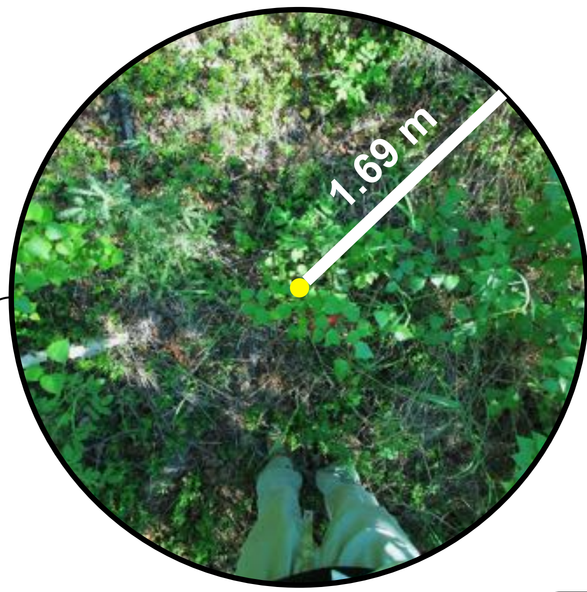


Methods: Field Sampling

Summer 2013/14

741 plots

Plot (1/450 acre)

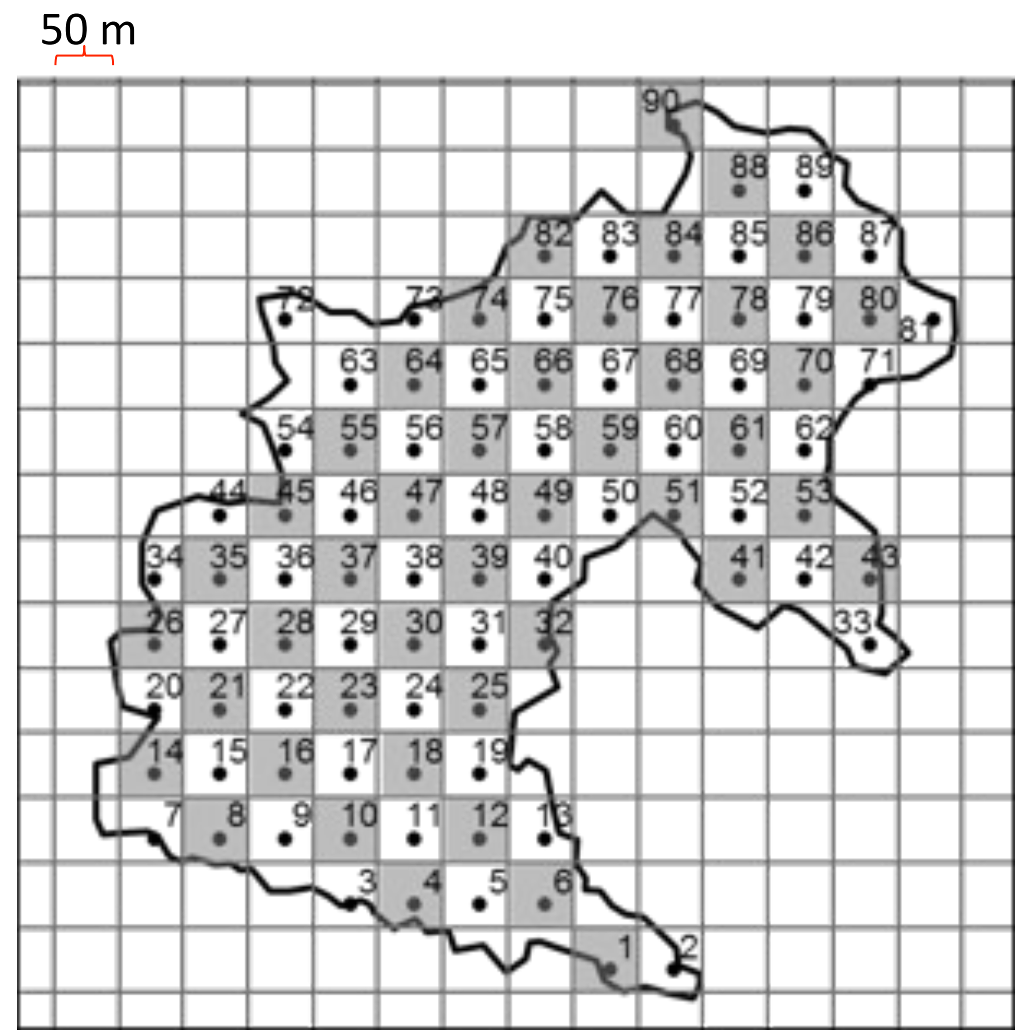


White spruce

- *< 1.37 m height* → **Count**
- *≥ 1.37 cm height* → **DBH Total height**

Birch
Aspen
Balsam poplar
Black spruce

- *< 1 cm DBH* → **Count**
- *≥ 1 cm DBH* → **DBH Total height**



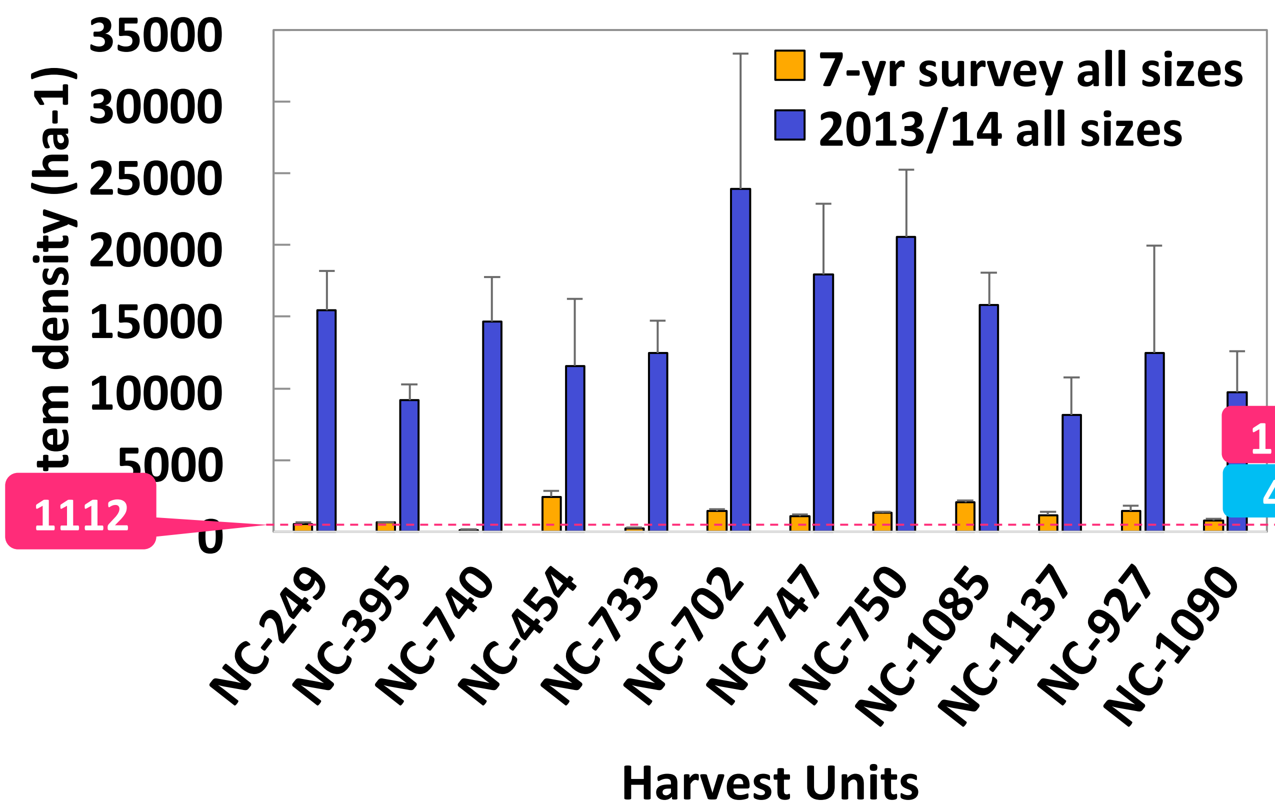
DBH = Diameter at breast height

White spruce
Or
Hardwood
????????

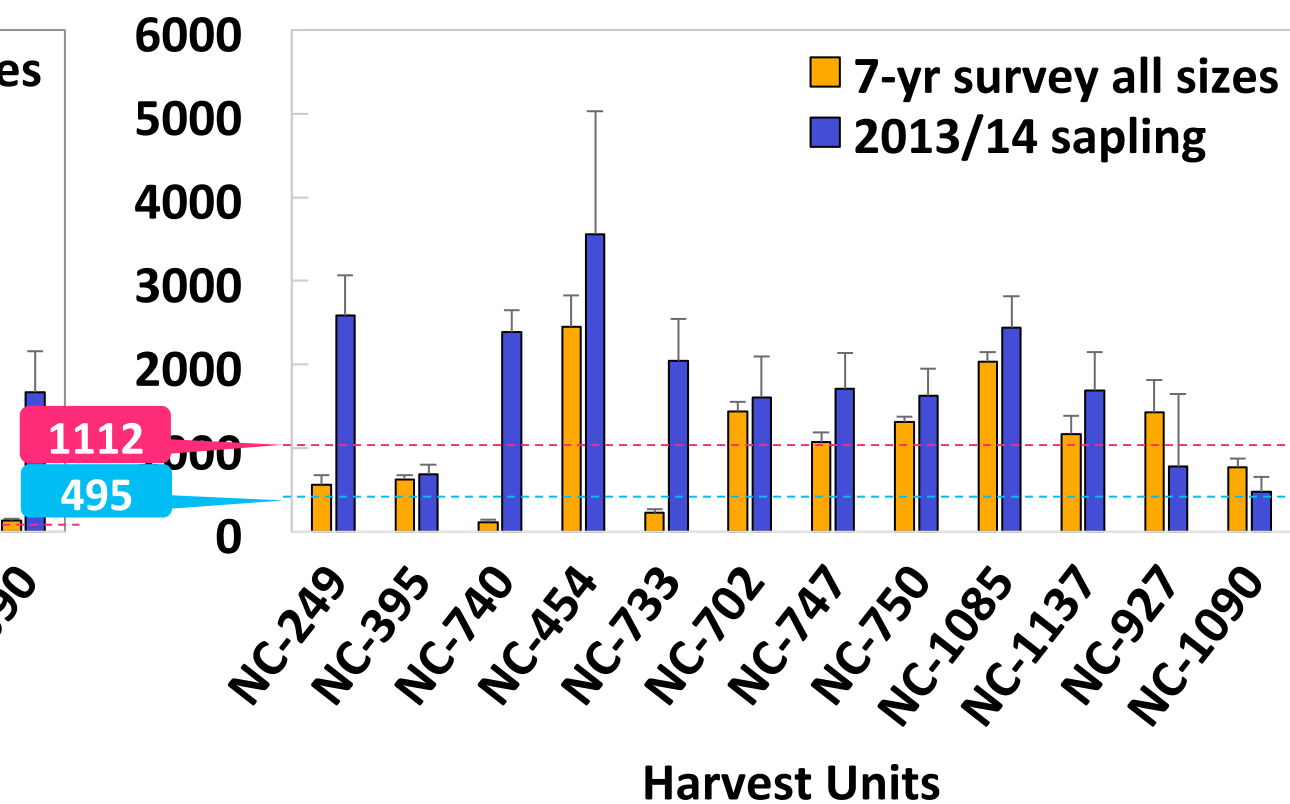
Post-harvest regeneration tree density 10-40 years after harvest compared to density within 7 years

12 harvest units compared
7-yr survey = 2 to 10* yrs *exception to 7-yr period
This study = 14 to 33 yrs

"All size" class



Sapling (DBH > 2.5cm) class



- 6 of 12 harvest units did not meet the standard in 7-yr survey
- All units met the standard at 10-40 yrs
- Tree recruitment appears to continue for longer than 7 years

- 11 out of 12 units met the standard of 495 ha^{-1} of sapling at 10-40 yrs

Methods

<u>Response variables (Binary class)</u>

- White spruce, birch, and aspen
  - Presence/absence
    - Any size
    - Sapling class (DBH ≥ 2.5 cm)

    (1 = present; 0 = absent)
  - Basal area

    (1 = high; 0 = low)
    (Threshold
    White spruce = 0.5 m^2
    Birch = 1.0 m^2
    Aspen = 0 m^2)
- Aggregated species
  - Biomass

    (1 = high; 0 = low)
    (Threshold = 5 $t{\cdot}ha^{-1}$)

<u>Predictor variables</u>

- Management practices
  - Harvest type
  - Site preparation method
  - Reforestation technique
- Year of harvest
- Size of harvest
- Distance to various features
  - Edge of harvest unit
  - White spruce forest
  - Birch forest
  - Aspen forest
  - Water
  - Highway
  - Forest road
  - Urban area
  - Developed area
- Topography
  - Elevation
  - Slope
  - Aspect
  - Topographic position index
- Soil subgroup
- Climate of growing season (May-August)
  - Mean average monthly temperatures
  - Total monthly precipitation

Results: predictive accuracies of presence/absence

Correct prediction
Incorrect prediction

		Predicted presence/absence		Specificity Sensitivity	Mean accuracy	AUC
Any size		Absent	Present			
Aspen	Absent	491	92	84.22%	0.84	0.92
	Present	22	121	84.62%		
Birch	Absent	176	91	65.92%	0.68	0.74
	Present	138	321	69.93%		
White spruce	Absent	196	74	72.59%	0.73	0.78
	Present	123	333	73.03%		
Sapling class		Absent	Present			
Aspen	Absent	653	43	93.82%	0.94	0.98
	Present	2	28	93.33%		
Birch	Absent	394	84	82.43%	0.82	0.90
	Present	47	201	81.05%		
White spruce	Absent	422	108	79.62%	0.79	0.88
	Present	44	152	77.55%		

* AUC = area under curve

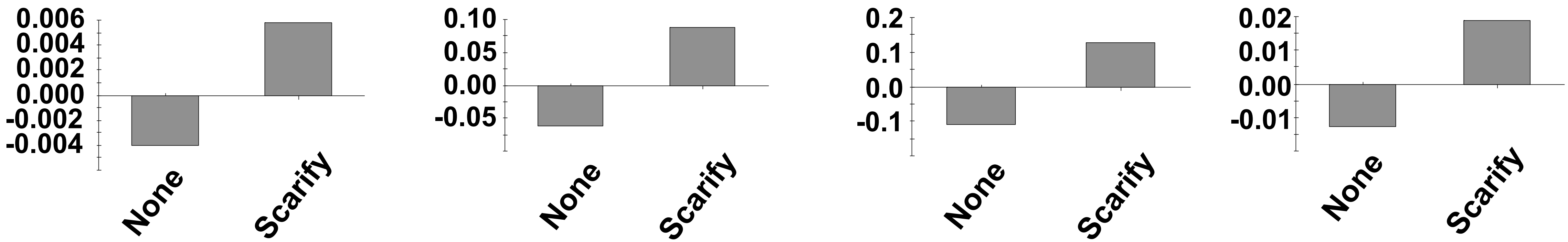
The effect of harvest type on post-harvest regeneration prediction

- Clearcutting resulted in greater predicted stem presence, high basal area and biomass

