Resilience, Triggers, Feedbacks and Thresholds: A Western Juniper Model

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Overview

- Definition of terms
- Models of juniper-related ecological succession
- Proposed model for western juniper dominated ecosystems
- Case study in southeastern Oregon
- Implications to juniper management

Ecological Resilience

Ecological resilience describes the degree of ecosystem modification that is required before the system begins to reorganize around an alternative set of reinforcing processes (Briske 2006)

The magnitude of disturbance or stress that can be absorbed before the system redefines its structure by changing the variables and processes that control function (Gunderson 2000)

Feedback Mechanism

Feedbacks are described as those ecological processes that “reinforce or degrade ecosystem resilience and function” (Bestelmeyer et al. 2003).

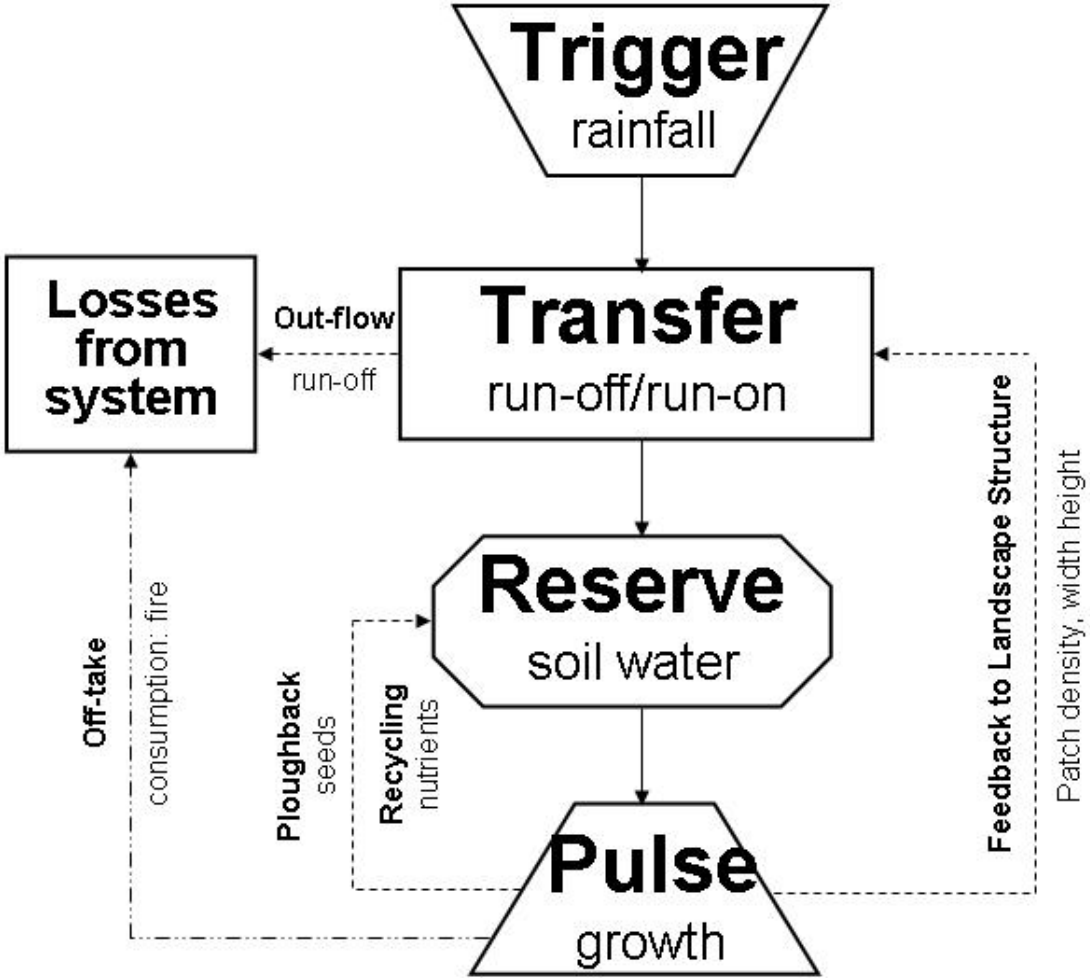
Negative feedbacks maintain ecosystem stability by reinforcing resilience after disturbance whereas positive feedbacks reduce resilience and shift a system toward alternative states (Walker and Meyers 2004).

Triggers

- Changes in biotic and abiotic variables that initiate ecological threshold development (Briske 2006)
  - Continuous vs. discontinuous
  - Chronic or acute

- Triggers can lead to a shift from negative to positive feedback mechanisms

Ludwig, J., D. Tongway, D. Freudenberger, J. Noble, and K Hodgkinson. 1997. Landscape Ecology: Function and Management. Principles from Australia's Rangelands. CSIRO, Australia. Pp. 158.

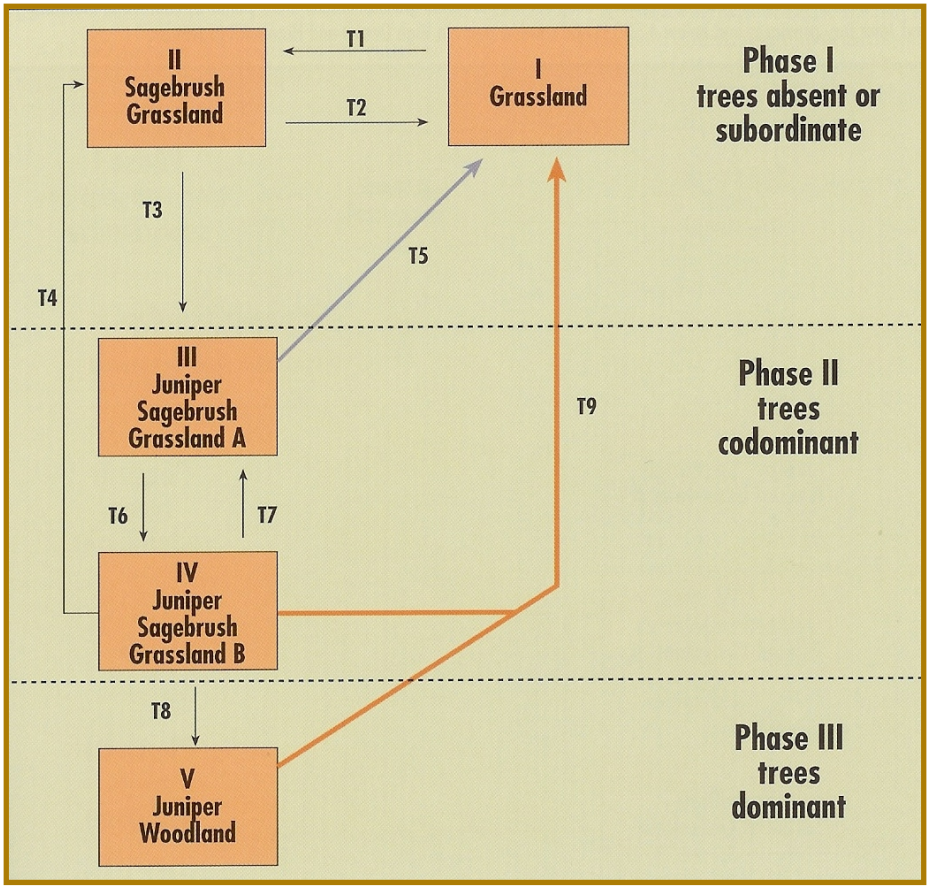


Ecological Thresholds

"Thresholds are boundaries in space and time between any and all states, such that one or more of the primary ecological processes has been irreversibly changed and must be actively restored before return to the previous state is possible." (Stringham et al. 2003)

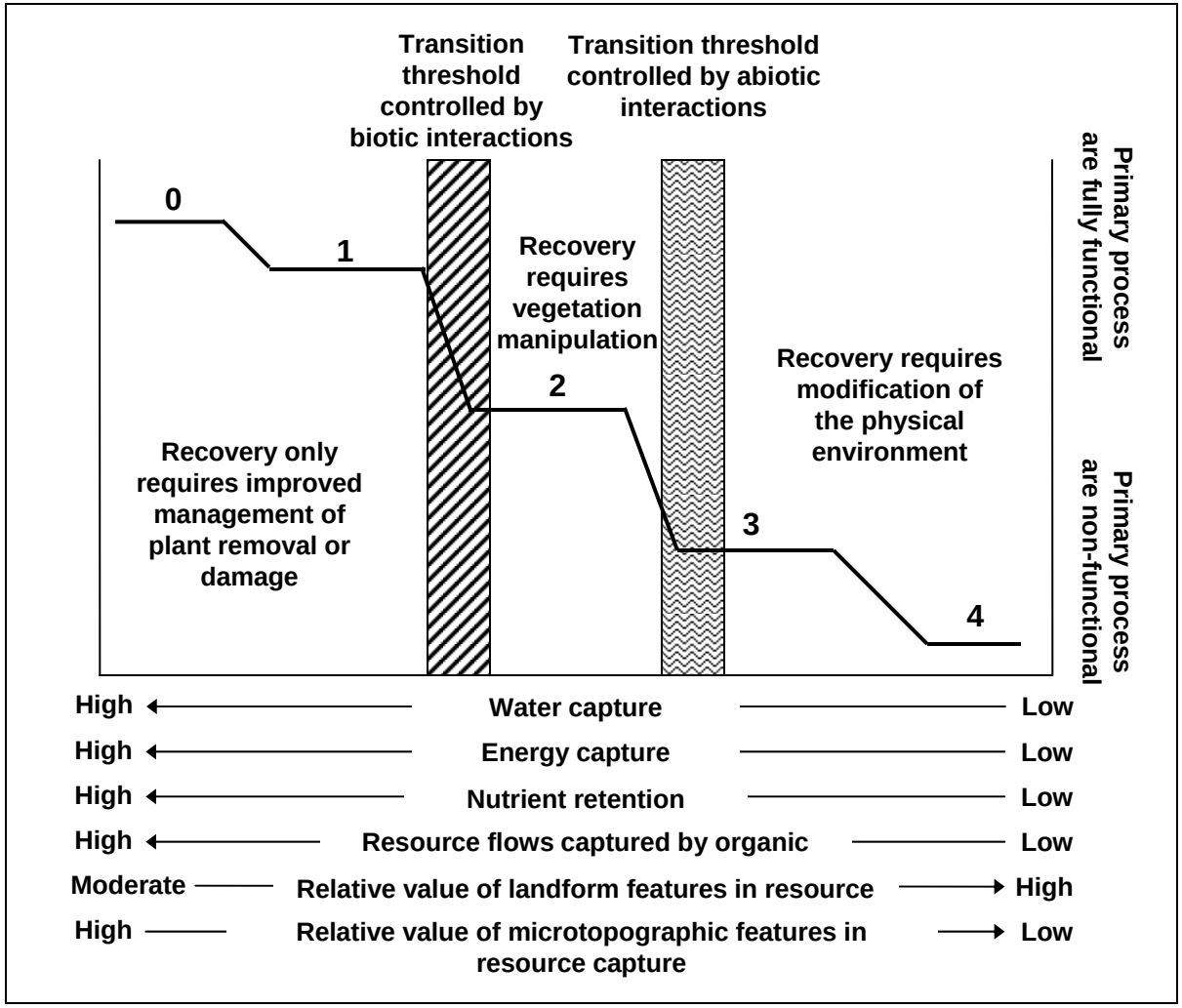
Miller et al. Model

- T1 – lack of fire
- T3 – lack of fire
- T5 – fire
- T8 – conversion to woodland
- T9 – cutting or cutting plus fire

