State-and-Transition Models:

Concepts and Components

Pat L. Shaver
USDA-Natural Resources Conservation Service
West National Technology Support Center
Portland, OR

State and Transition Models

- Westoby et al. (1989) – Management influences and models
- Archer (1989) – Domain changes from herbaceous dominated to woody dominated
- Friedel (1991) Thresholds
- Olivia et al. (1998) – Patagonia
- West (1999) - Successional change in sagebrush steppe
- Stringham et al. (2003) – Consistent definitions
- Briske et al. (2008) - Developing resilience based STM's
- Bestelmeyer et al. (2009) - Development and application

Many others

STATES

***STATE** - a recognizable, resistant and resilient complex of two ecosystem components, the soil base and the vegetation structure*

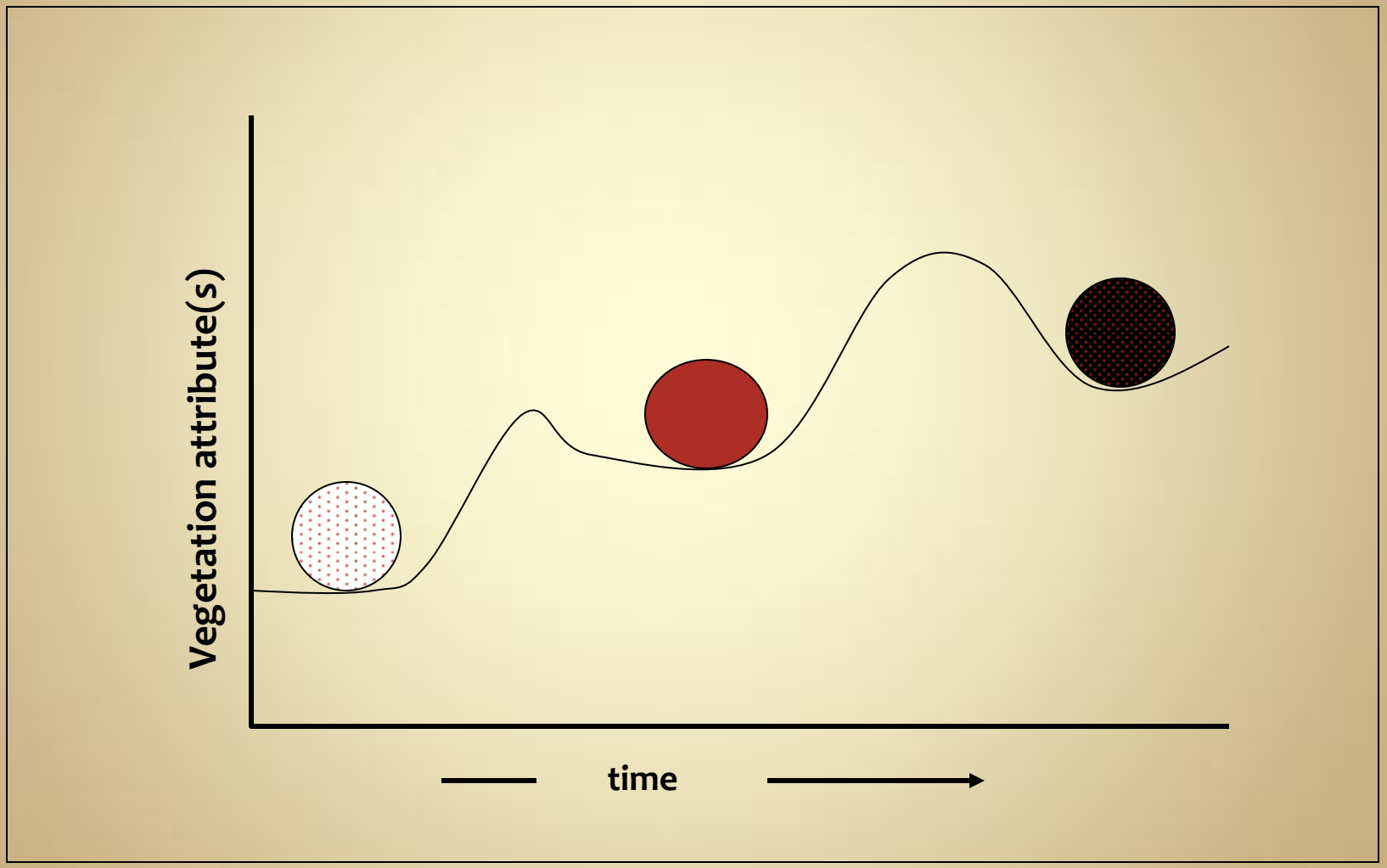
- *soil - developed through time from specific parent material, climate, landscape position and interaction with biota*