The effect of site preparation on post-harvest regeneration

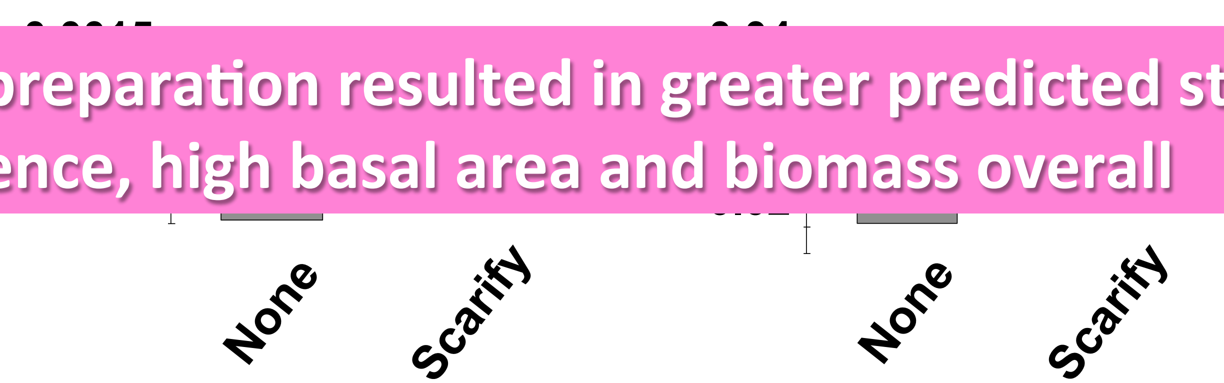
Presence (any size) | *Presence of sapling class* | *Basal area* | *Biomass*

White spruce | **Aggregated**



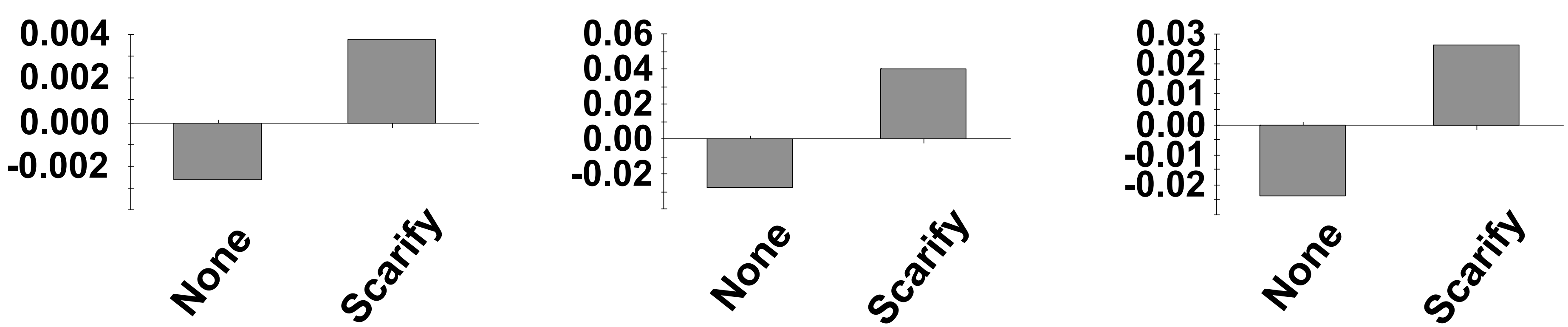
Partial Dependence

Birch



- Site preparation resulted in greater predicted stem presence, high basal area and biomass overall

Aspen



Site preparation in a high white spruce seed crop year can result in OVERSTOCKING

1987 – too dense

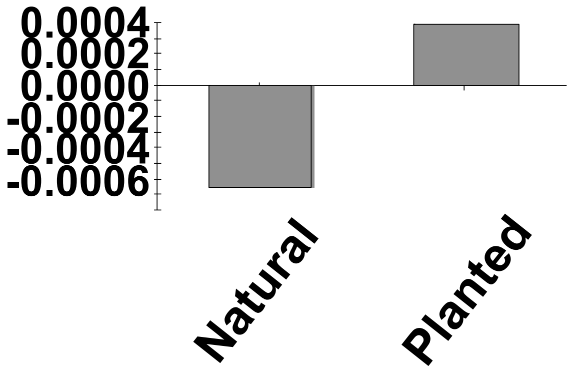
1989 – density OK

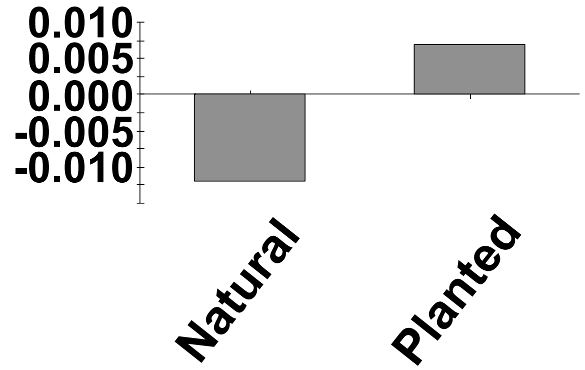
The effect of reforestation method on post-harvest regeneration

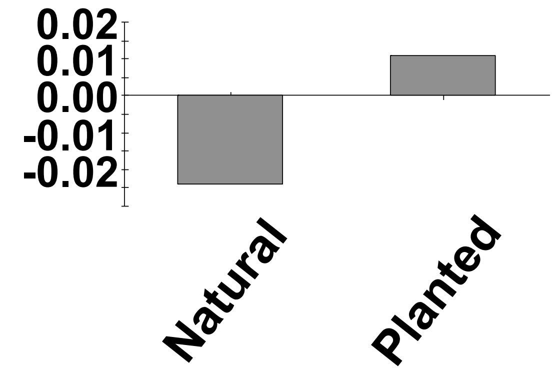
Presence (any size) | *Presence of sapling class* | *Basal area* | *Biomass*

White spruce

Aggregated

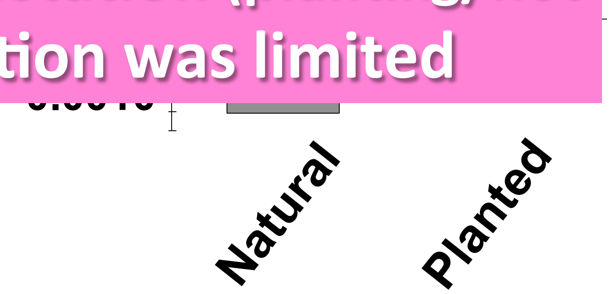






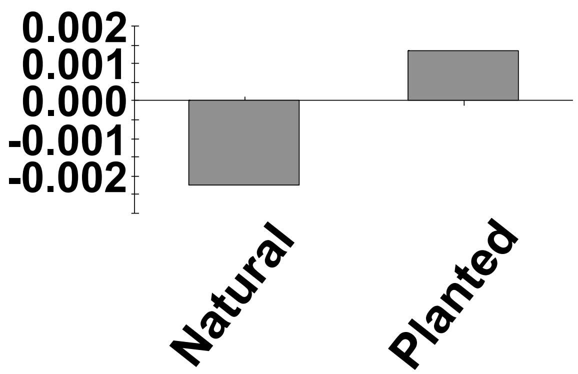
Partial Dependence

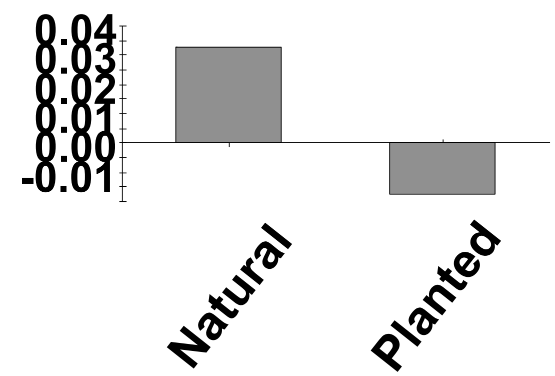
Birch



- Contribution of reforestation (planting/not planting) to the prediction was limited

Aspen

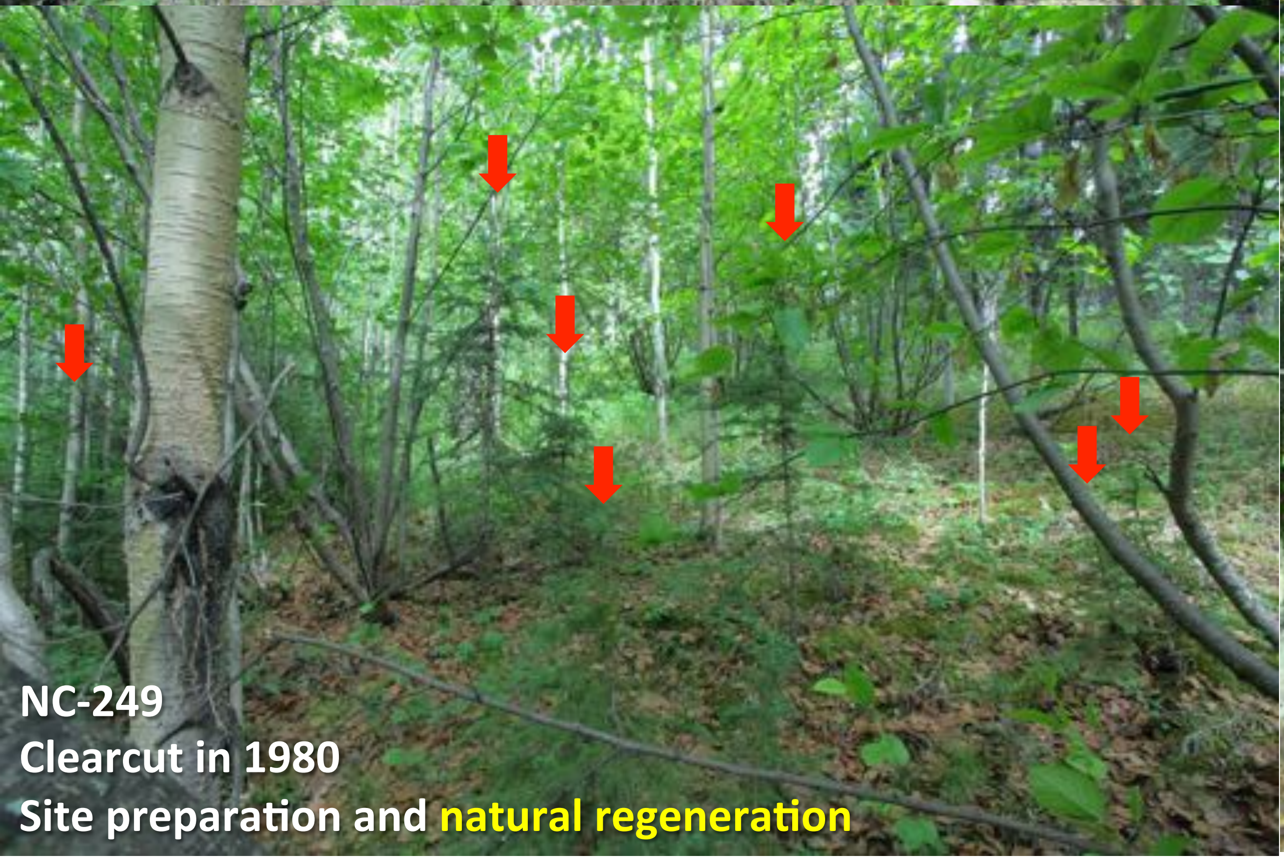




Planted white spruce seedlings are larger and better positioned for early canopy dominance but white spruce natural regeneration is present under hardwood canopy

NC-556
Partial cut in 1987
Site preparation and planting white spruce seedlings

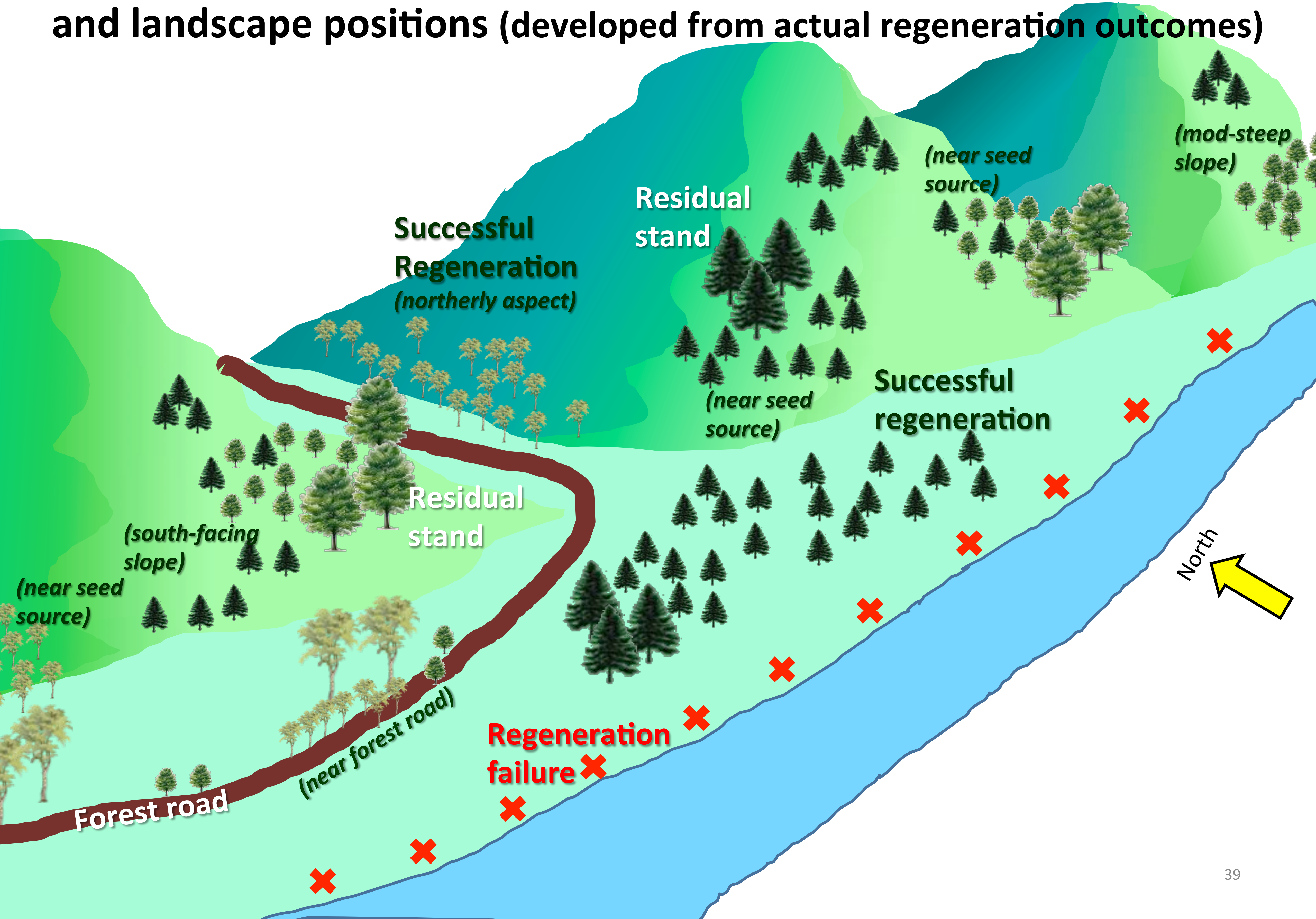
NC-709
Partial cut in 1987
Site preparation and planting white spruce seedlings