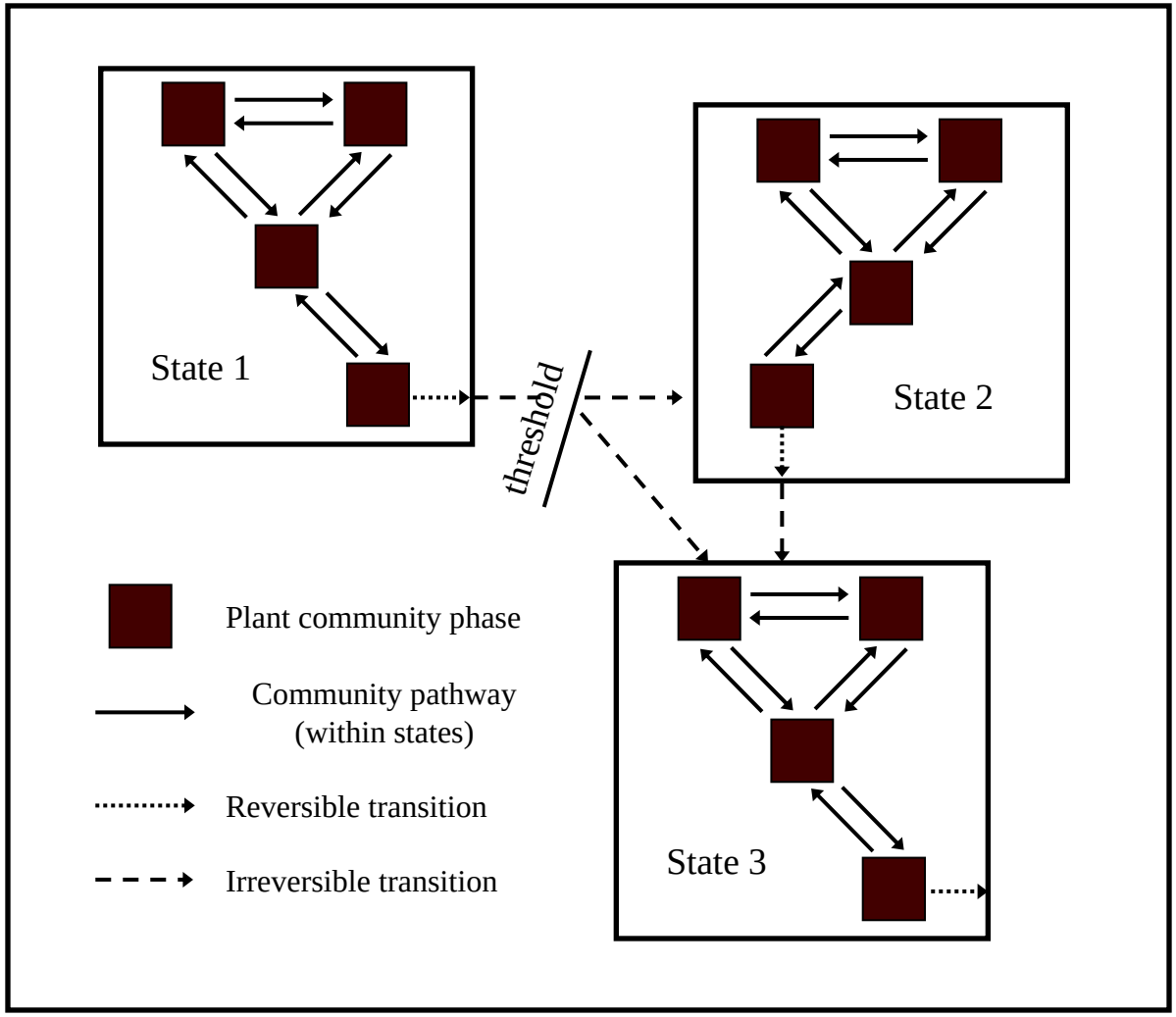


Miller, et al. 2005. Biology, Ecology, and Management of Western Juniper. Technical Bulletin 152. Ag. Ex. Station, Oregon State University, Corvallis, OR.

Whisenant, S.G. 1999. Repairing Damaged Wildlands: biological conservation, restoration, and sustainability. Cambridge University Press, Cambridge, UK.



Stringham, T.K., W.C. Krueger, and P.L. Shaver. 2003. State-and-transition modeling: an ecological process approach. Journal of Range Management 56:106-113.

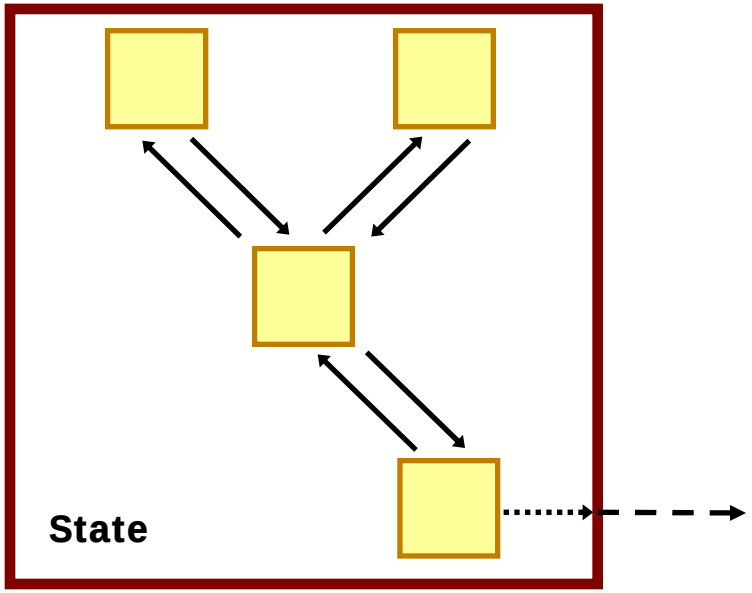


States, Transitions and Thresholds

State – climate-soil-vegetation domain that encompasses wide variation in species composition. States exhibit resiliency and resistance to regular disturbance regimes. Soil and plant components are connected through the interaction of functional ecological processes.

Phase – different plant communities that exist within a state

Community Pathway – mechanism (succession, fire, grazing, drought) that results in community change



Transition – Vector of system change leading to a new state without removing the stressor, defined by a systems ability to self-repair

Threshold – when one or more of the primary ecological processes responsible for maintaining the sustained equilibrium degrades beyond self-repair

Plant Community Dynamics

Structure Function

Process

Western Juniper Expansion

- 90%-95% increase in 130 years
- Woodland expansion (>10% canopy cover) in Oregon from 456,000 acres in 1936 to 2.2 million acres in 1988 (Gedney et al. 1999)