  - determine the site's capability

  - interaction between soil and vegetation determines functional status of site and inherent resistance to change

Stringham, et al., 2003

STATES



TRANSITIONS

TRANSITION *- the trajectory of a change*

- change is precipitated by natural events, management actions, or both

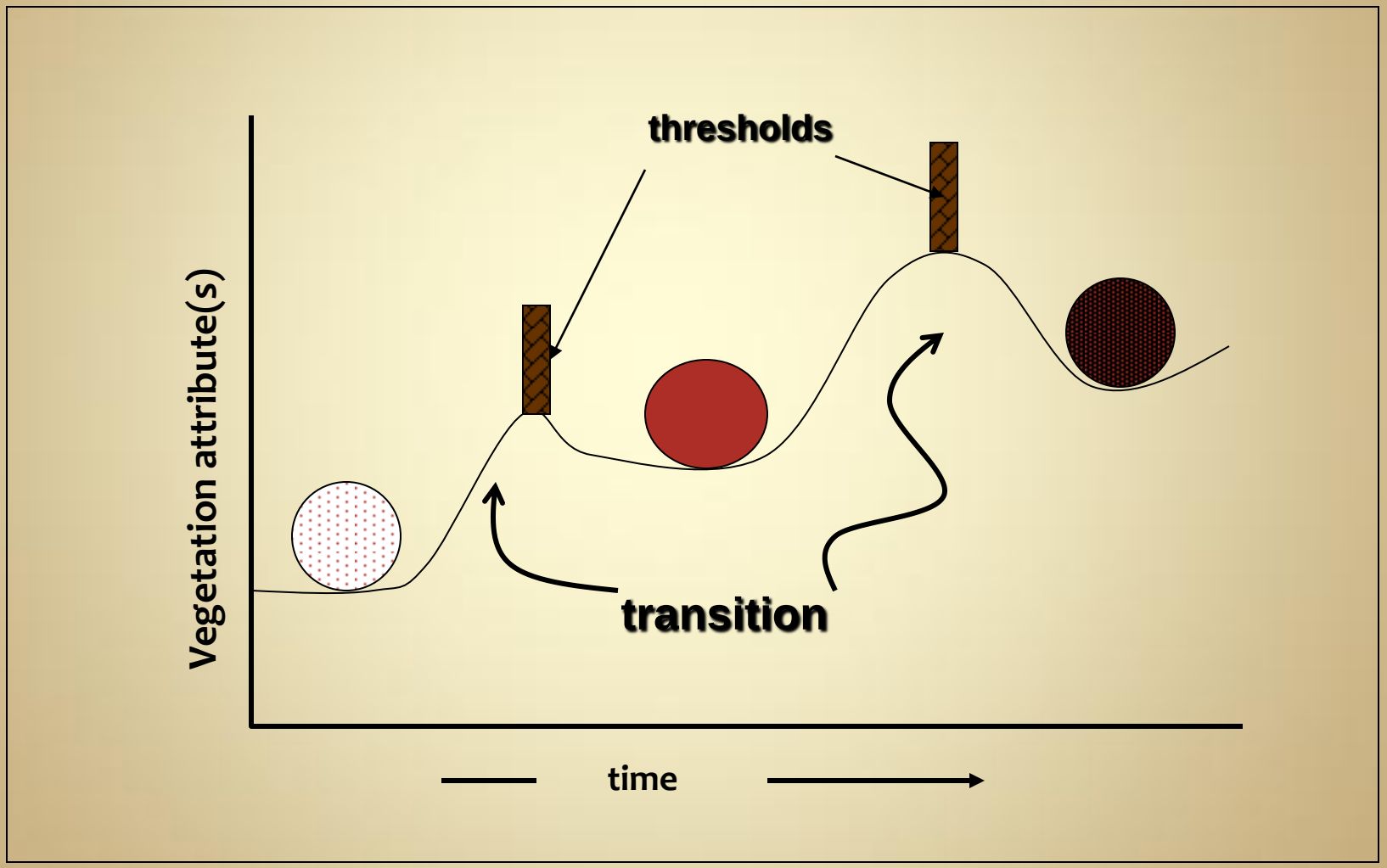
- degrades the integrity of one or more of the state's primary ecological processes beyond the point of self repair