NC-249
Clearcut in 1980
Site preparation and natural regeneration

NC-190
Partial cut in 1977
Site preparation and natural regeneration

Conceptual diagram of post-harvest regeneration and landscape positions (developed from actual regeneration outcomes)

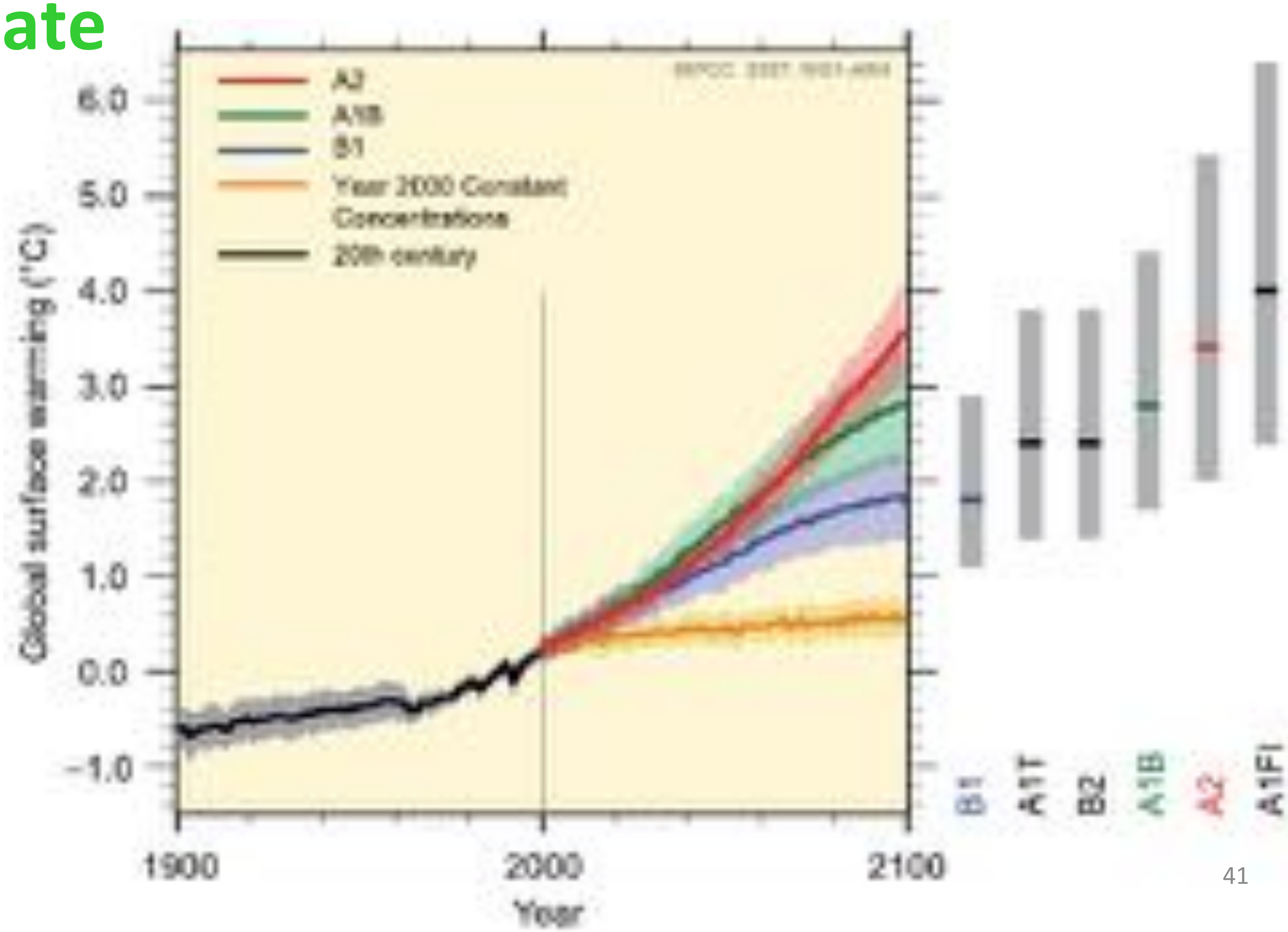


Methods

1. Same method and predictors as Chp 3 were used to build predictive models
   - Only presence/absence was analyzed (no basal area, biomass)
   - Birch and apen predictive models were the same as Chp 3, but for white spruce only natural regeneration was analyzed in Chp 4
2. Build post-harvest **regeneration scenarios** under **historical and warming climate** for **different management practices**
   - Management practices
     - **Harvest type** (**clearcutting** vs. **partial cutting**)
     - **Site preparation** method (**scarify** vs. **none**)
     - **Reforestation technique** (**plant** vs. **natural**)

Methods

- Climate scenarios
  - **B1** (*lowest emissions/warming*)
  - **A1B** (*mid-range*)
  - **A2** (high emissions/strong warming)
  - **Historical climate**



Results: predictive accuracies for basal area and biomass

Correct prediction
Incorrect prediction

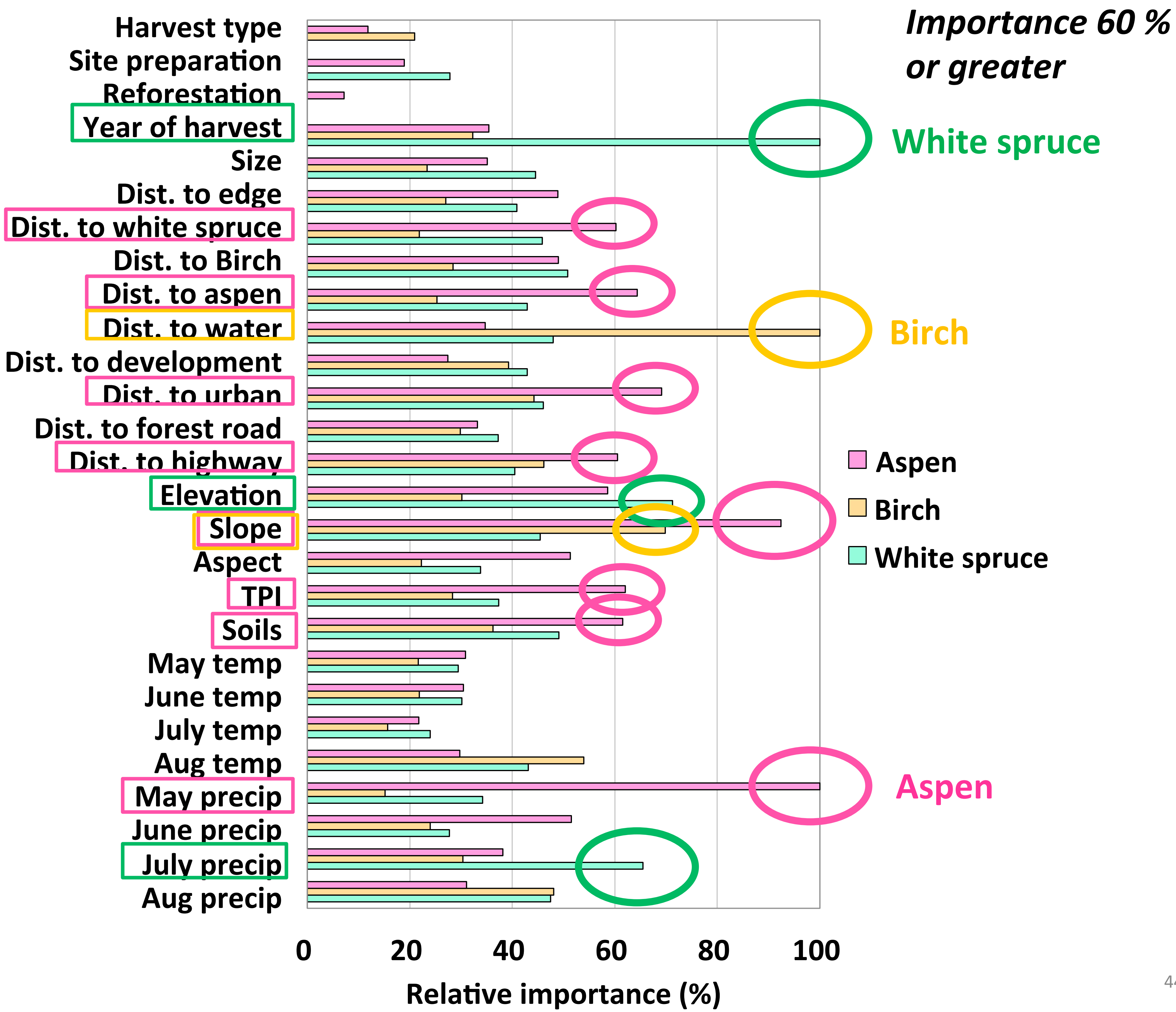
		Predicted low/high		Specificity Sensitivity	Mean accuracy	AUC
Basal area		Low	High			
Aspen	Low	**103**	**6**	94.50%	0.94	0.98
	High	**2**	**32**	94.12%		
Birch	Low	**194**	**30**	86.61%	0.86	0.93
	High	**33**	**201**	85.90%		
White spruce	Low	**190**	**43**	81.55%	0.81	0.88
	High	**45**	**177**	79.73%		
Biomass		Low	High			
Aggregated	Low	**319**	**87**	78.57%	0.78	0.85
	High	**72**	**261**	78.38%		

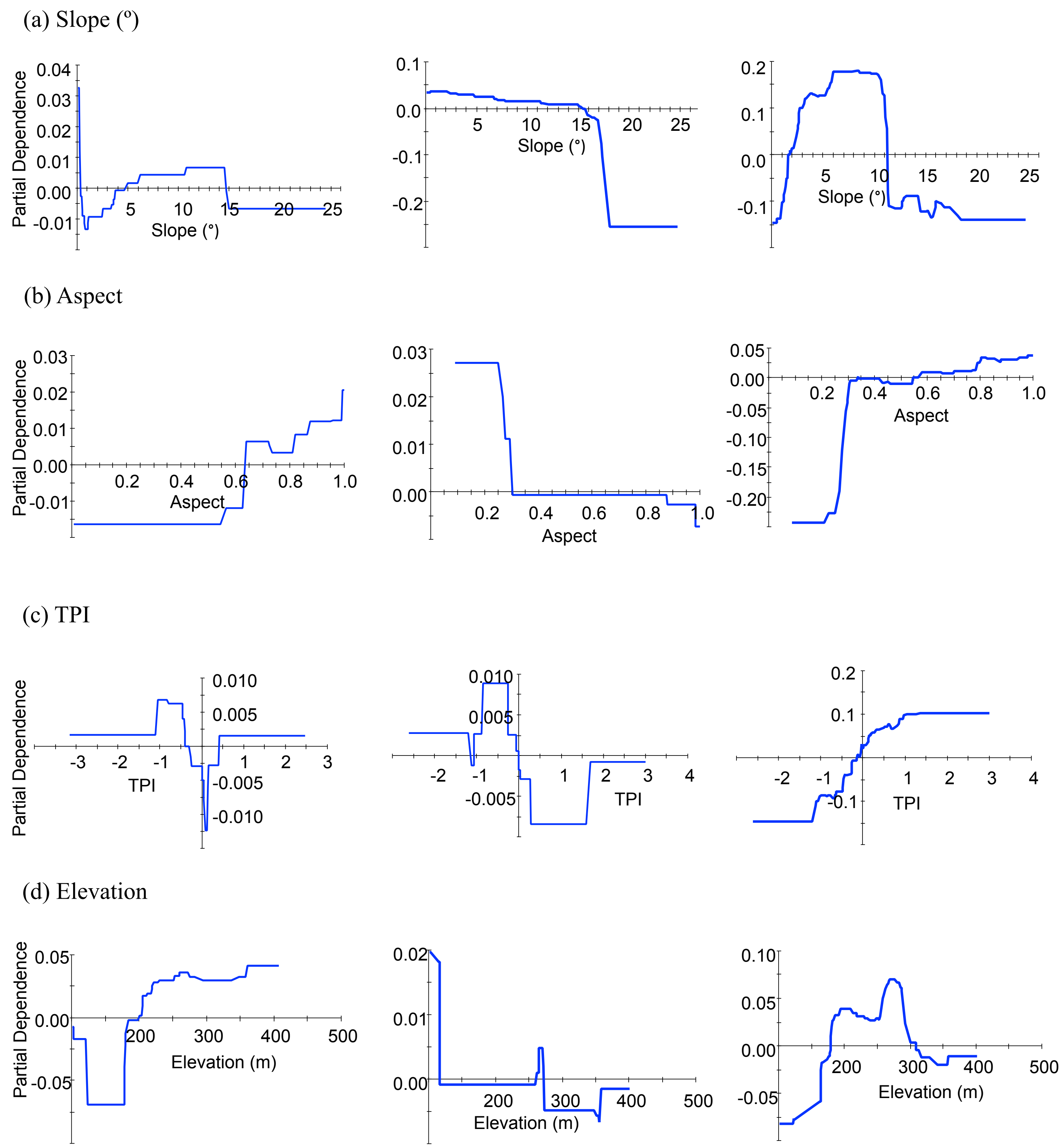
Results: predictive accuracies of presence/absence developed from actual regeneration outcomes

Correct prediction
Incorrect prediction

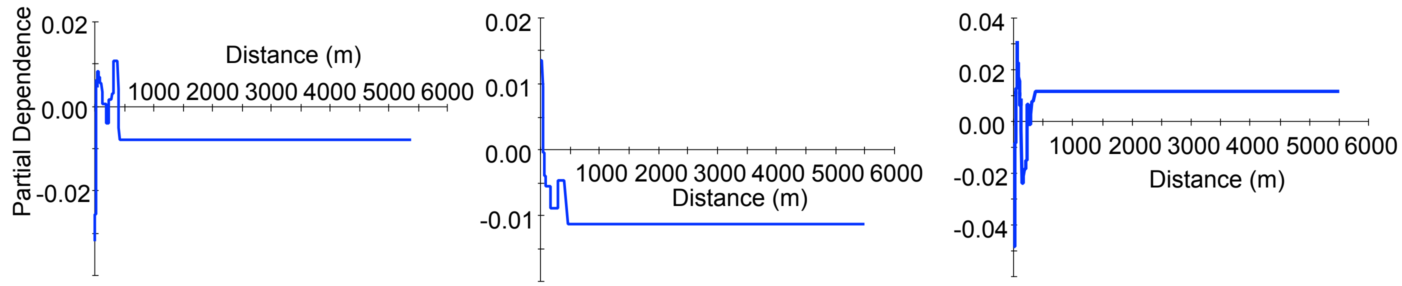
		Predicted presence/absence		Specificity Sensitivity	Mean accuracy	AUC
		Absent	Present			
Aspen	Absent	**491**	**92**	84.22%	0.84	0.92
	Present	**22**	**121**	84.62%		
Birch	Absent	**176**	**91**	65.92%	0.68	0.74
	Present	**138**	**321**	69.93%		
White spruce	Absent	**239**	**93**	71.99%	0.72	0.79
	Present	**108**	**286**	72.59%		