Keystone Ranch, OR - 1890

From Miller et al. 2005

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Keystone Ranch, OR - 1989

From Miller et al. 2005

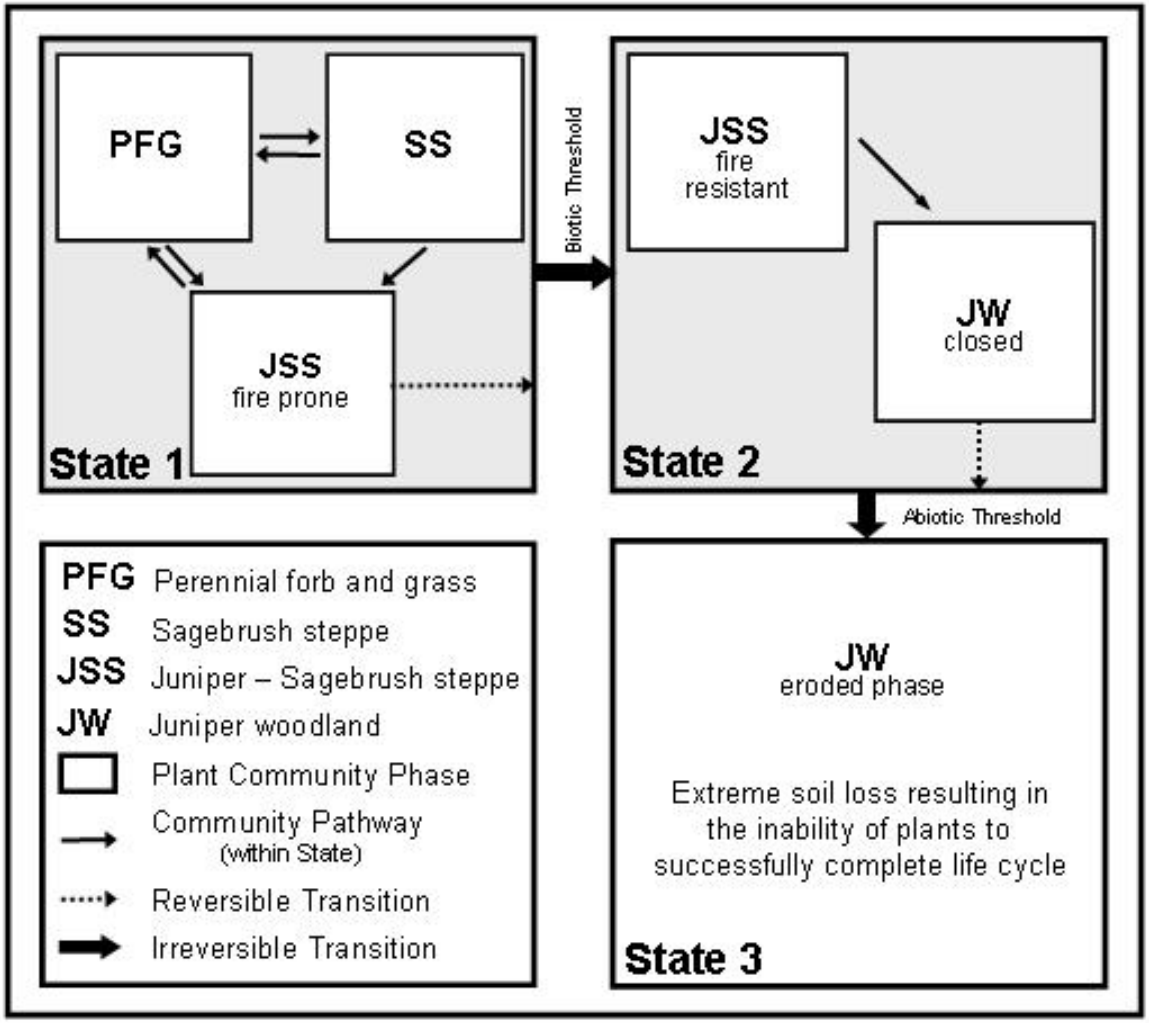
Triggers and Thresholds

What triggers initiate threshold development in western juniper ecosystems?

How can thresholds be identified in these systems?

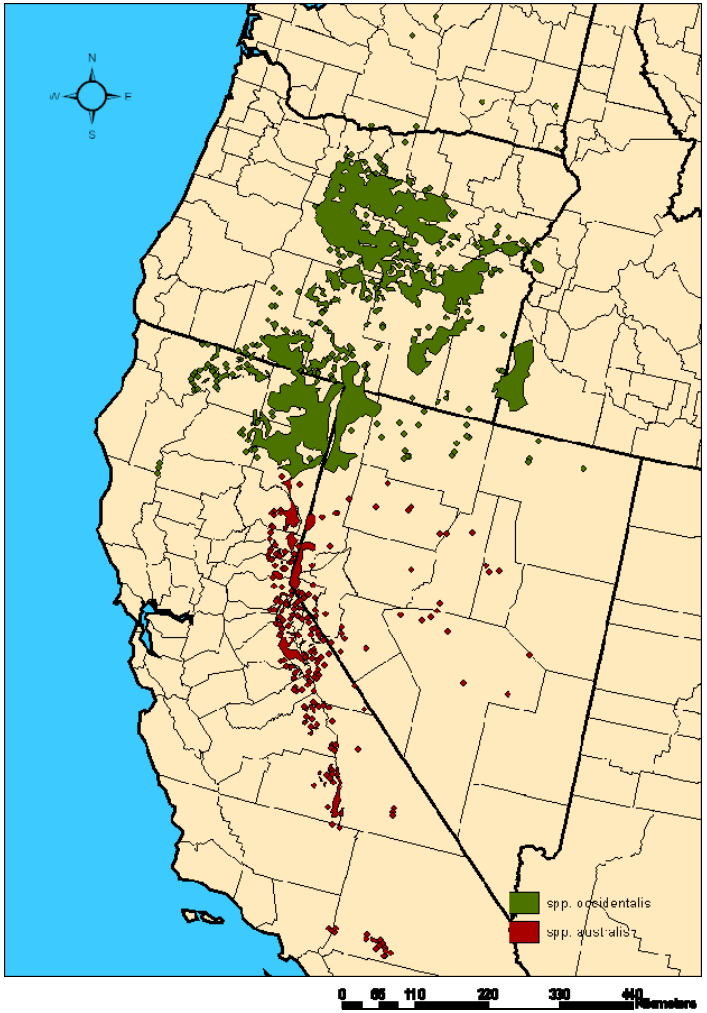
When do these systems become irreversible?

Process-based western juniper state-and-transition model



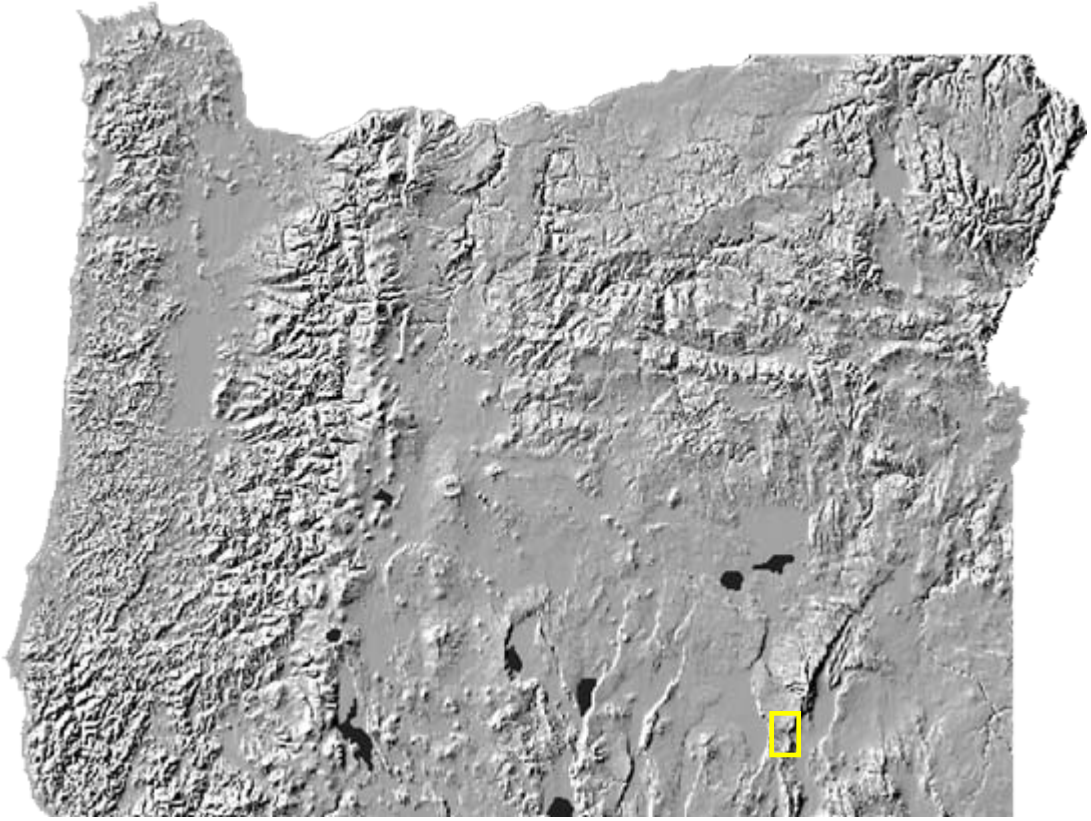
Western Juniper

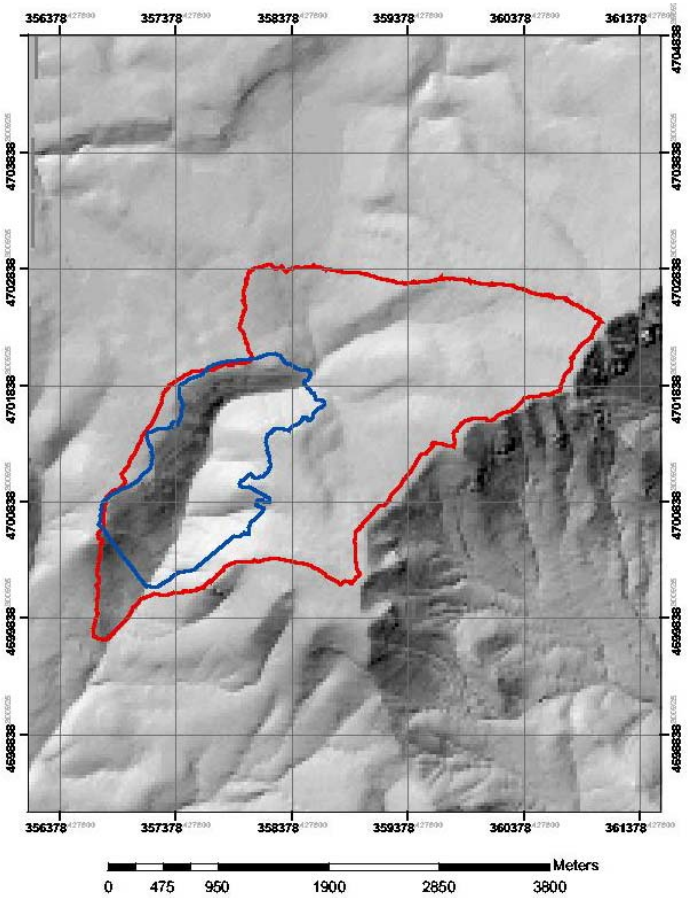
- *Juniperus occidentalis*
- Occupies 7.5 million acres in 5 western states
  - 5 million acres in OR
  - 2 million acres in CA
- 10-15” precip zone
- 600 - 8,000 ft. elevation