THRESHOLD *- boundary in space and time between two states*

- irreversible for practical purposes without input of outside energy

Stringham, et al., 2003

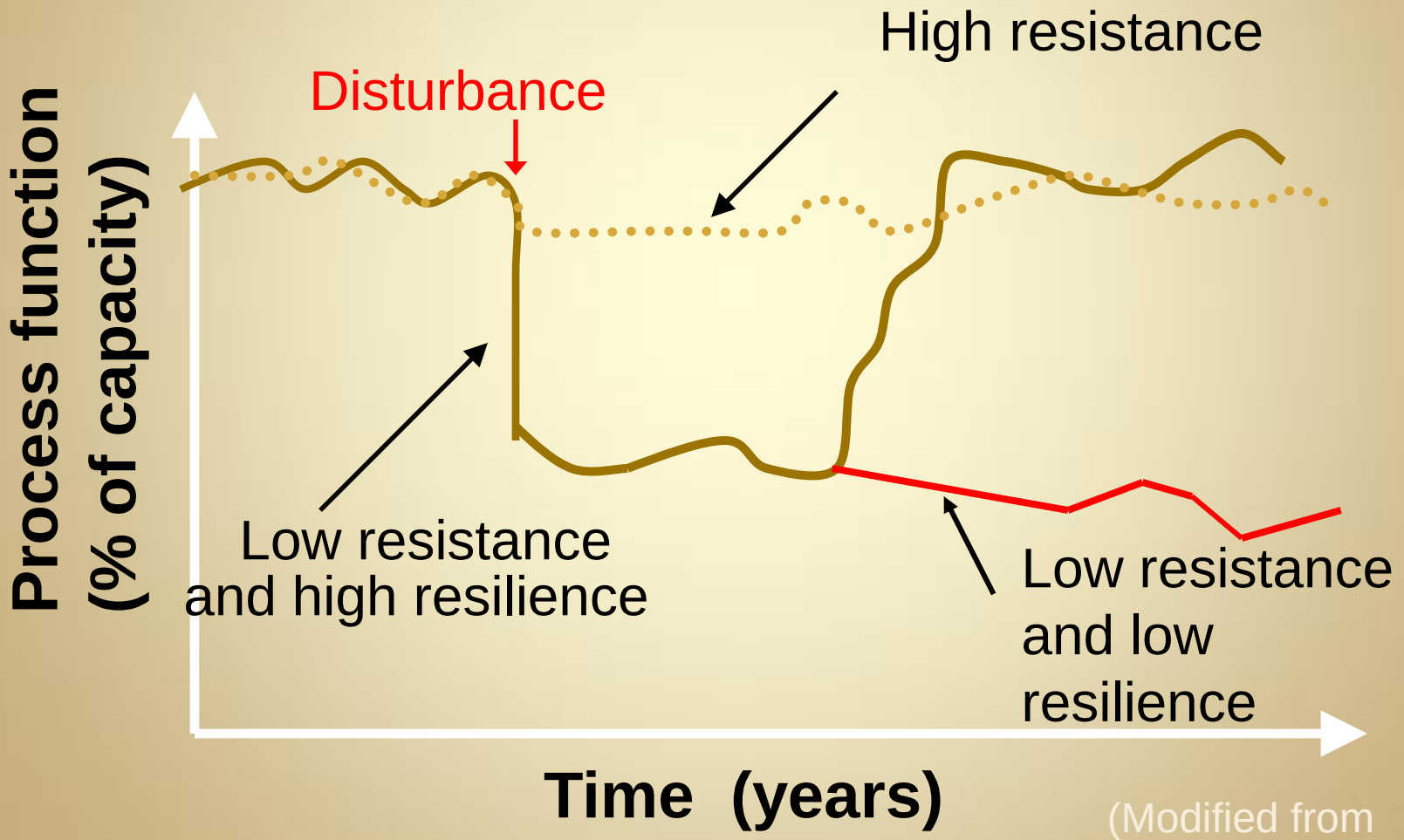
TRANSITIONS



- **ECOLOGICAL RESILIENCE** – Amount of change required to transform a system from being maintained by one set of mutually reinforcing processes to a different set of processes.