Results: relative importance of predictors to presence

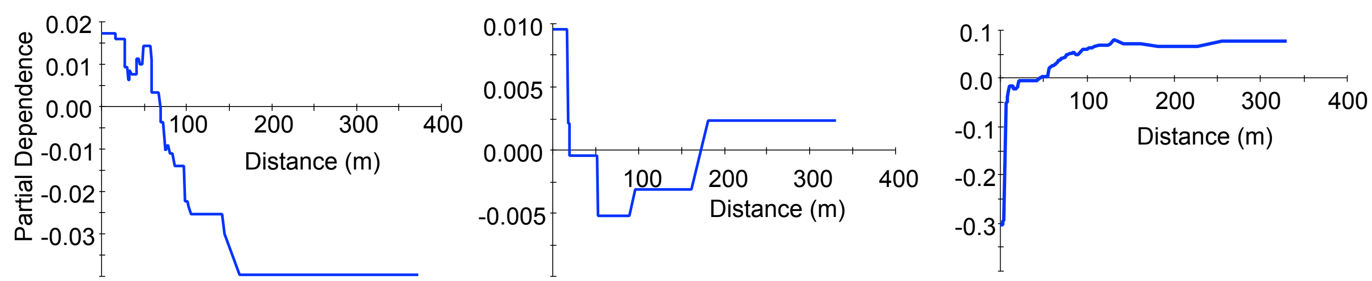



(a) Slope (°)
Partial Dependence
Slope (°)
(b) Aspect
Partial Dependence
Aspect
(c) TPI
Partial Dependence
TPI
(d) Elevation
Partial Dependence
Elevation (m)