Study Site Description

Steens Mountain, Oregon





Ecological Site Description

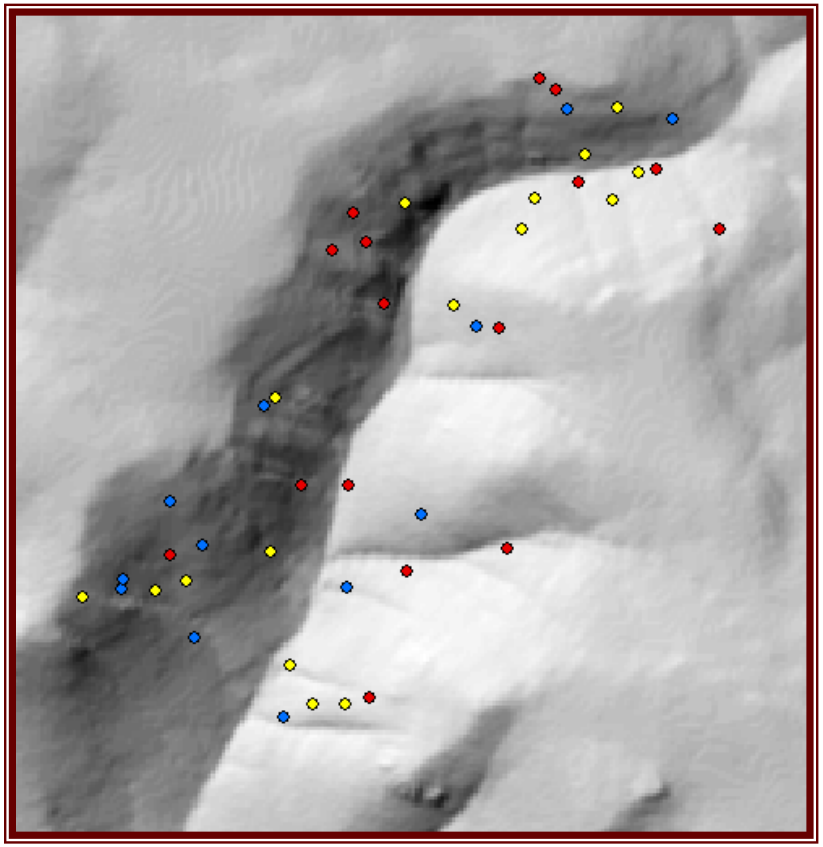
- South-Slopes 12-16 PZ
  - loamy-skeletal, mixed frigid lithic Argixerolls
  - gravely to cobbly silt loam from the surface to 20cm deep and cobbly loam from 20-38cm below the surface
  - contain between 20-60% rock (stones and cobbles)
  - Historic vegetation composition
    - 70% grasses
      - 30-50% *Pseudoroegneria spicata*
      - 5-15% *Festuca idahoensis*
    - 20% shrubs
      - 5-10% *Artemesia tridentata* var. *vaseyana*
      - 2-10% *Purshia tridentata*
    - 10% forbs

Ecological Site Description

- North-Slopes 12-16 PZ
  - mixed, superactive frigid pachic Haploxerolls
  - Soils ranging from the surface to 30cm depth are considered stony loam
  - The surface material contains 20-70% rock fragments (stones and cobbles)
  - Historic vegetation composition
    - 70% grasses
      - 40-50% *Festuca idahoensis*
    - 10-15% shrubs
      - 5-10% *Artemesia tridentata* var. *vaseyana*
      - 2-10% *Purshia tridentata*
      - 2-5% *Symphoricarpos rotundifolius*
    - 10% forbs

Study Plot Description

- Aspect delineation (10m DEM)
- 44 stratified random plots
  - State 1
    - 0.6% juniper cover
    - 40.3% shrub cover
  - State 2
    - 14.1% juniper cover
    - 18.2% shrub cover
  - State 3
    - 27.1% juniper cover
    - 2.5% shrub cover
- Randomized block design
- No north-facing sites having State 3 attributes



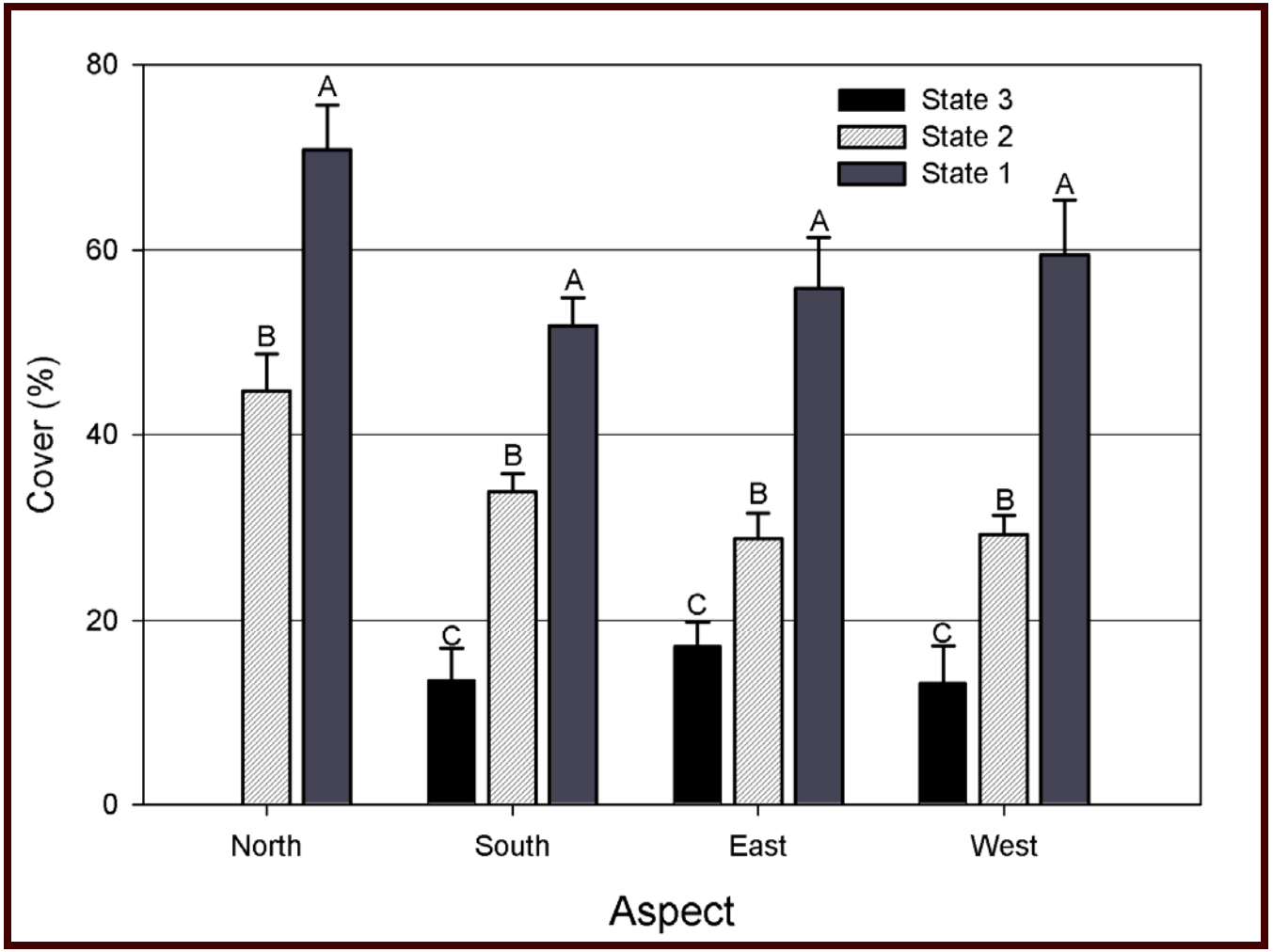
Data Collection Description

- Ecological Structure
  - Plant density (1m^2 quadrat)
  - Plant cover (point intercept)
  - Litter (point intercept)
  - Bare ground (point intercept)
  - Gap intercept
- Ecological Processes
  - Runoff volume measured in 5 minute intervals (12)
  - Steady-state infiltration calculated using the Green-Ampt equation

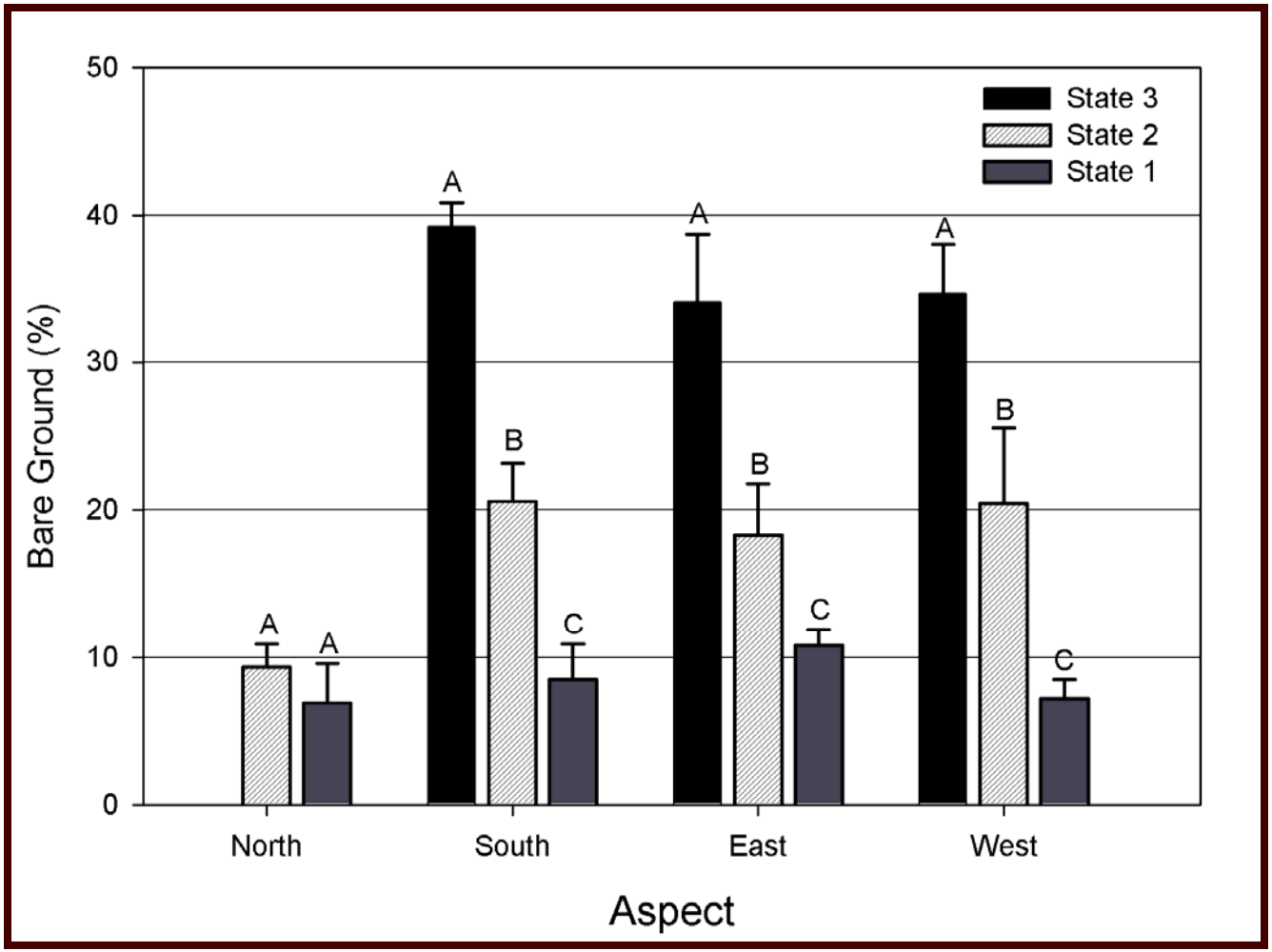
Data Analysis

- Analysis of Variance
  - For main effects, post hoc tests by Fishers LSD (significance at 0.05)
- Linear and non-linear regression
  - Relationship between steady-state infiltration and bare ground, percent litter
- Indicator species analysis
  - Identifies the percent of perfect indication for individual species occurring within each state
- Hierarchical agglomerative cluster analysis
  - Sørensen (Bray Curtis) distance measure
  - Ward's group linkage method (PC-ord®)