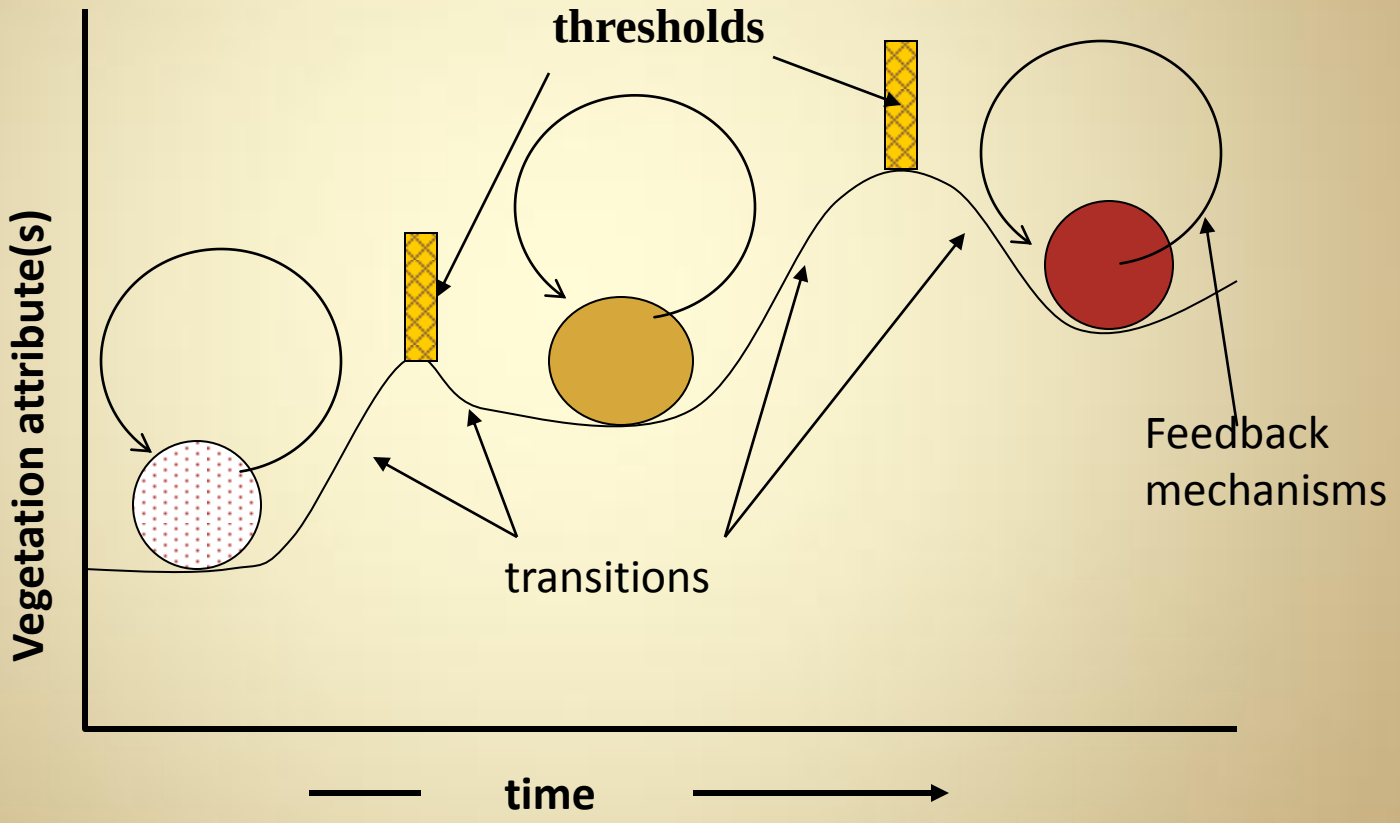
(Briske et al 2008)

Function, Resistance and Resilience



(Modified from Seybold, et al, 1999)