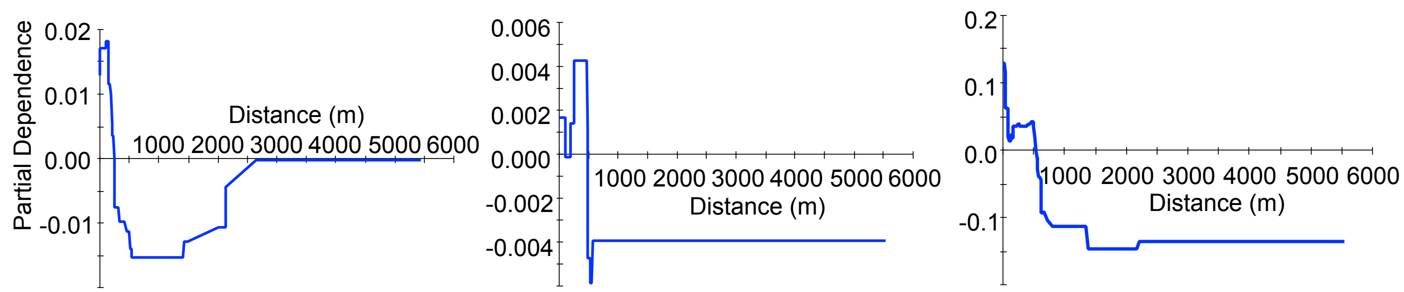
(e) Distance to birch forest



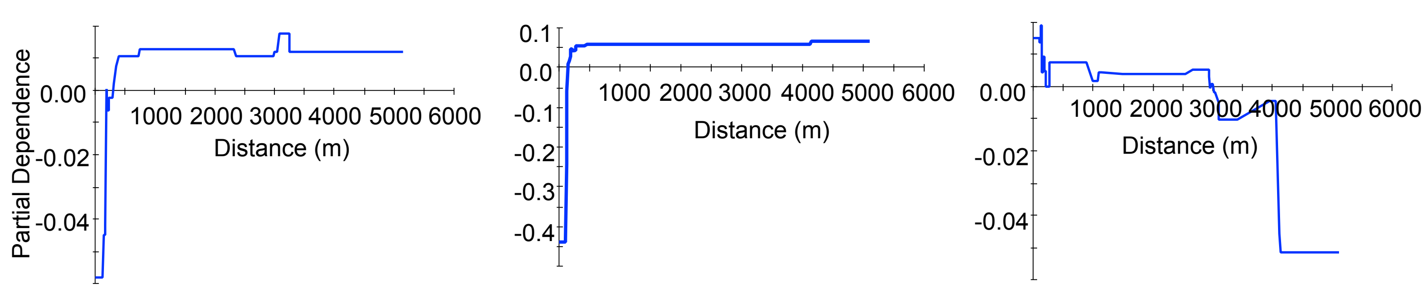
(f) Distance to white spruce forest



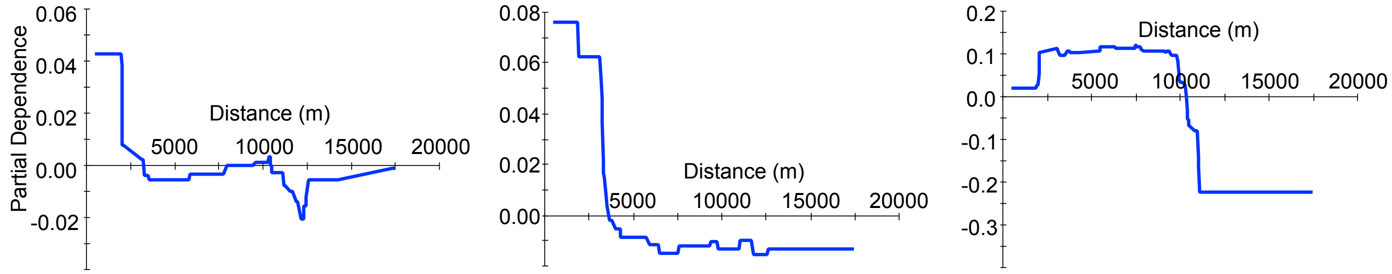
(g) Distance to aspen forest



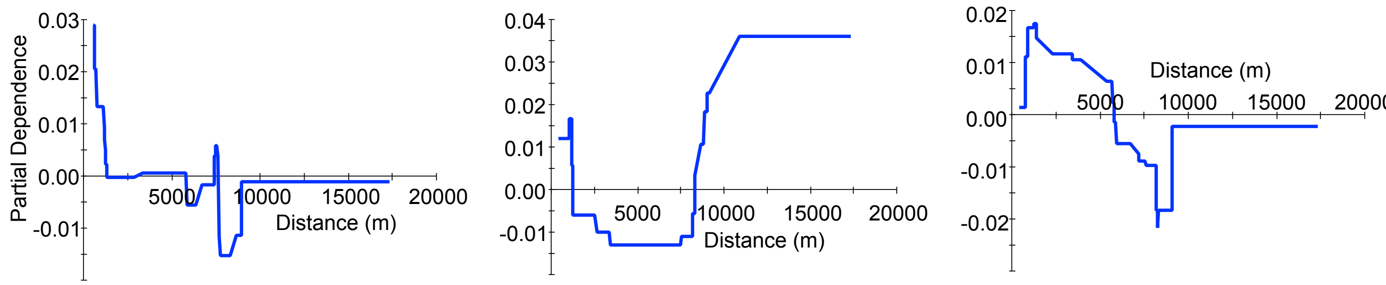
(h) Distance to water



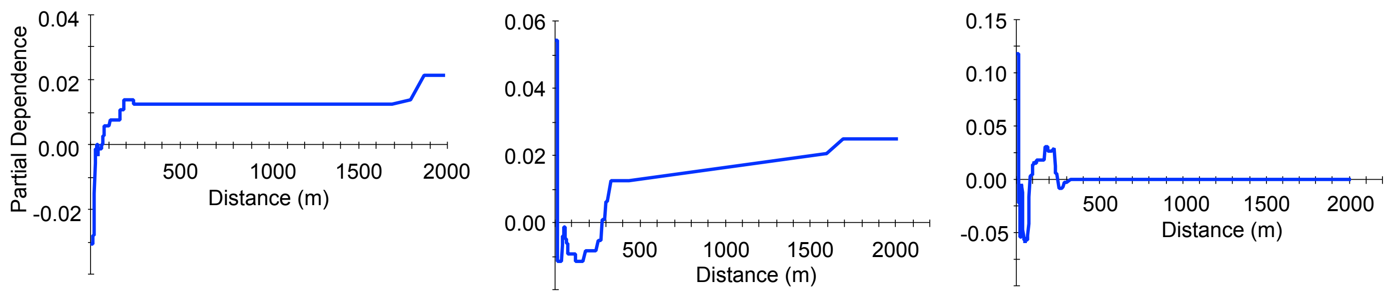
(i) Distance to urban area



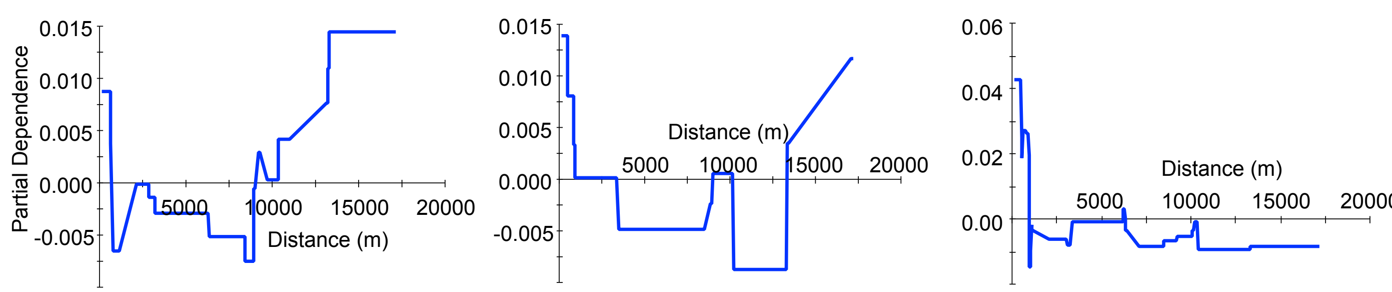
(j) Distance to development



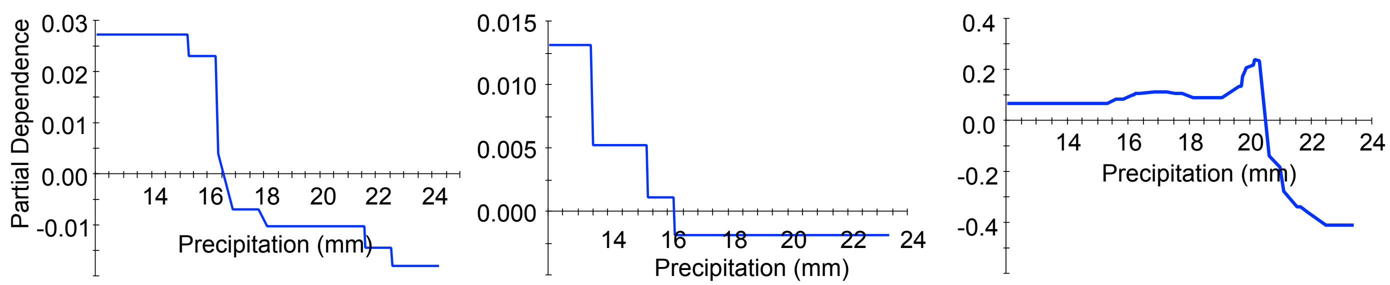
(k) Distance to forest road



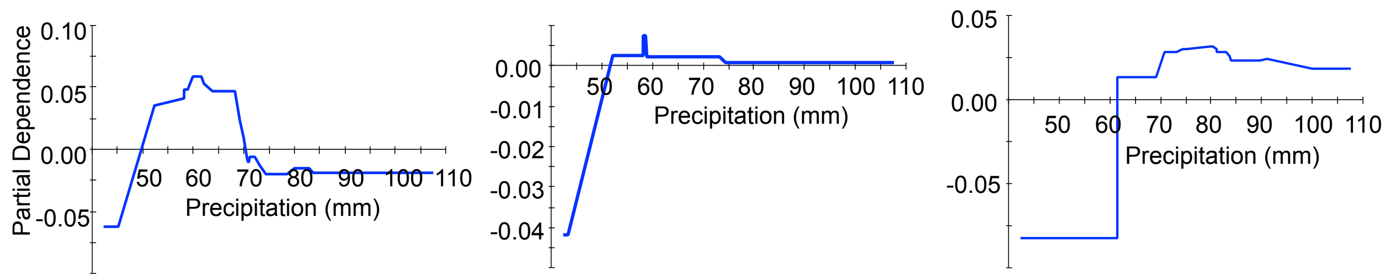
(l) Distance to highway



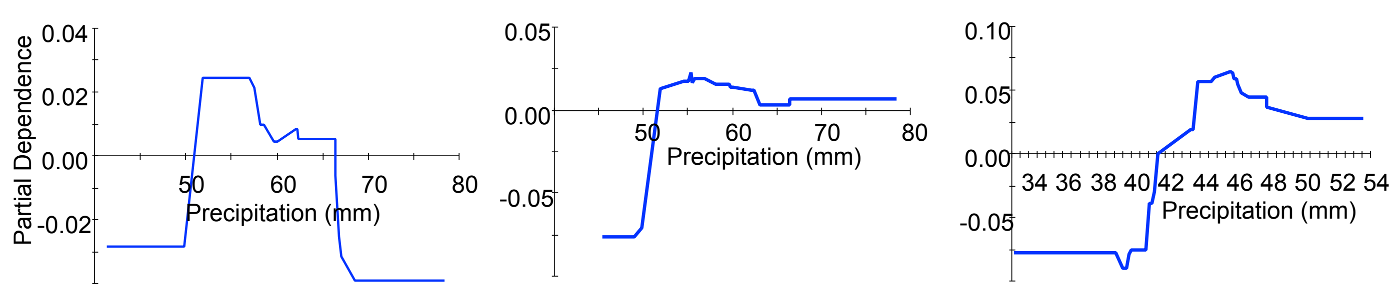
(m) May precipitation



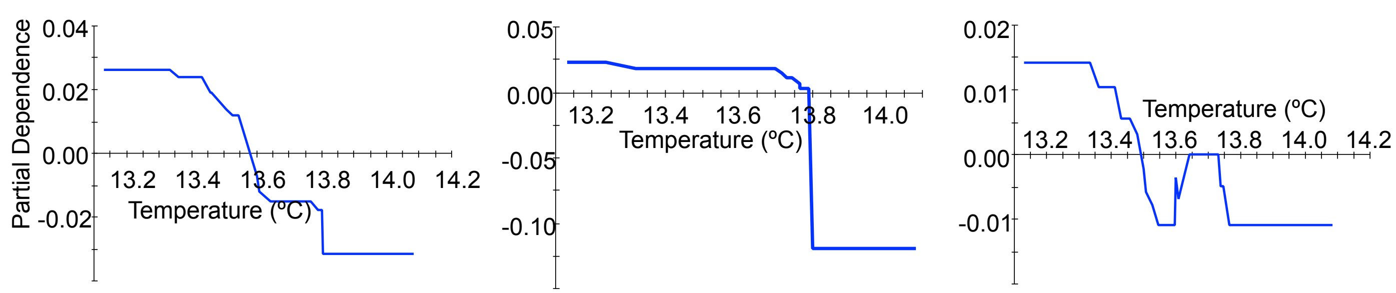
(n) July precipitation



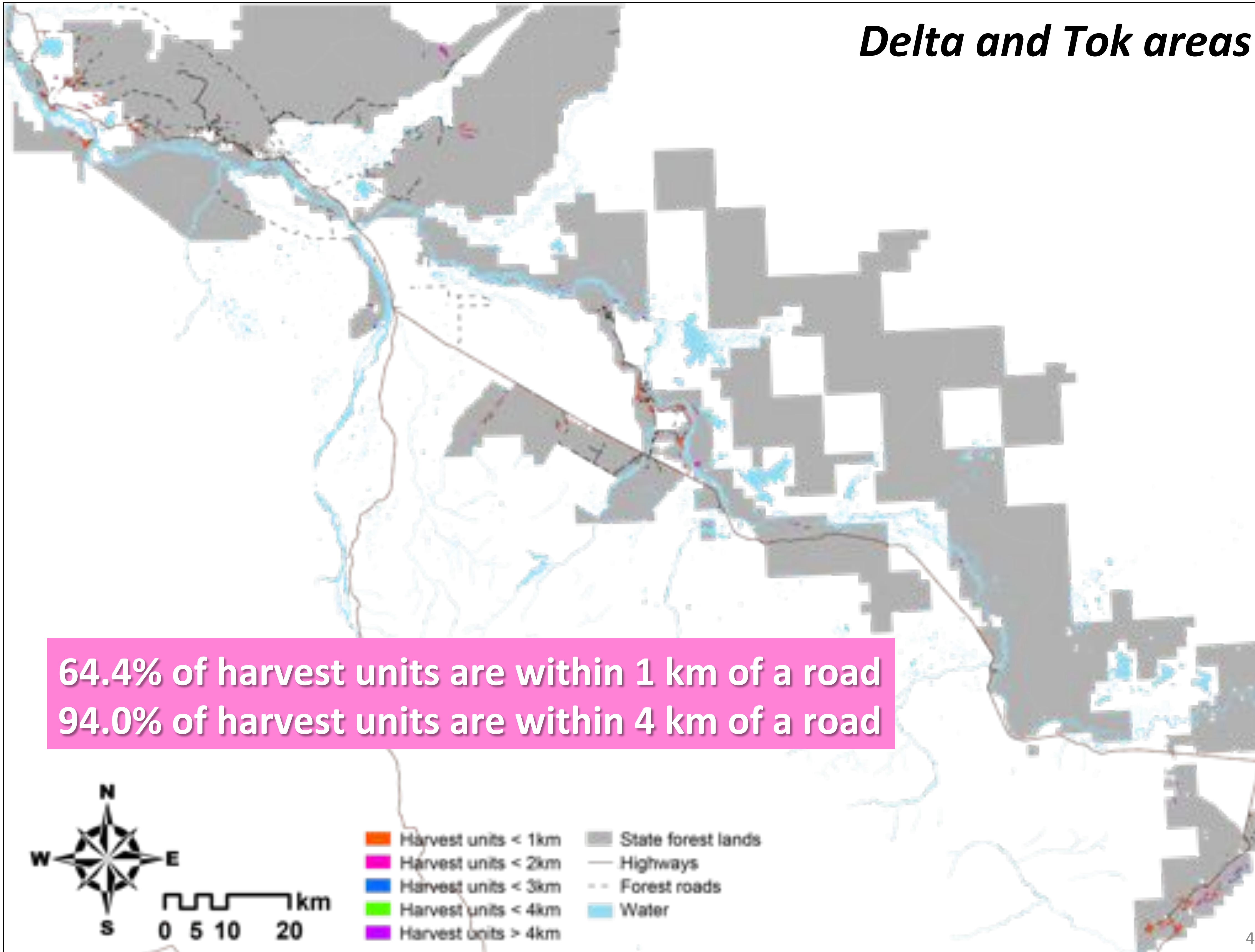
(o) August precipitation | August precipitation | June precipitation