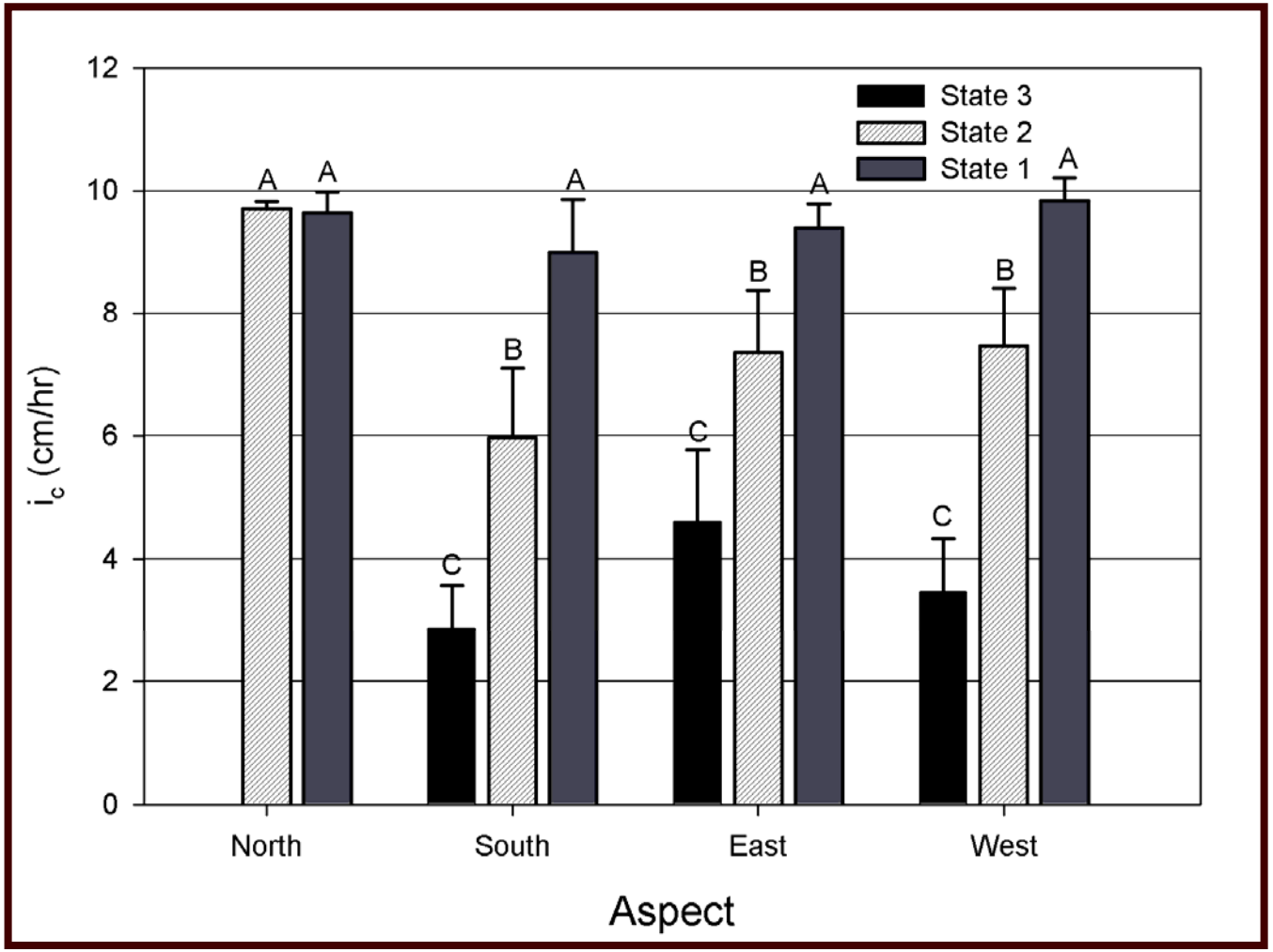
Total Plant Cover



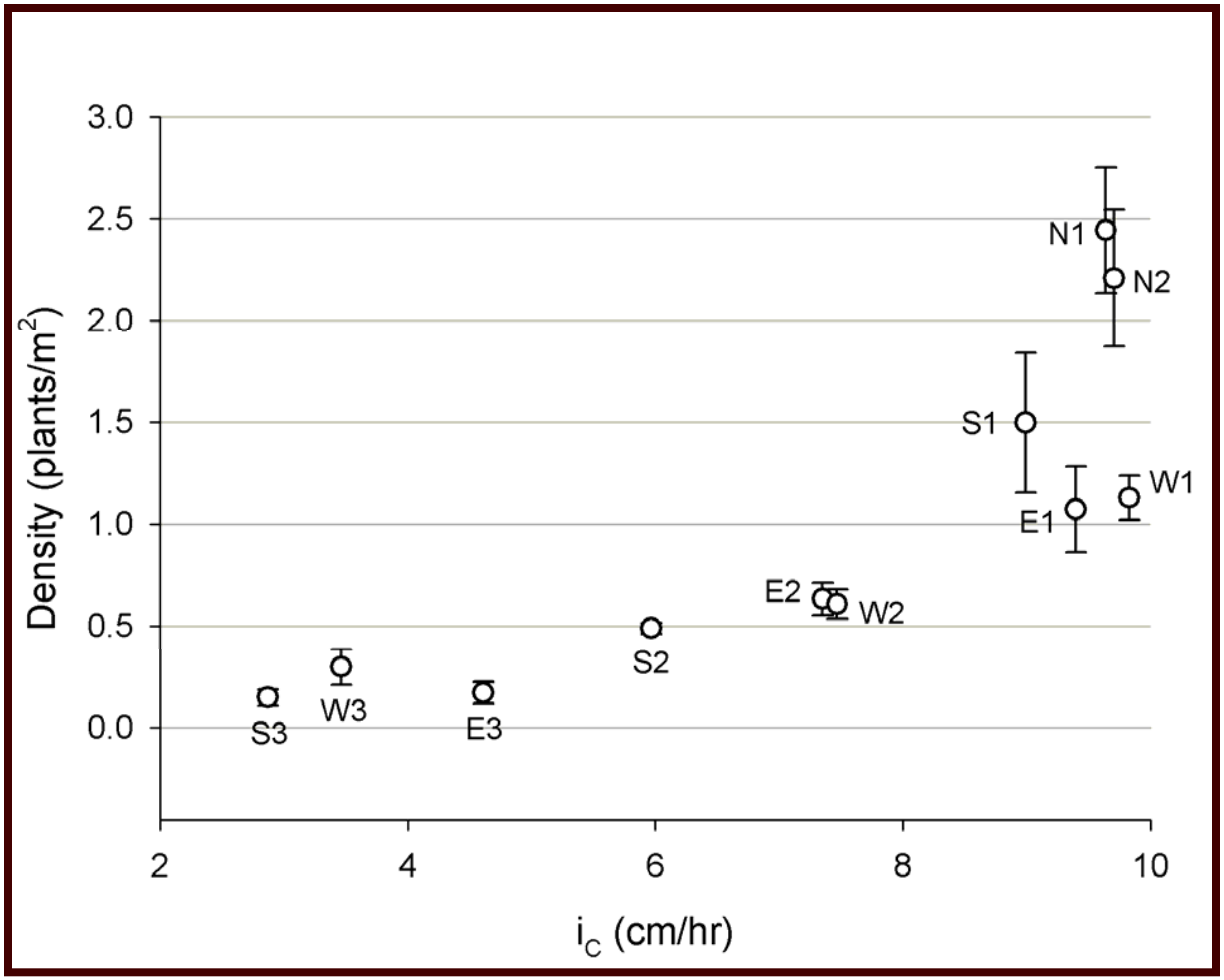
Percent Bare Ground



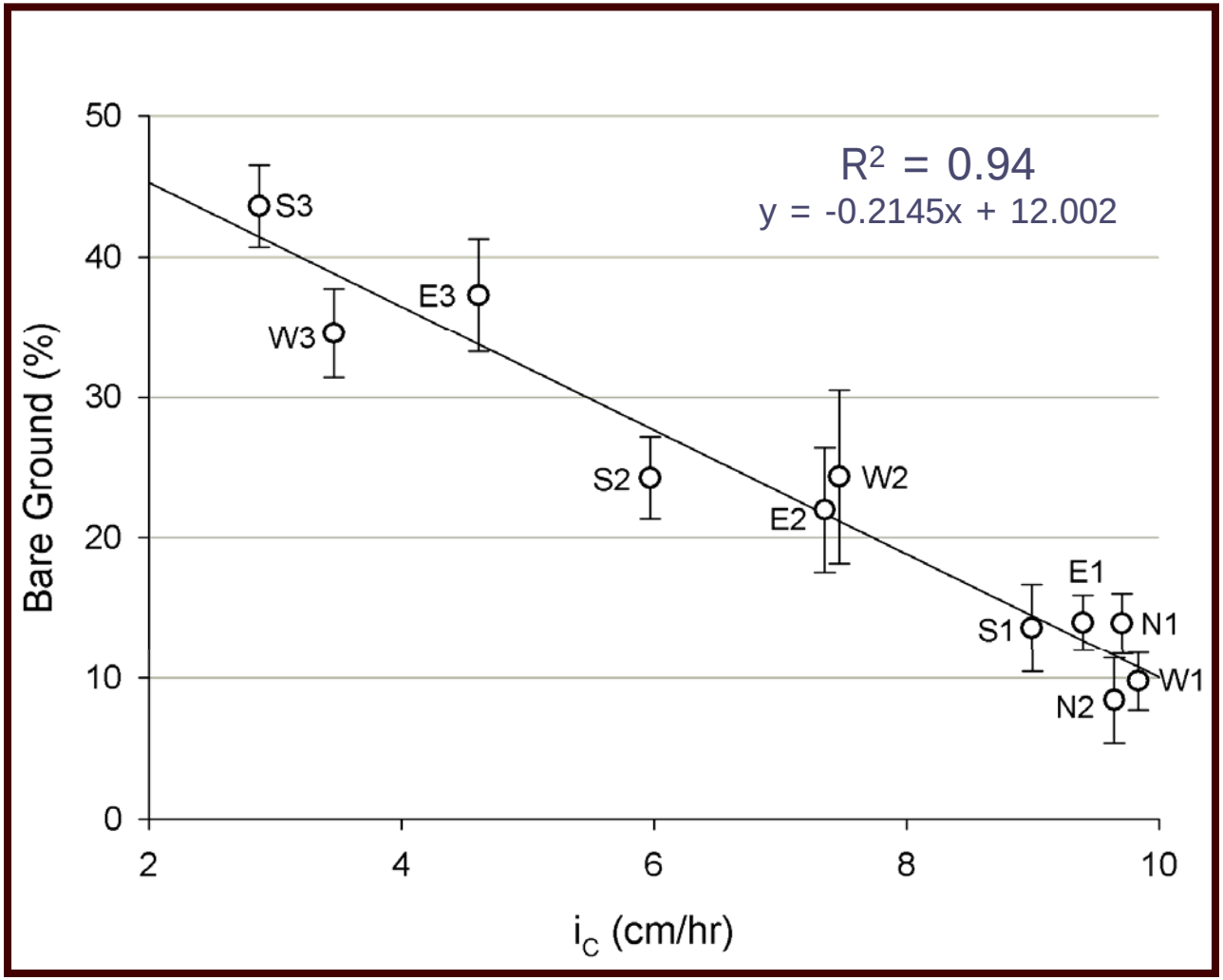
Steady-State Infiltration



Steady-State Infiltration and Total Plant Density



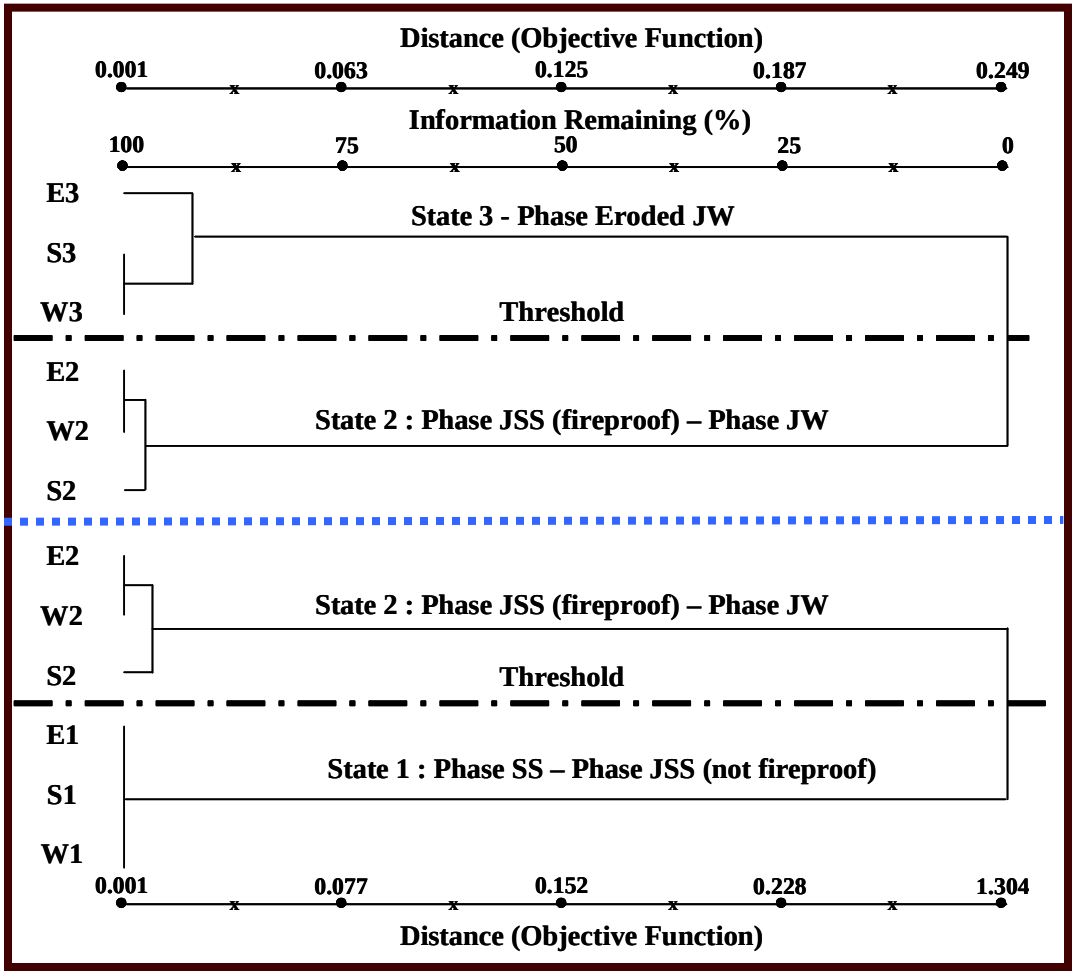
Steady-State Infiltration and Bare Ground



Hierarchical Cluster Analysis