STATES


thresholds
Vegetation attribute(s)
Feedback
mechanisms
transitions
time

PLANT COMMUNITY PHASES

COMMUNITY PHASES

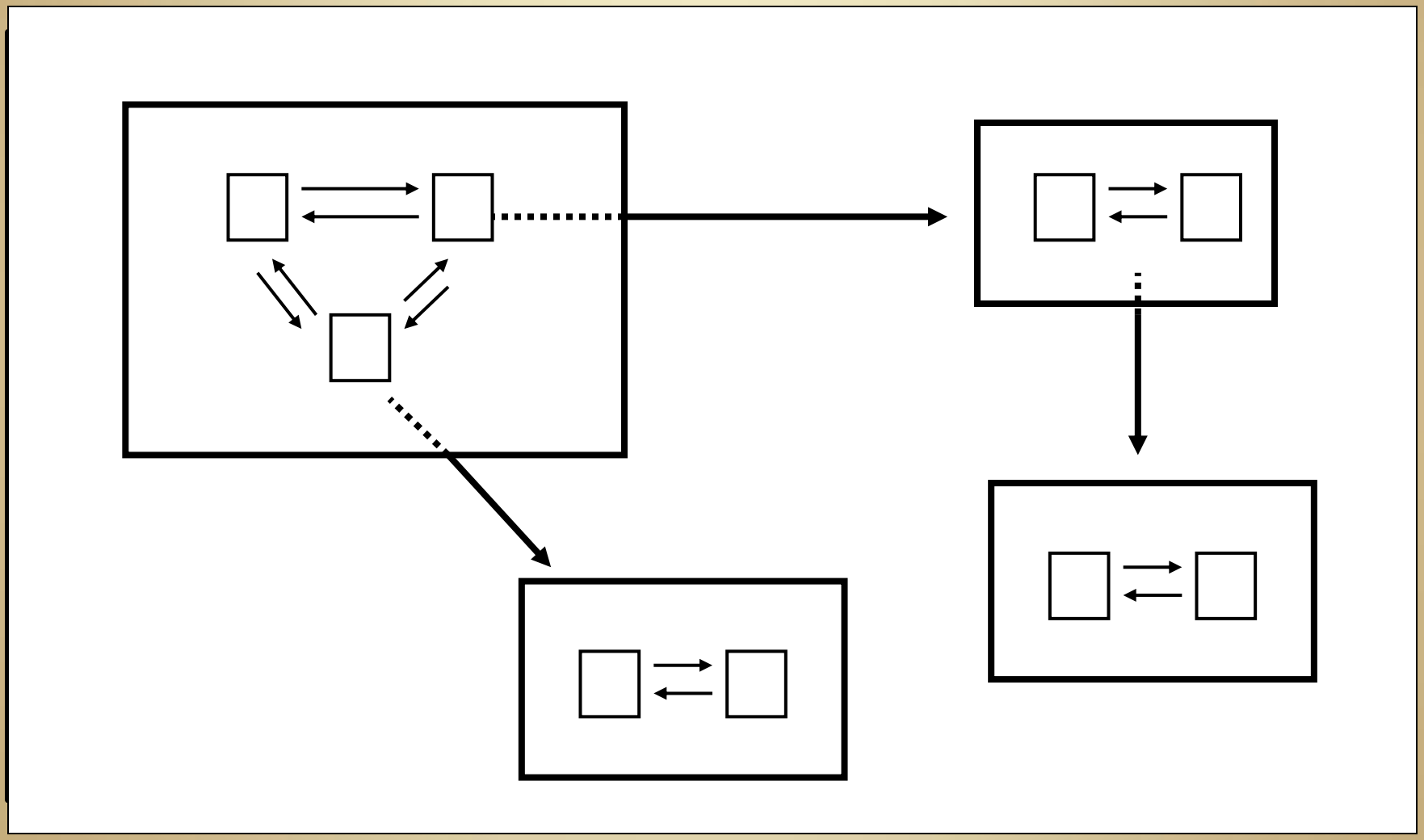
-Different assemblages within a state that do not represent a state change since a threshold has not been crossed

- Vegetation dynamics within a state (succession/regression and/or non-equilibrium)

COMMUNITY PATHWAYS

- Causes of change between plant communities

BUILDING STATE and TRANSITION MODELS



Developing State-and-Transitions Models
Deep Sand Savannah Ecological Site

- 1750 – 2000 m elevation
- Flat to rolling dune topography
- Aeolian sand deposits – Deep, fs, lfs; lfs, fsl
- 33 – 40 cm average annual precipitation
- 75 % of precipitation comes during late growing season (late July, August and early Sept.)
- 130 – 160 day growing season (early May to early Oct)

Historical Accounts

- Golden-grassed plains
  - Spanish mission early 1600's– (Horgan, 1954)
    - Abandoned 1671
- Good grass cover, scattered piñon and juniper (McLeullough, 1882)
- Treeless but very grassy with sabinos (junipers) dotting it (Bandelier, 1884)

Natural Range of Variability

- Fire maintained grassland or savannah aspect (Natural and human ignition)
  - 4 – 6 years (Frost, 1998)
  - 6 – 11 years (Baisan & Swetnam, 1997)
  - 16 – 20 years (Allen, 1989)
- Drought/Wet Years
- Herbivory
  - Blacktailed Jackrabbit
  - Pronghorn Antelope

Pre-Anglo/American Settlement

- Tall and mid warm season bunchgrasses
- Mid and short warm and cool season grass understory
- Forbs – variable with season and weather
- Woody – spatially and temporally variable depending on time since last fire
- Annual Production ~ 1200 kg/ha

Deep Sand Savannah

Post-Anglo/American Settlement Dynamics

- Large herds of livestock
  - 1870 - 1880 – < 1 million sheep & 137,000 cows
  - 1890 – 5 million sheep & 1.3 million cows
  - 1906 – 6 million sheep & 1 million cows
  - 1979 – 600,000 sheep & 1.5 million cows
  - 2007 – 127,000 sheep & 1.5 million cows
- Fire suppression
  - Lack of fine fuel
  - Active suppression