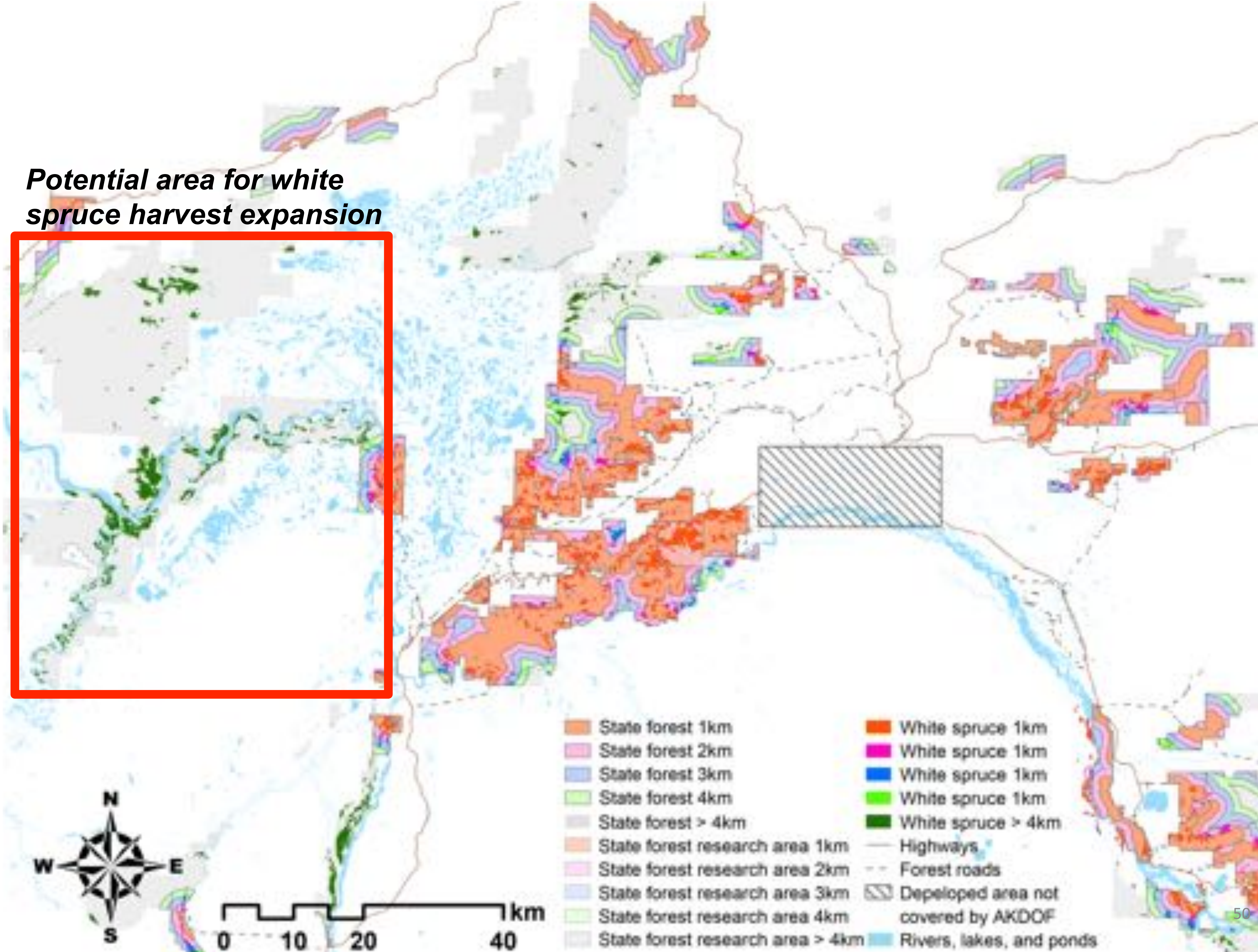
(p) August temperature



Distribution of Historical Harvest Units and Roads

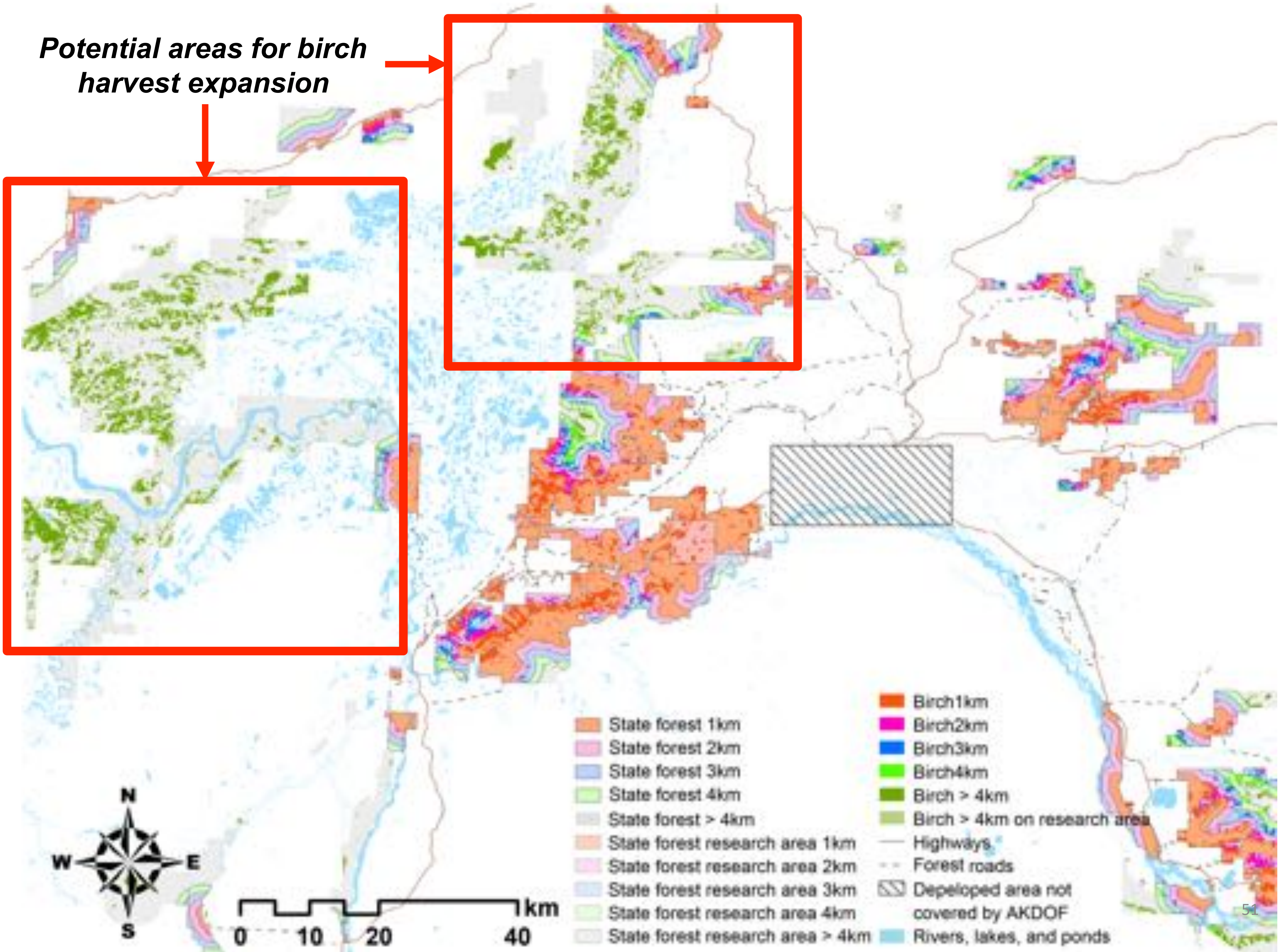


Accessibility of stands of sawlog white spruce on state forest lands

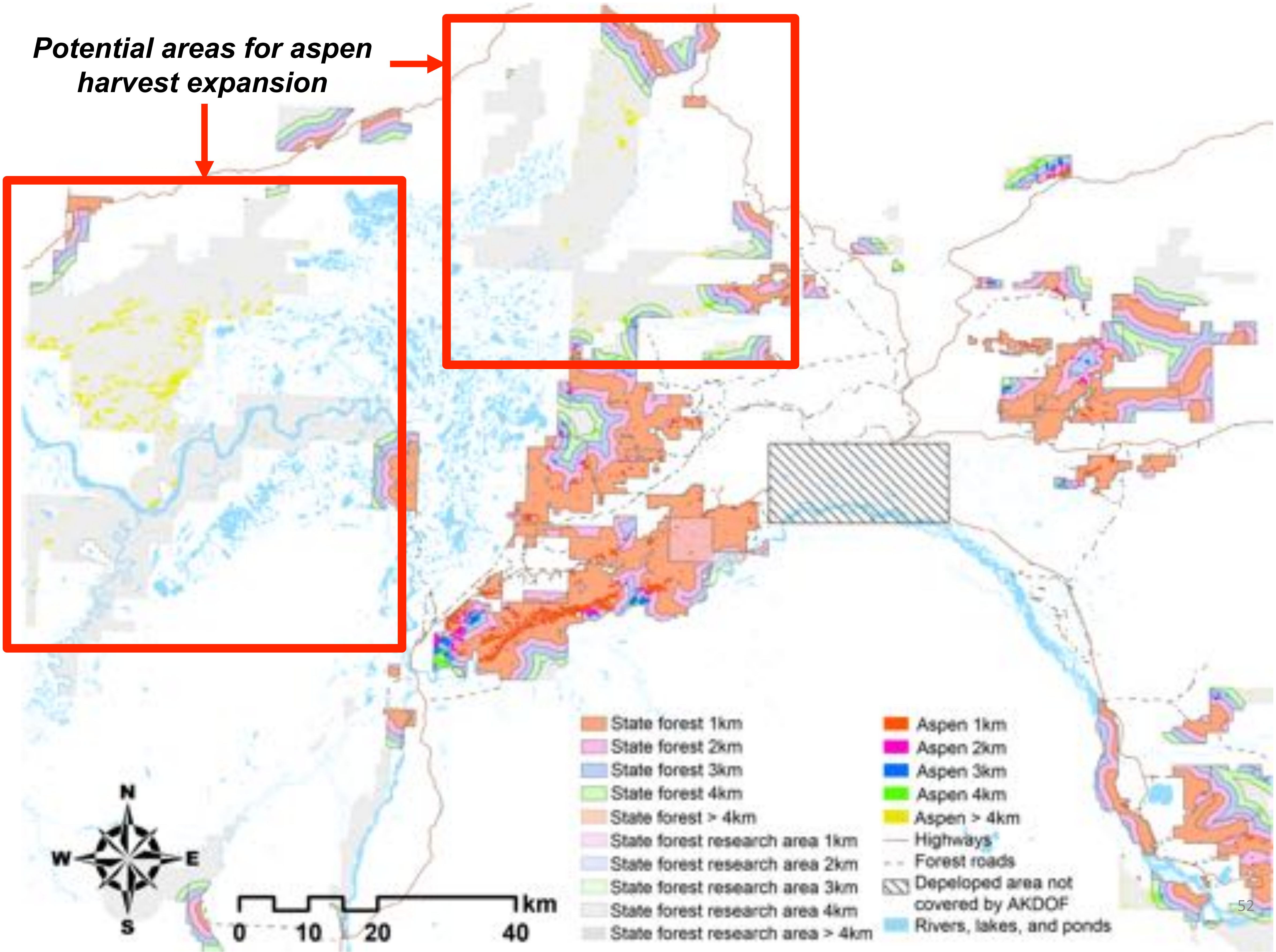


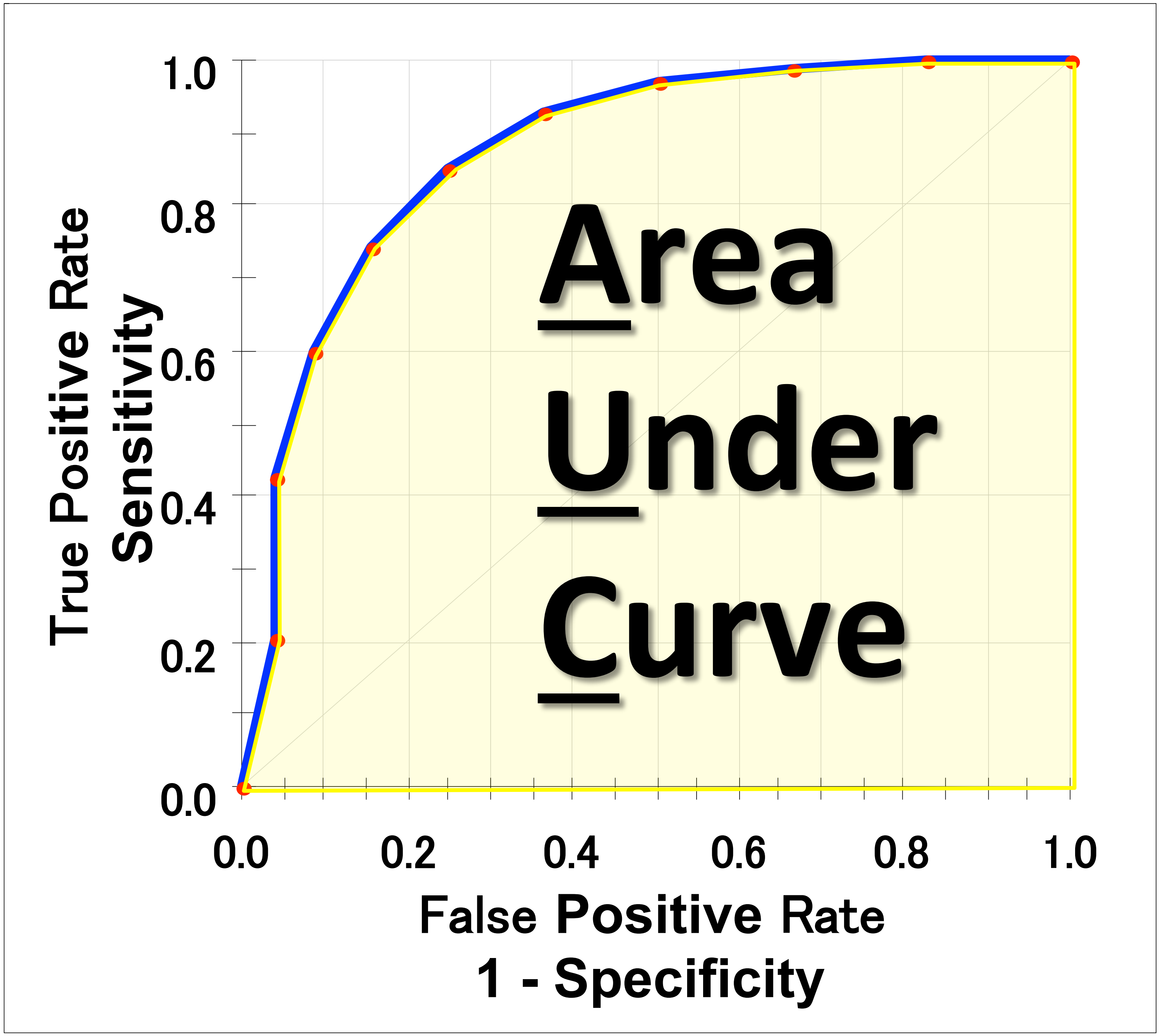
Accessibility of stands of larger birch on state forest lands

Potential areas for birch harvest expansion



Accessibility of stands of larger aspen on state forest lands





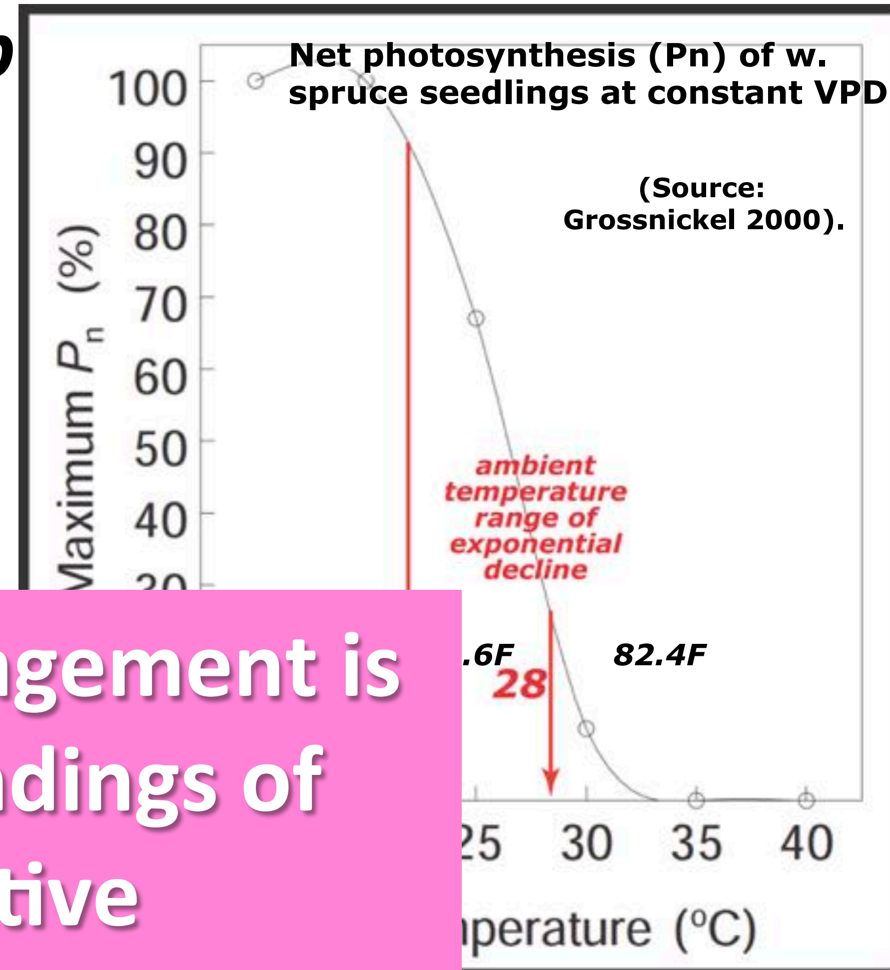
1.0
0.8
0.6
0.4
0.2
0.0
True Positive Rate
Sensitivity
Area
Under
Curve
0.0
0.2
0.4
0.6
0.8
1.0
False Positive Rate
1 - Specificity

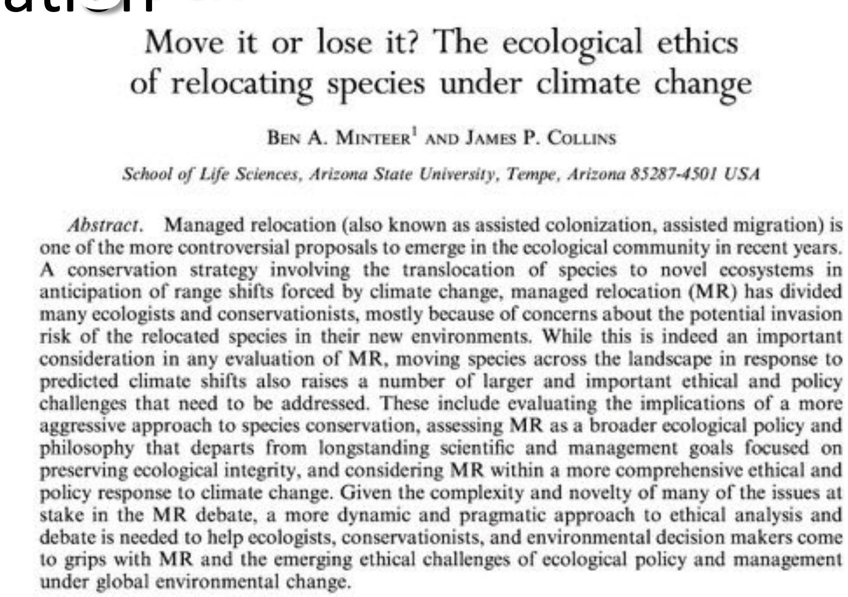
Key Factors in Climate Adaptive Management

Plan for the next step

- Hypothesis: regeneration failure under climate warming (Chp 4)
- Uncertanties: species adaptability, rate of warming, resource availability, fire occurrence and effectiveness of suppression, demand for wood
- Risks: failu assisted m
- Challenge resources, stakeholder issues, desires, collaborati

Implementing adaptive management is not easy but the tools and findings of this research and the cumulative monitoring would help achieve the goal





Move it or lose it? The ecological ethics of relocating species under climate change

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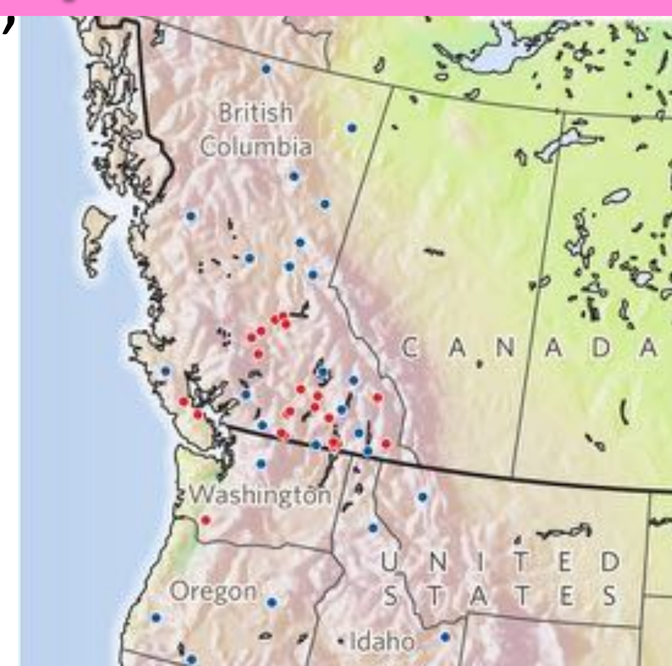
School of Life Sciences, Arizona State University, Tempe, Arizona 85287-4501 USA

Abstract. Managed relocation (also known as assisted colonization, assisted migration) is one of the more controversial proposals to emerge in the ecological community in recent years. A conservation strategy involving the translocation of species to novel ecosystems in anticipation of range shifts forced by climate change, managed relocation (MR) has divided many ecologists and conservationists, mostly because of concerns about the potential invasion risk of the relocated species in their new environments. While this is indeed an important consideration in any evaluation of MR, moving species across the landscape in response to predicted climate shifts also raises a number of larger and important ethical and policy challenges that need to be addressed. These include evaluating the implications of a more aggressive approach to species conservation, assessing MR as a broader ecological policy and philosophy that departs from longstanding scientific and management goals focused on preserving ecological integrity, and considering MR within a more comprehensive ethical and policy response to climate change. Given the complexity and novelty of many of the issues at stake in the MR debate, a more dynamic and pragmatic approach to ethical analysis and debate is needed to help ecologists, conservationists, and environmental decision makers come to grips with MR and the emerging ethical challenges of ecological policy and management under global environmental change.

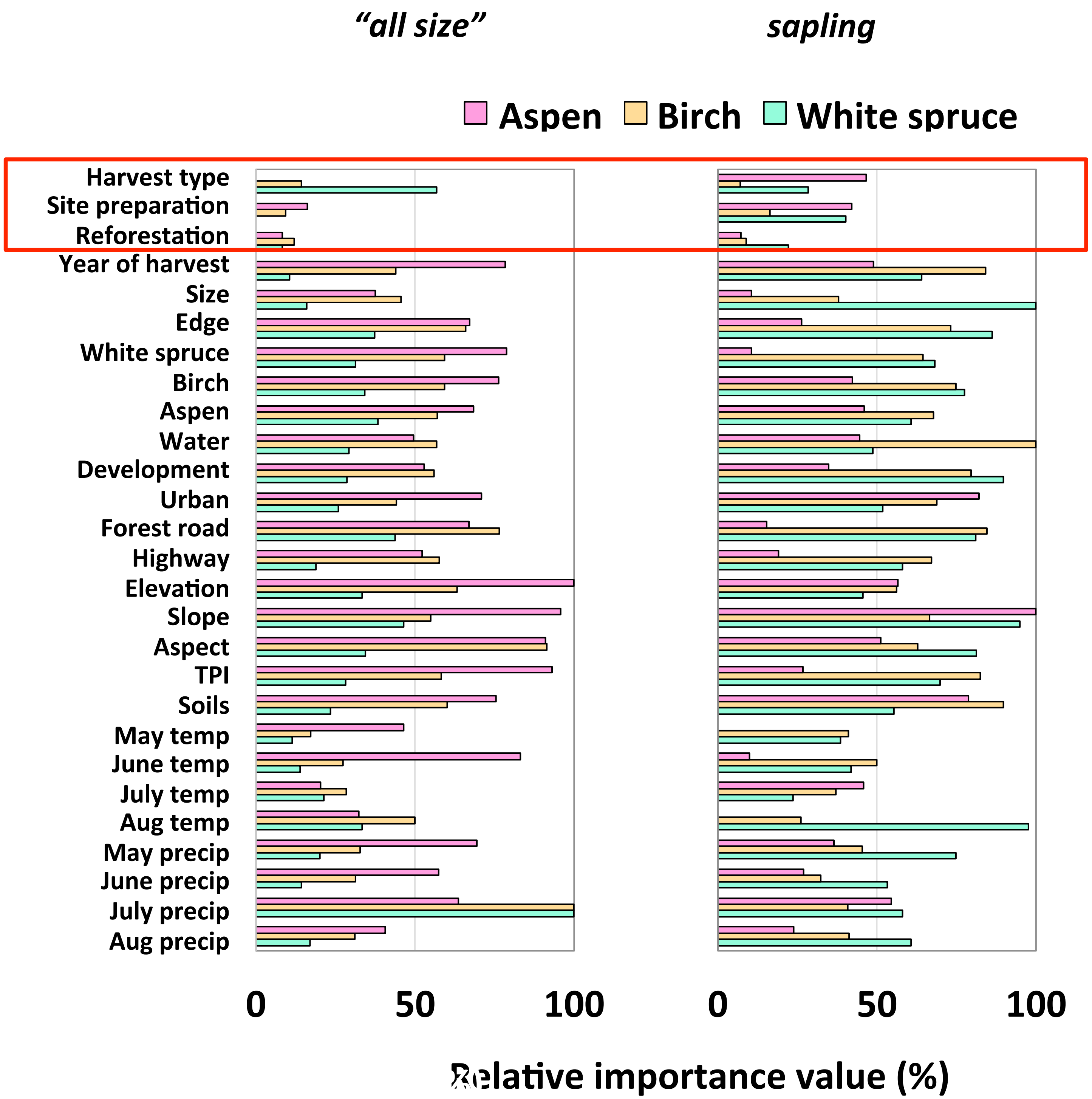


Source: *Nature* "Forestry: Planting the forest of the future" (Marris 2009)