Shrub Cover, Juniper Cover, Infiltration

Plot	Shrub Cover	JUOC Cover	i_c
E1	30.6	0.3	9.4
E2	13.2	13.0	7.4
E3	2.0	31.6	4.6
S1	35.8	0.8	9.0
S2	18.4	14.3	6.0
S3	3.0	27.0	2.9
W1	41.1	1.2	9.8
W2	12.7	15.8	7.5
W3	2.4	22.7	3.5



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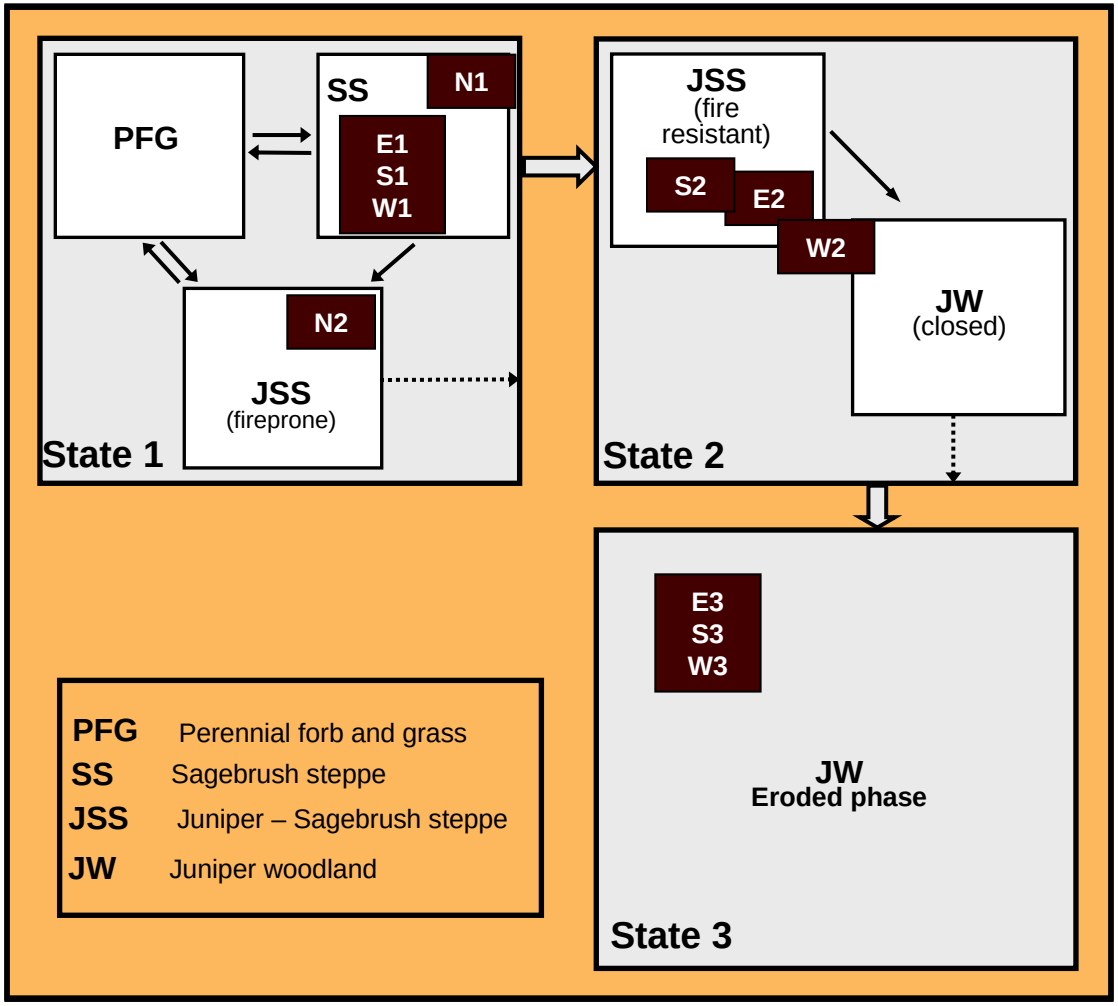
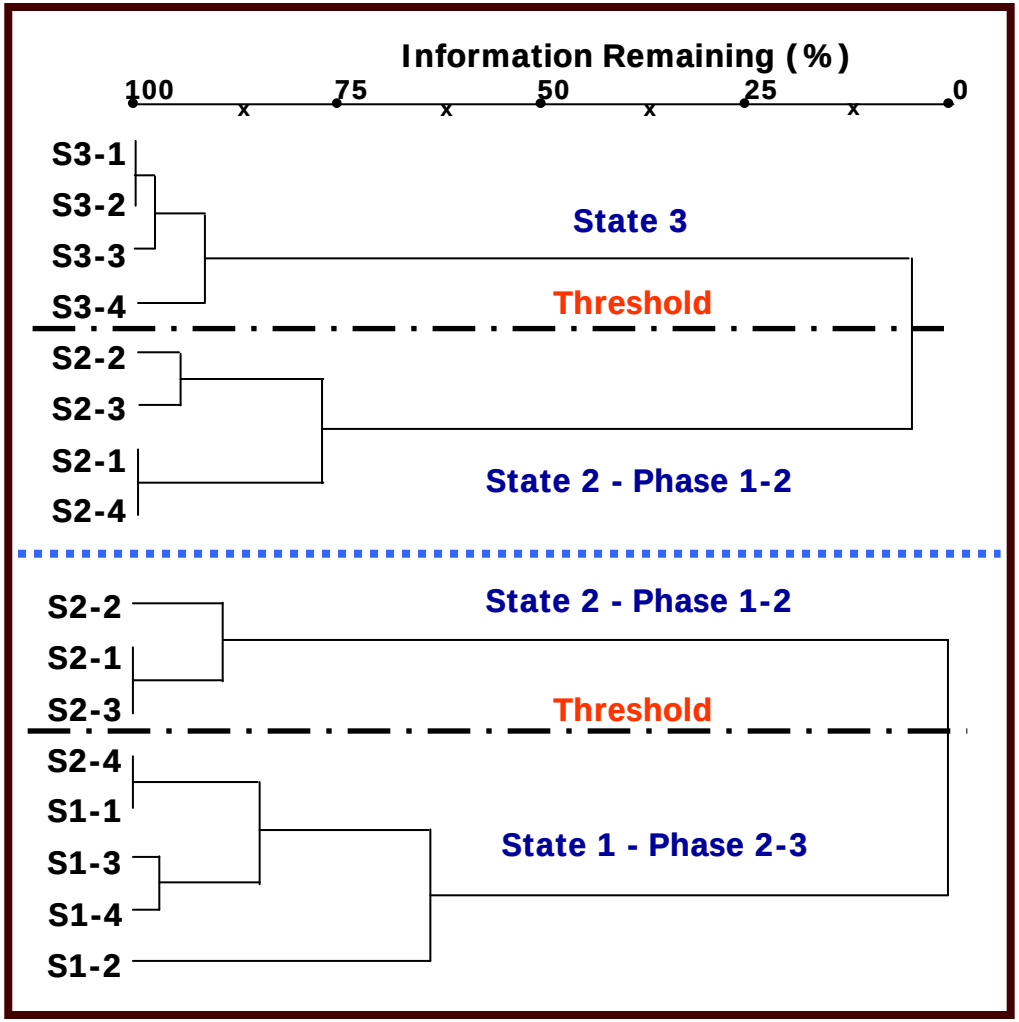