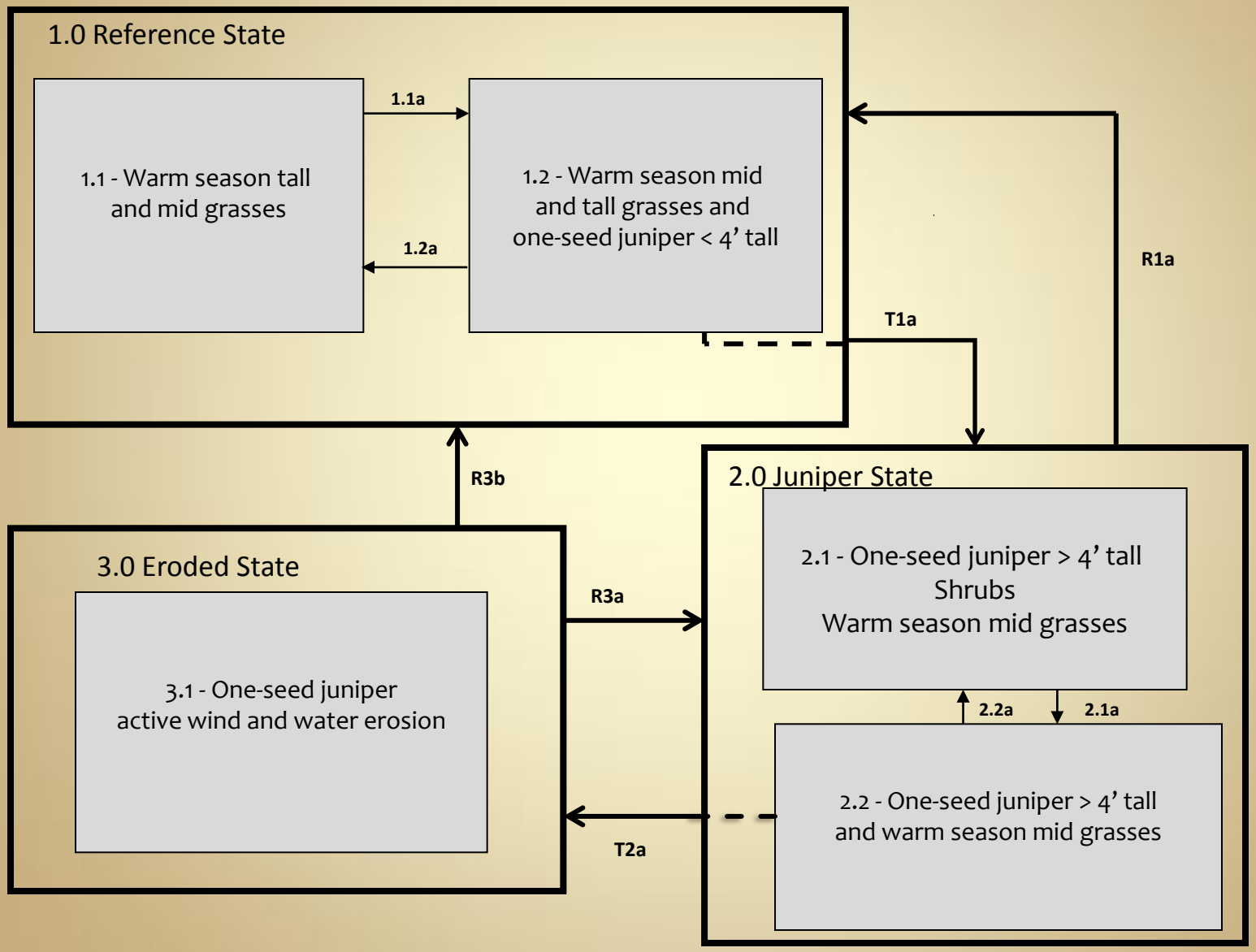
Present

- One-seed juniper > 4 m tall
- Juniper canopy cover 15 - 25%
- Annual herbaceous production 100 – 200 kg/ha