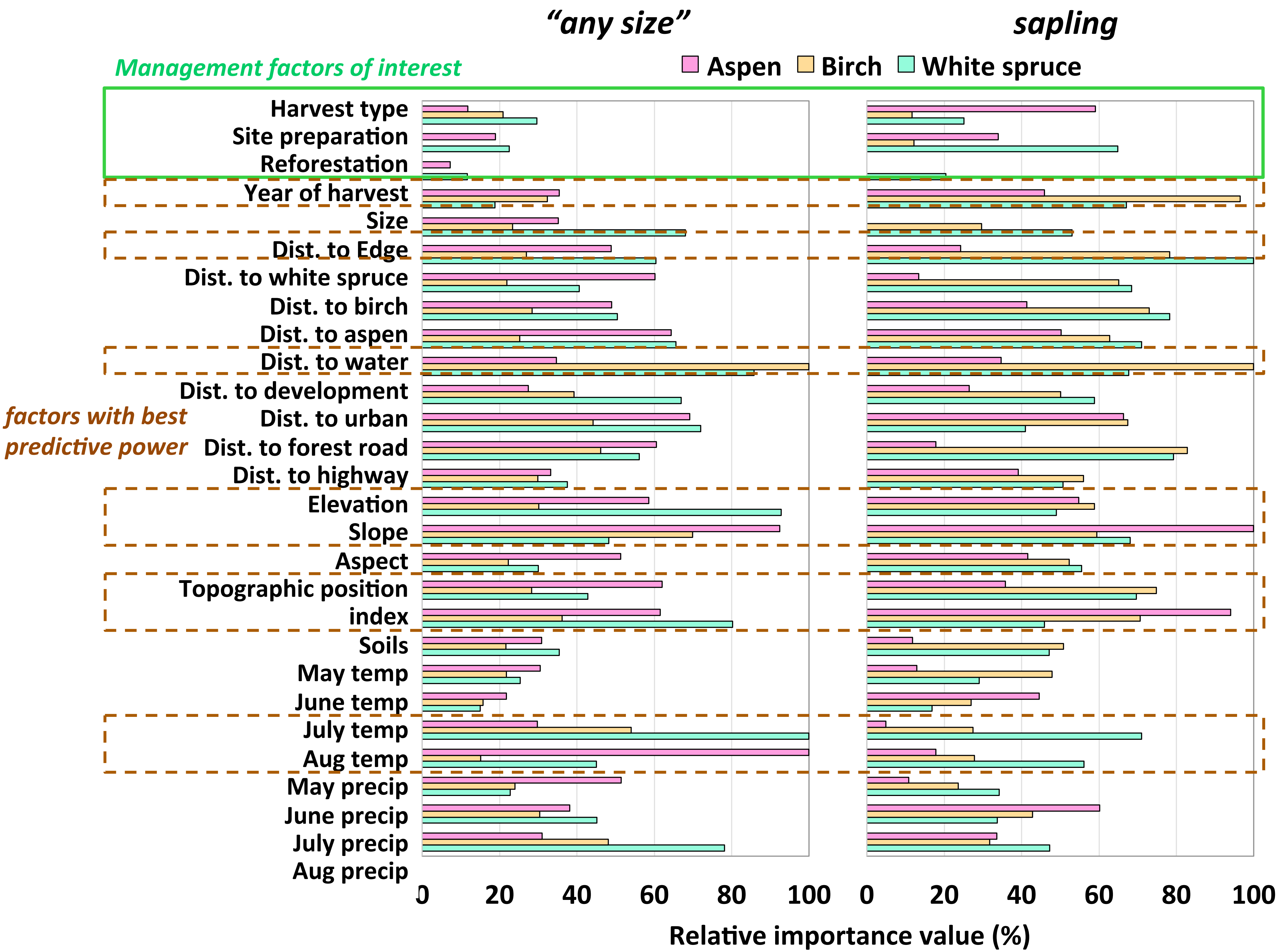
Results: Predictive Accuracies of Dominance

		Dominance group predicted		Specificity Sensitivity	Mean accuracy	AUC
<u>**"All size" group**</u>		Low	High			
Aspen	Low	**580**	**79**	88.01%	0.88	0.95
	High	**9**	**58**	86.57%		
Birch	Low	**296**	**84**	77.89%	0.78	0.85
	High	**78**	**268**	77.46%		
White spruce	Low	**377**	**115**	76.63%	0.76	0.83
	High	**58**	**176**	75.21%		
<u>**Sapling**</u>		Low	High			
Aspen	Low	**656**	**44**	93.71%	0.94	0.97
	High	**2**	**24**	92.31%		
Birch	Low	**423**	**83**	83.60%	0.84	0.90
	High	**36**	**184**	83.64%		
White spruce	Low	**472**	**111**	80.96%	0.81	0.88
	High	**27**	**116**	81.12%		

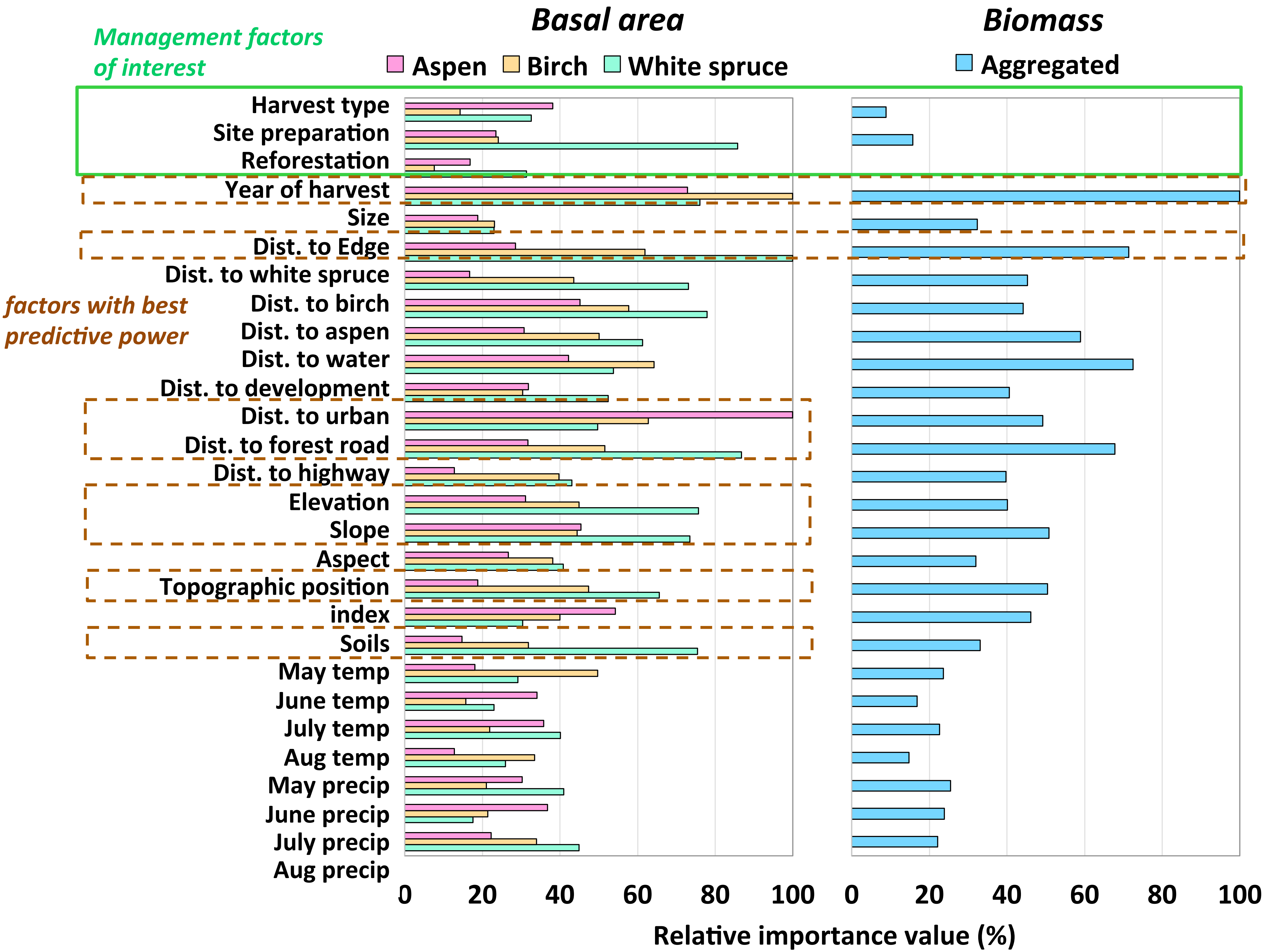
Results: Relative Importance of Predictors for Dominance



Results: relative importance of predictors to presence



Results: relative importance of predictors



Wildfire and Harvest: Landscape-Level Biodiversity

- Landscape-scale diversity contribute substantially to sustaining habitats for a full range of species
- Wildfire creates landscape mosaic with various size and shape of disturbed patches
- Fire occurrence and severity are largely controlled by vegetation type
- Forest harvest is generally small in size and concentrated near road and in white spruce


http://www.trunity.net/


Boundary and Wolf Creek wildland fire (2003)
0.3 million ha
Dale A. Haggstrom


http://beforeitsnews.com/


https://mastereia.wordpress.com


http://www.newtonsapple.org.uk/


https://www.robertharding.com

Wildfire and Harvest: Stand-Level Biodiversity

Fire produces coarse woody debris for carbon balance, nutrient retention, wildlife species

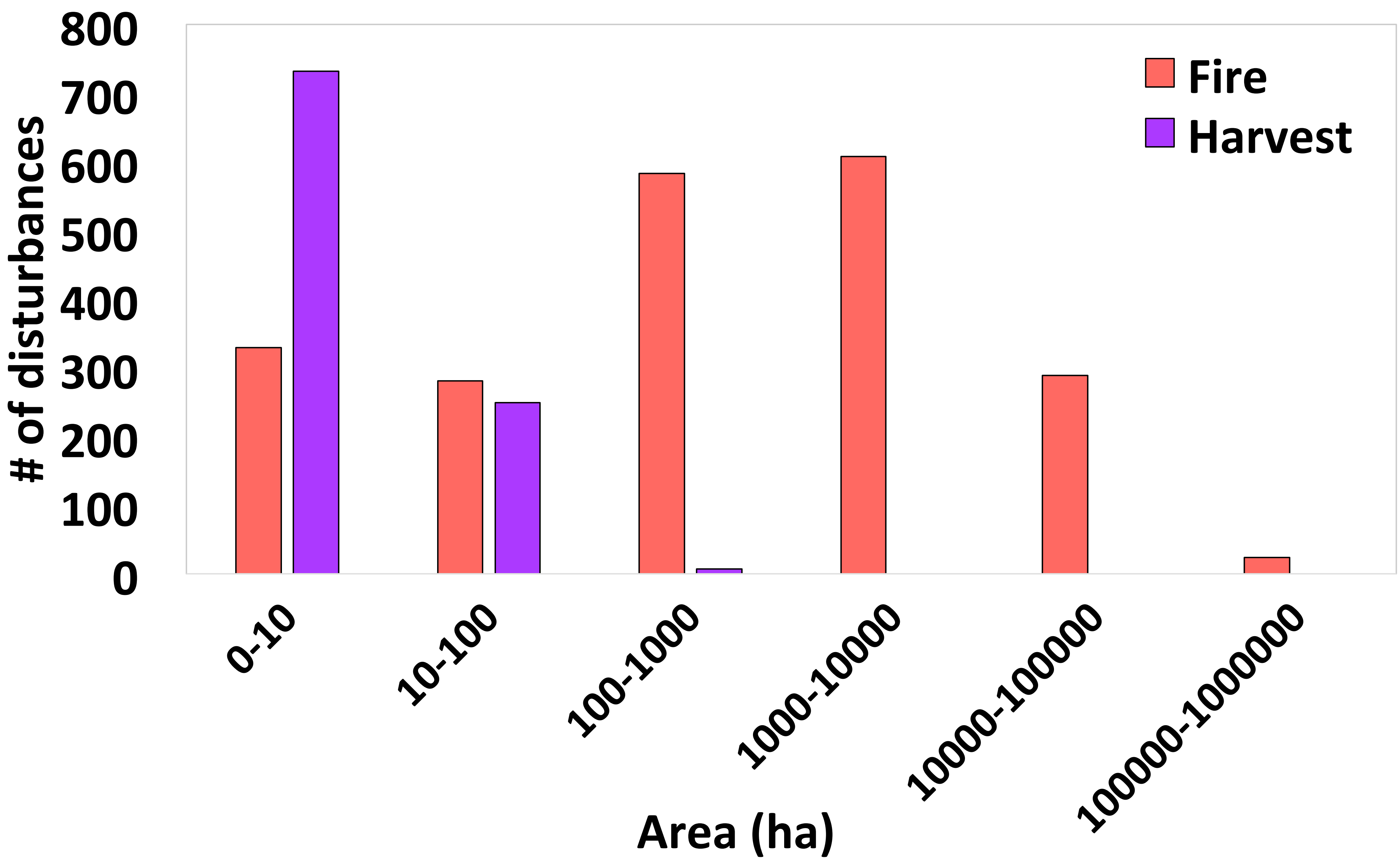
Harvest *traditionally* removes coarse woody debris

Comparison of fire and harvest disturbance
(size of continuous area harvested versus fire perimeter (1969-2012))

DIFFERENCE

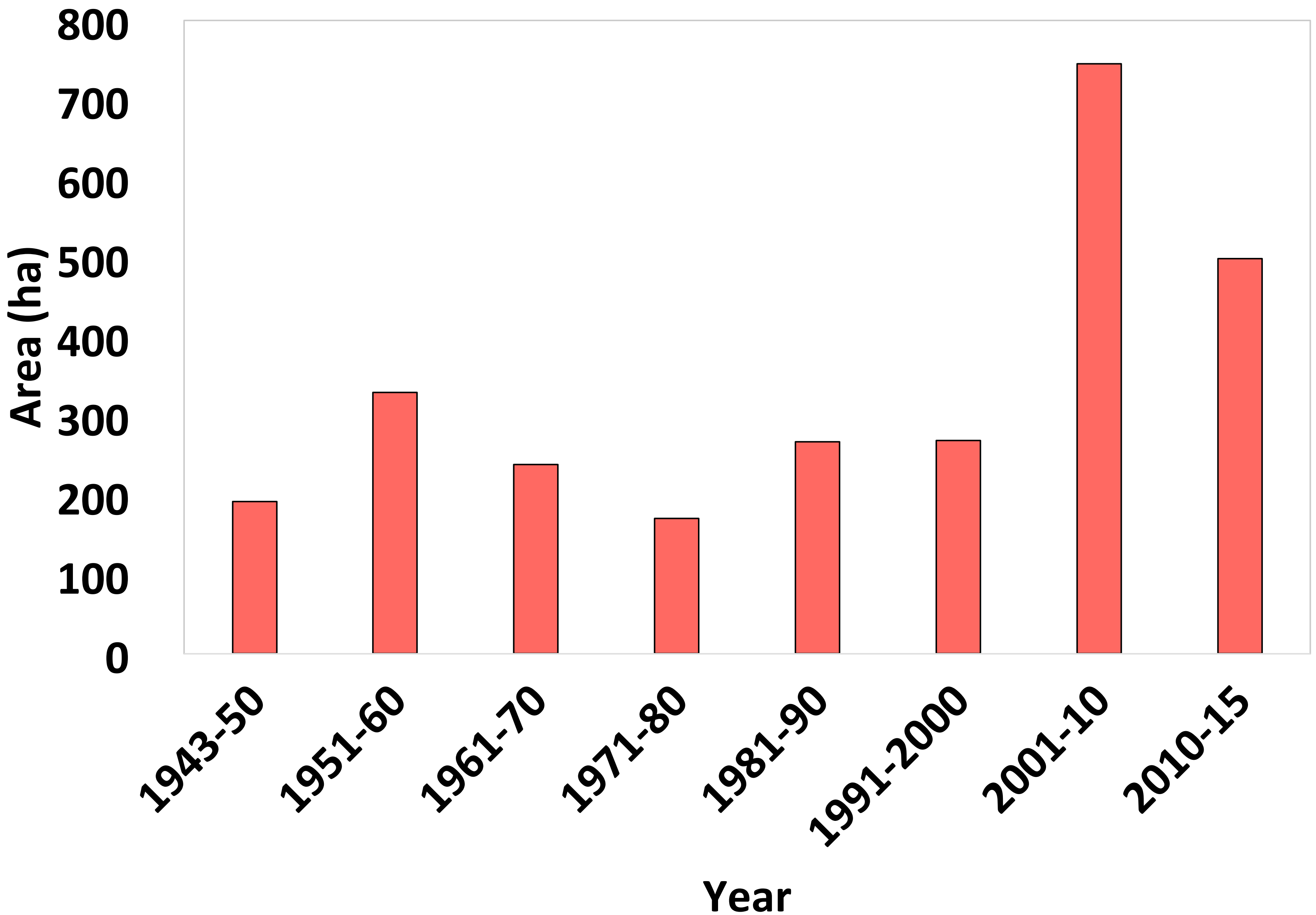
Harvests (to date) are only small.