Indicators of South-facing Plots

- State 1
  - *Chrysothamns nauseosus* (rubber rabbitbrush) 78%
    - Outcompeted by juniper
  - *Prunus virginiana* (chokecherry) 75%
    - Prefers moist conditions
  - *Mertensia oblongifolia (oblongleaf bluebells)* 75%
    - Moist, undisturbed soils
  - *Achnatherum occidentale (western needlegrass)* 64%
    - Moist, undisturbed soils
- State 2
  - *Carex rosii* (Ross' sedge) 67%
    - Moderately dry soils
    - Poor competitor with large shrub species
- State 3
  - *Elymus elymoides* (squirreltail) 24%

States of South-facing Plots

Plot	Shrub Cover	JUOC Cover	BG	i_c
S1-1	29.2	1.0	25.6	10.4
S1-2	52.5	0.0	7.5	5.7
S1-3	31.6	2.0	15.9	8.6*
S1-4	26.4	1.0	10.6	9.7
S2-1	21.7	13.0	26.3	5.6
S2-2	12.0	18.0	16.5	3.6
S2-3	12.8	18.0	27.1	6.2*
S2-4	31.0	8.0	27.2	6.1*
S3-1	3.1	29.0	47.2	2.0
S3-2	4.5	24.0	46.0	1.5
S3-3	1.0	34.0	41.8	3.0*
S3-4	7.3	21.0	39.4	3.6*



States of South-facing Plots

Plot	Shrub Cover	JUOC Cover	BG	i_c
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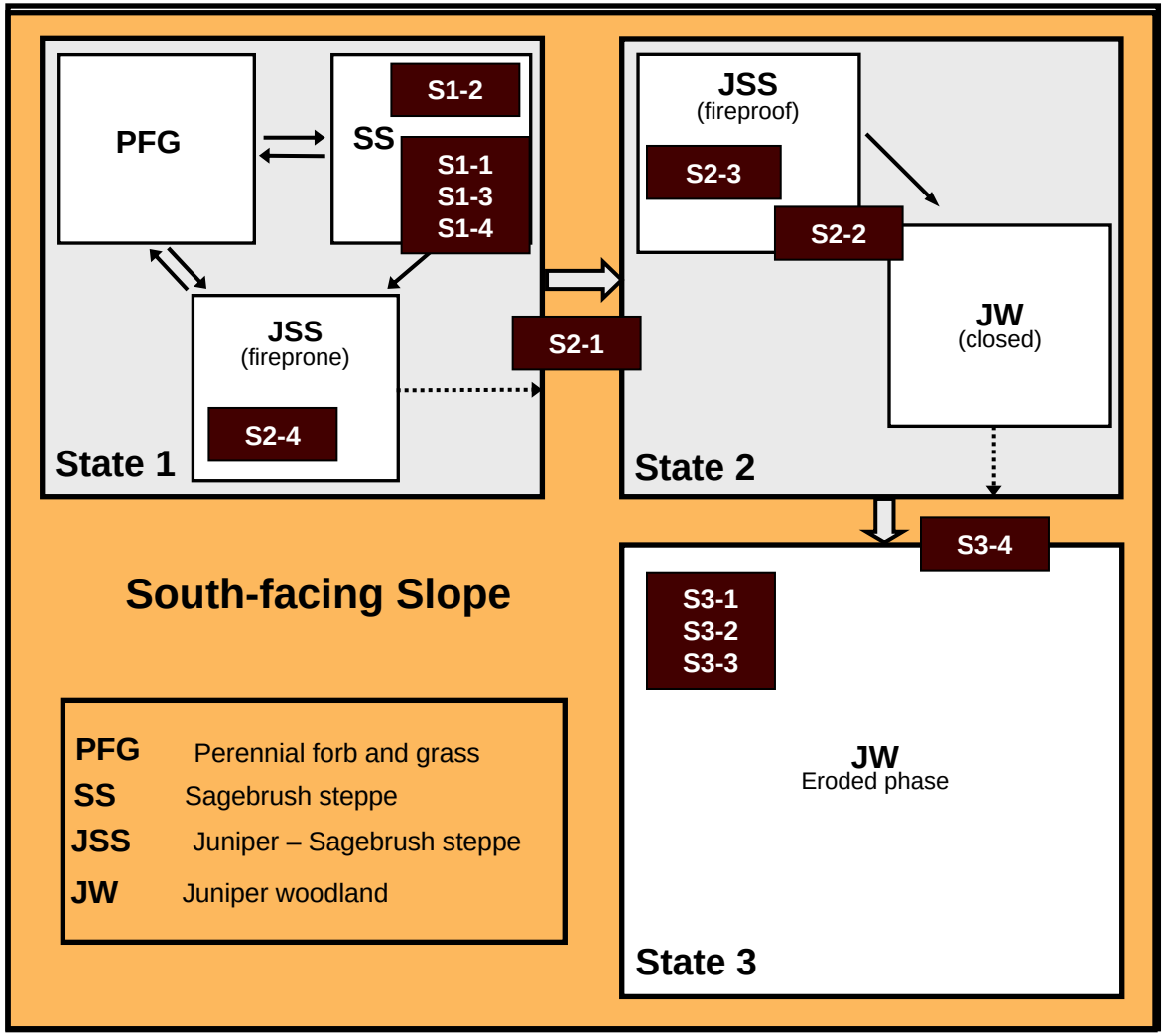
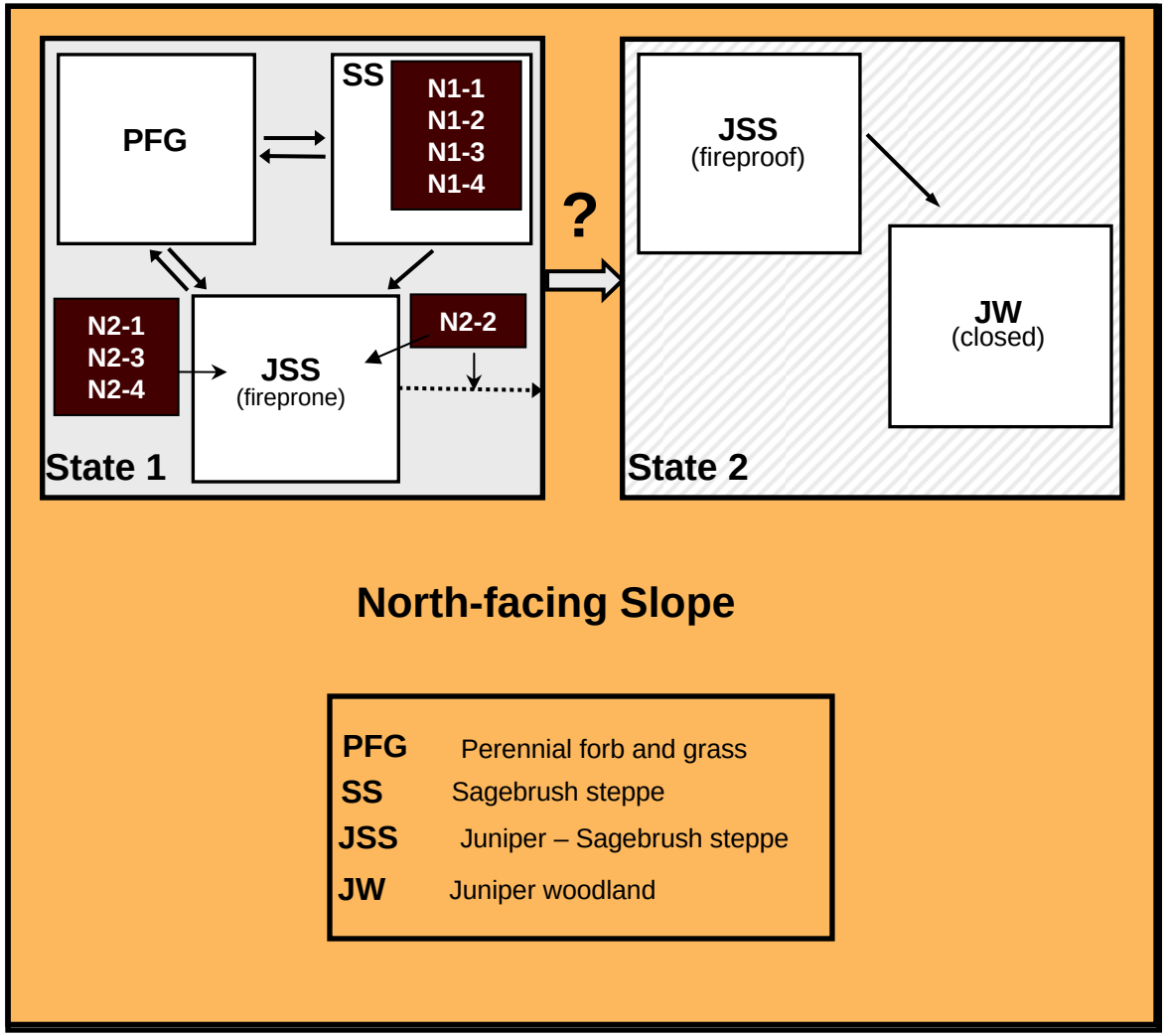