Deep Sand Savannah

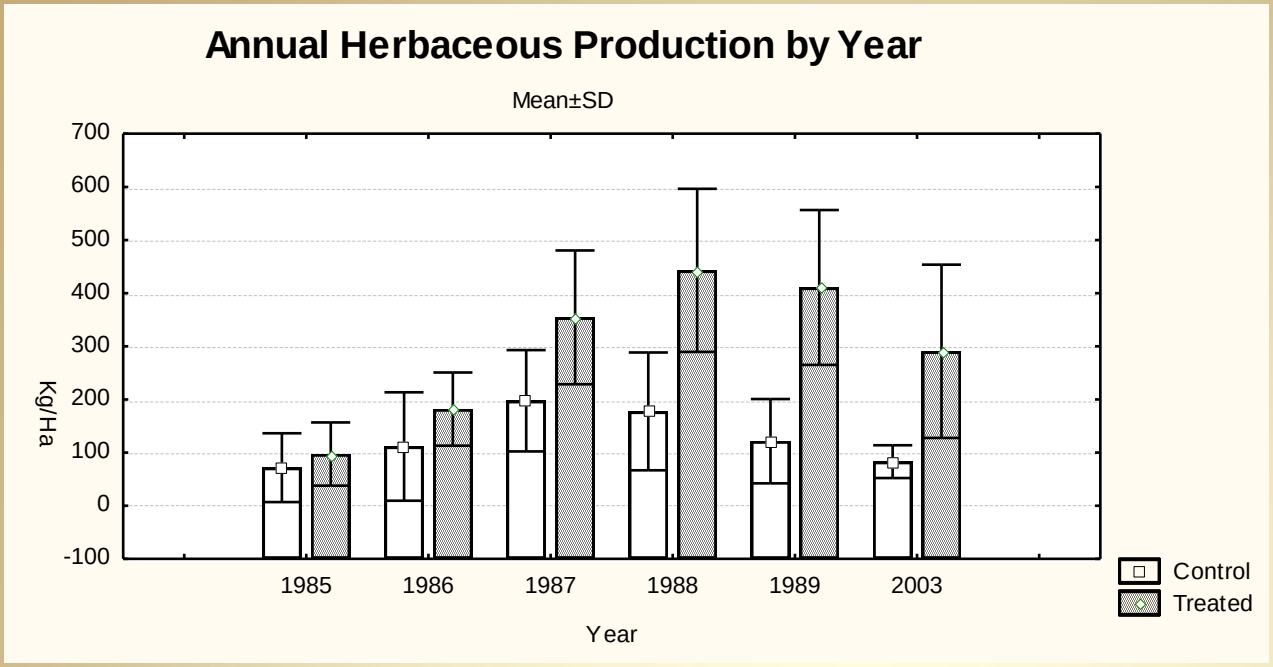
thresholds
Vegetation attribute(s)
transitions
Feedback
mechanisms
time