Fires are small to very large

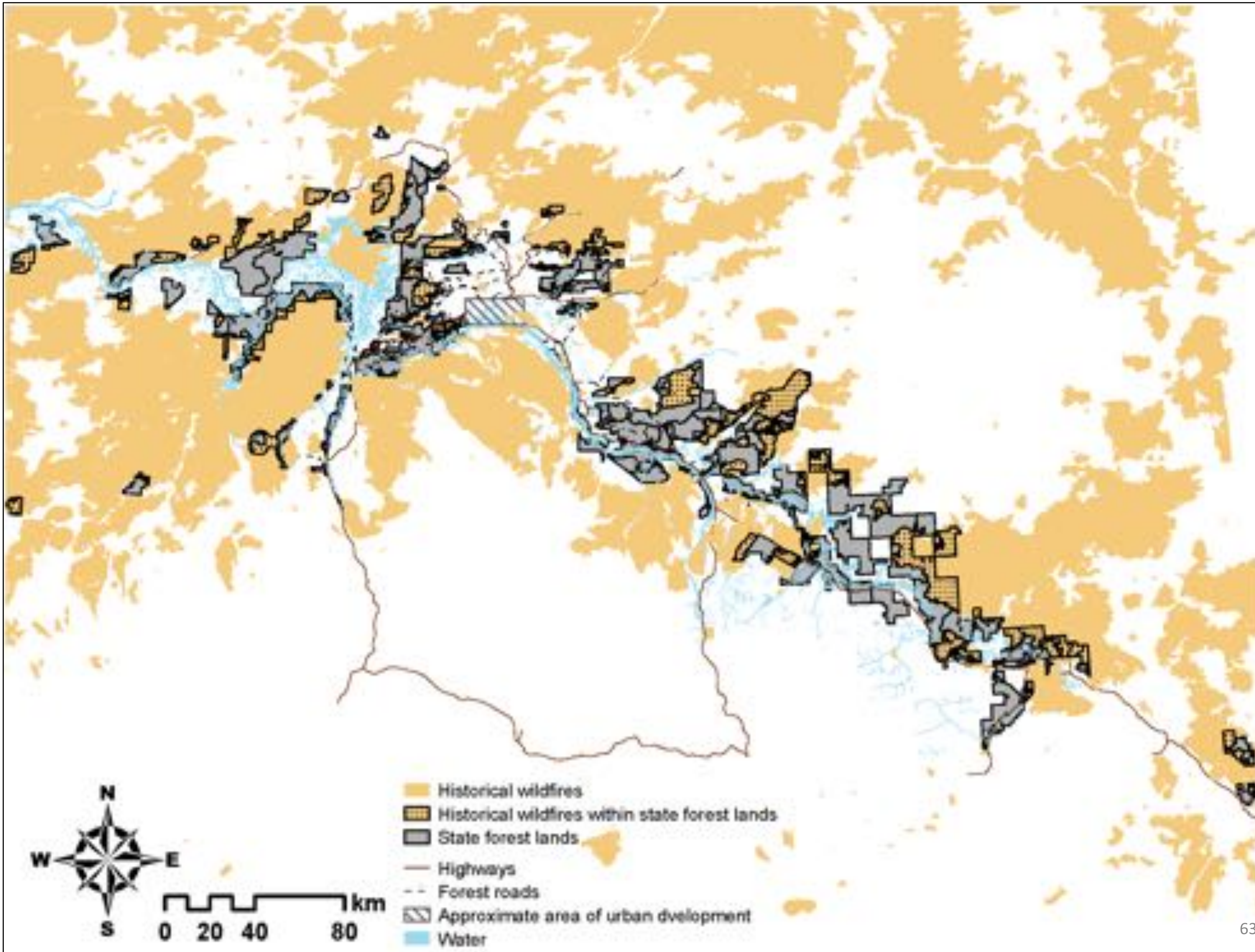


Average annual area burned by decade (1000 ha)

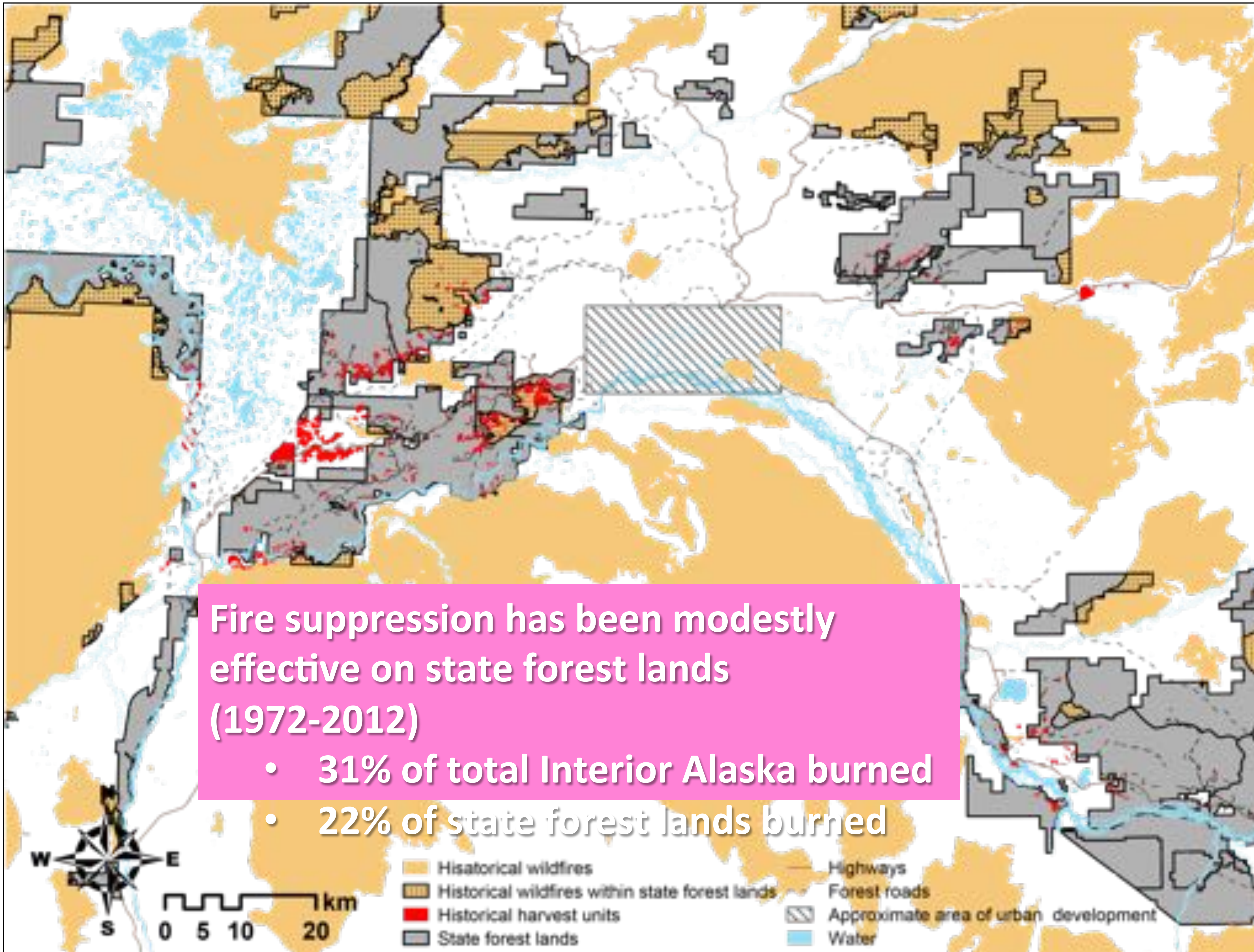
Fire is increasing



Historical wildfires around state forest lands

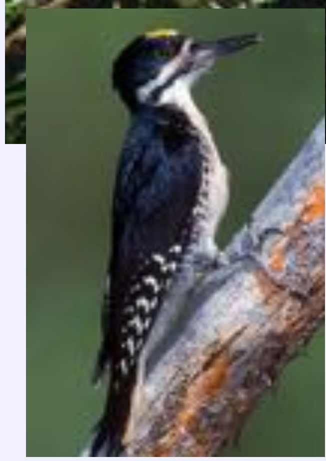


Historical wildfires within and outside of state forest lands



Fire suppression has been modestly effective on state forest lands (1972-2012)

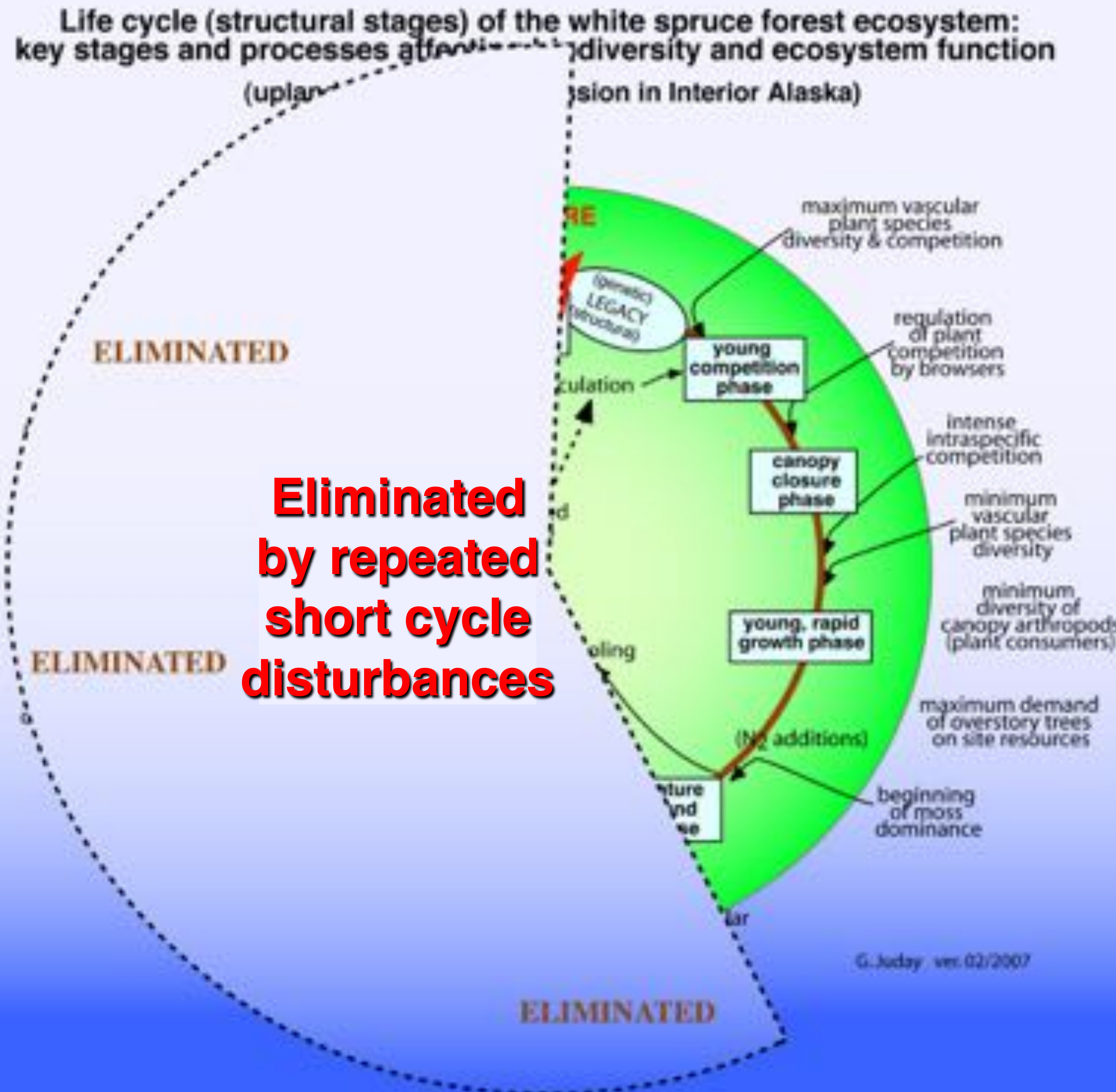
- **31% of total Interior Alaska burned**
- **22% of state forest lands burned**


l stages) of the white spruce forest ecosystem:
ses affecting biodiversity and ecosystem function
secondary succession in Interior Alaska)
insects
snow
wind
FIRE
(genetic) LEGACY (structural)
stand replacement phase
young competition phase
canopy closure phase
young, rapid growth phase
mature stand phase
old-growth forest phase
maximum vascular plant species diversity & competition
regulation of plant competition by browsers
intense intraspecific competition
minimum vascular plant species diversity
minimum diversity of canopy arthropods (plant consumers)
maximum demand of overstory trees on site resources
(N_2 additions)
beginning of moss dominance
development of new, specialized vascular plant component
soil cooling
accumulation of humus
inoculation
slow element release
wood-rotting fungi
log-associated insects
production of large logs
production of small-medium snags
spore dispersal of mycorrhyzial fungi
mycophagy
insectivory
insectivorous bird nesting habitat
maximum influence of large logs on forest floor
production of tree cavities by primary excavators
wood-rotting fungi on snags
(N_2 additions)
arboreal lichen development
habitat for flying squirrel
G.Juday ver. 02/2007




False truffles



Life cycle (structural stages) of the white spruce forest ecosystem:
key stages and processes
diversity and ecosystem function
Interior Alaska)
ELIMINATED
ELIMINATED
ELIMINATED
Eliminated by repeated short cycle disturbances
maximum vascular plant species diversity & competition
LEGACY
young competition phase
regulation of plant competition by browsers
canopy closure phase
intense intraspecific competition
minimum vascular plant species diversity
young, rapid growth phase
minimum diversity of canopy arthropods (plant consumers)
maximum demand of overstory trees on site resources
(No additions)
beginning of moss dominance
G. Juday ver. 02/2007