Indicators of North-facing Plots

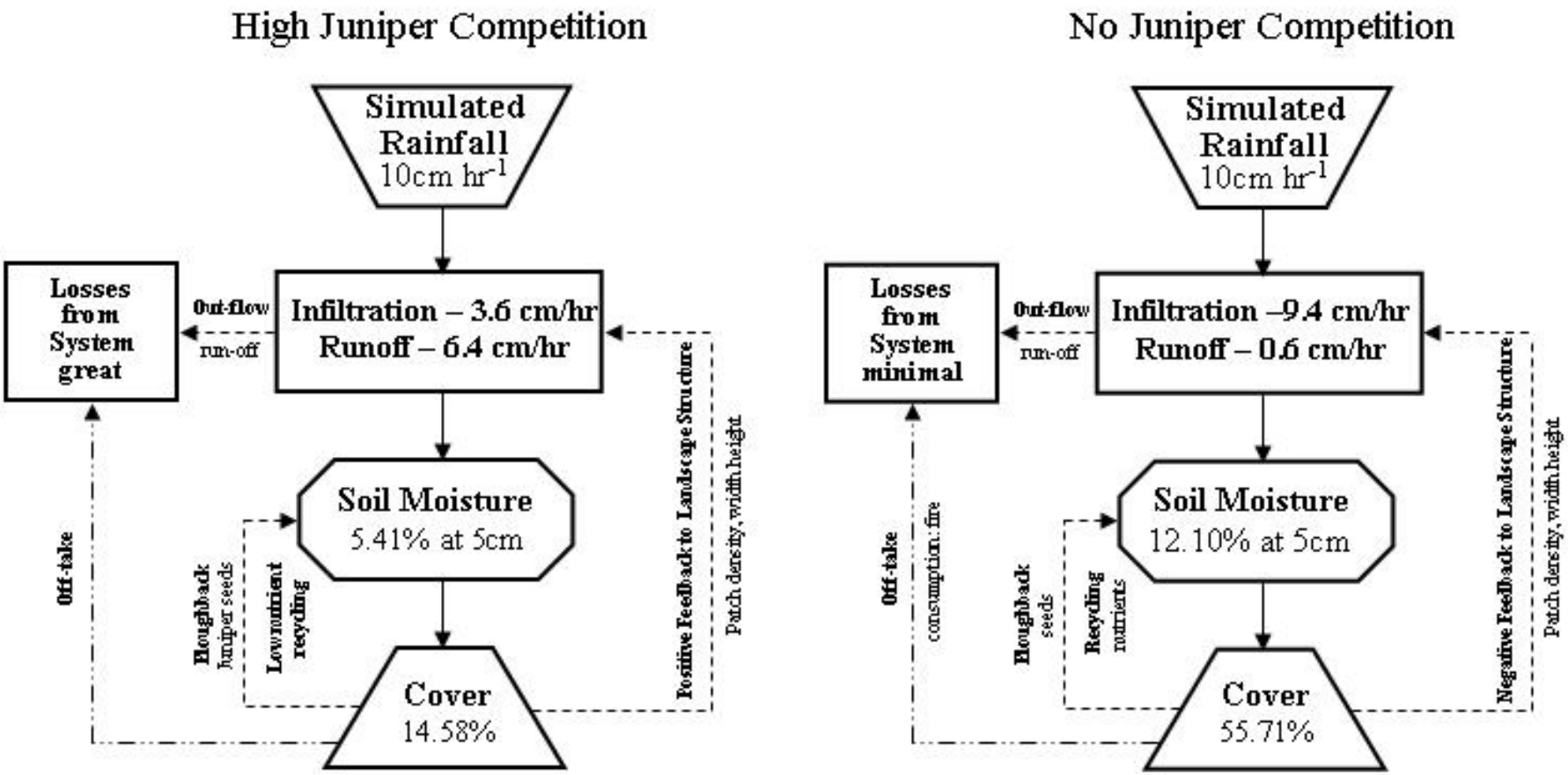
- State 1
  - *Elymus trachycalus* (slender wheatgrass) 86%
    - Wet to dry conditions
  - *Agastache urticifolia* (horsemint) 82%
    - Open slopes
- State 2
  - *Achnatherum lemmonii* (Lemmon's needlegrass) 100%
    - High drought tolerance
  - *Lupinus caudatus (tailcup lupine)* 69%
    - Low water requirement

States of North-facing Plots

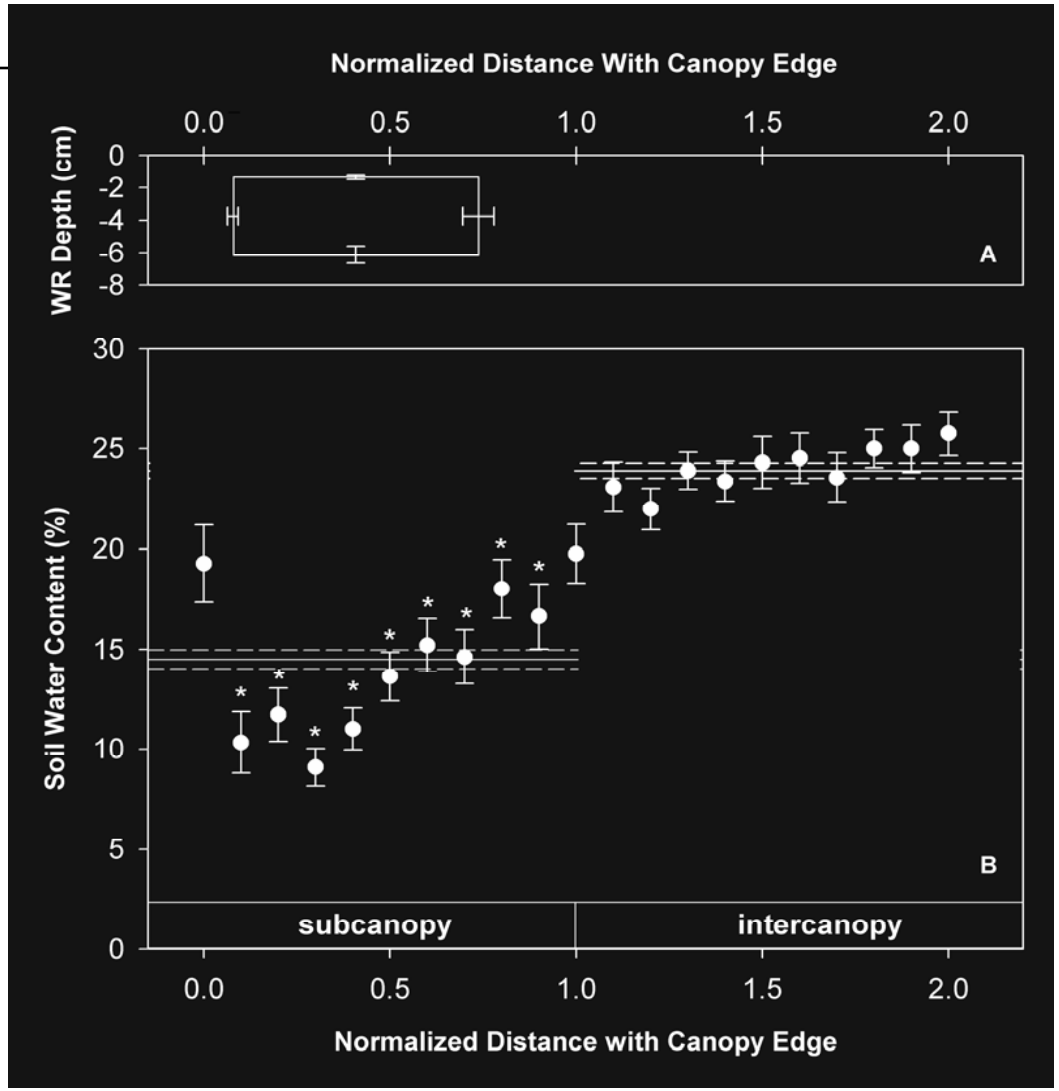
Plot	Shrub Cover	JUOC Cover	BG	i_c
N1-1	50.6	0	3.1	11.3*
N1-2	54.6	0	5.7	10.8*
N1-3	39.9	0	16.9	10.2
N1-4	69.7	0	7.9	10.0
N2-1	35.3	17.0	14.9	9.8
N2-2	12.6	9.0	11.5	9.6
N2-3	32.1	19.0	18.2	9.9
N2-4	33.5	12.0	11.0	9.9



Trigger – Transfer – Reserve – Pulse Western Juniper Model



Water Repellency and Soil Water Content Assessment



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Management and Scientific Implications

Resilience will vary across a juniper-encroached landscape, higher in north-facing slopes

Negative feedbacks maintained in State 1, Positive feedbacks dominate in State 3

Model for identifying sites that have exceeded ecological thresholds

Focus restoration efforts on sites that are at risk of crossing thresholds but can be reversed with management strategies

QUESTIONS?