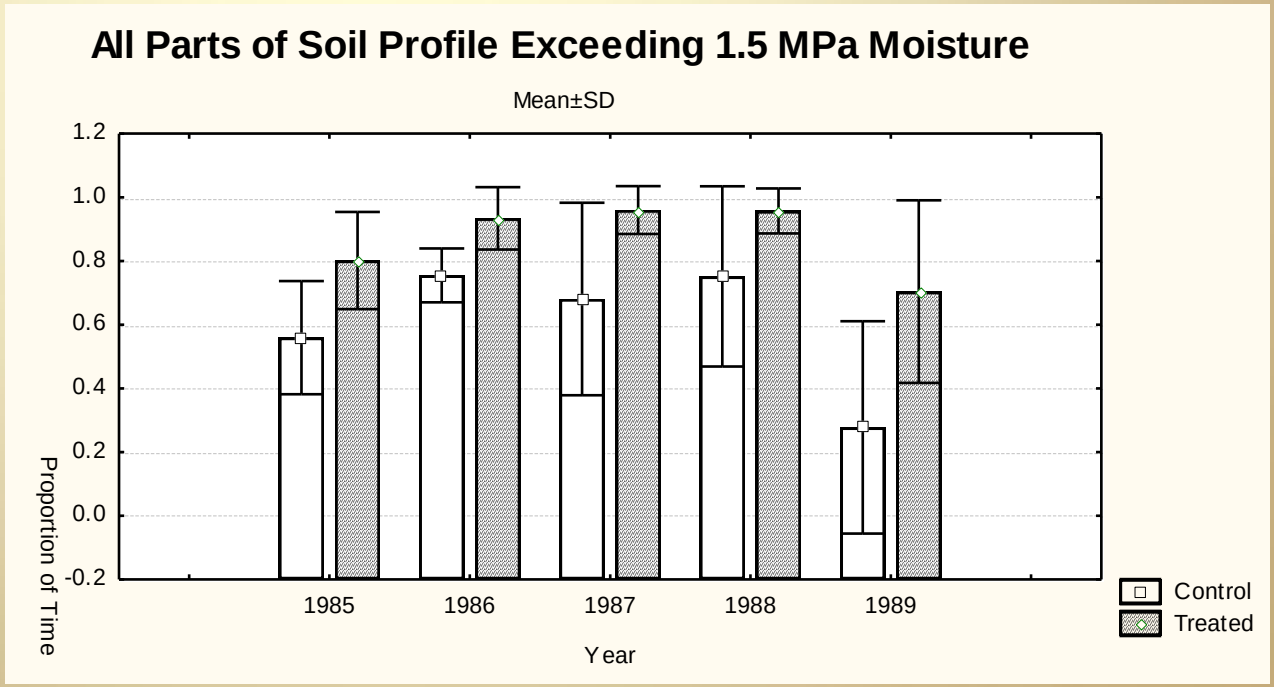
State-and-Transition Model



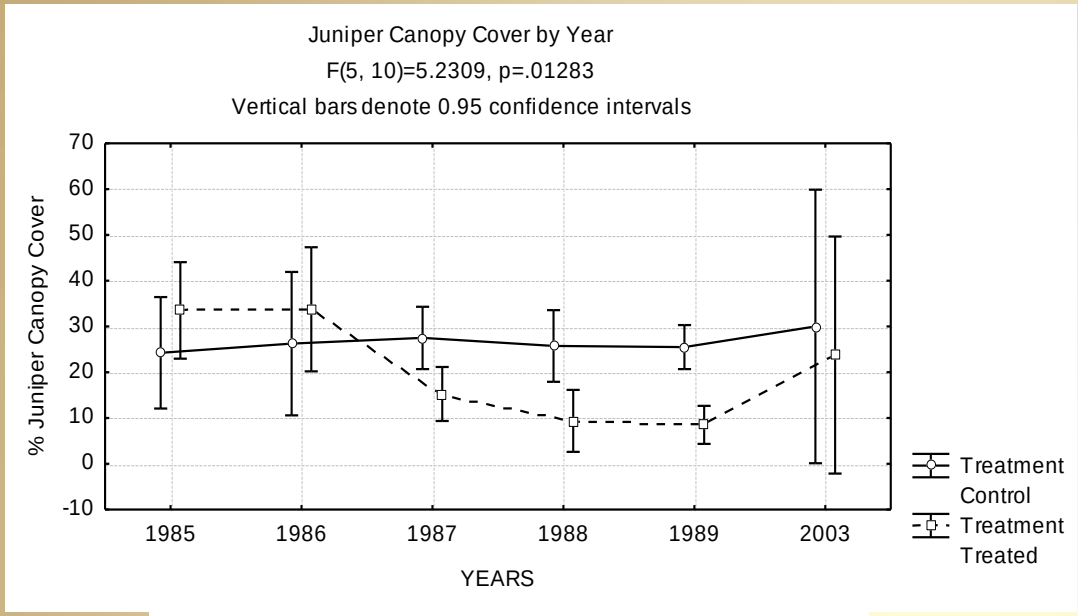
Available Data?

- How do you evaluate the quality of the information?
  - Go to the source, or people who knew it
  - Compare different sources
  - Peer-reviewed?


Annual Herbaceous Production by Year
Mean±SD
700
600
500
400
300
200
100
0
-100
Kg/Ha
1985
1986
1987
1988
1989
2003
Year
Control
Treated


All Parts of Soil Profile Exceeding 1.5 MPa Moisture
Mean±SD
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
Proportion of Time
1985
1986
1987
1988
1989
Year
Control
Treated

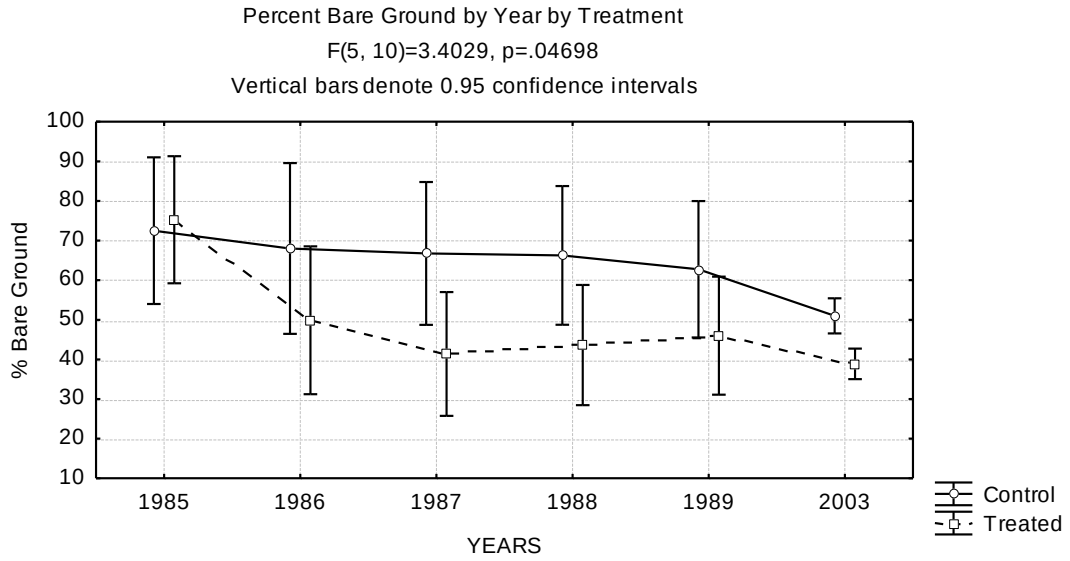
Ground Cover



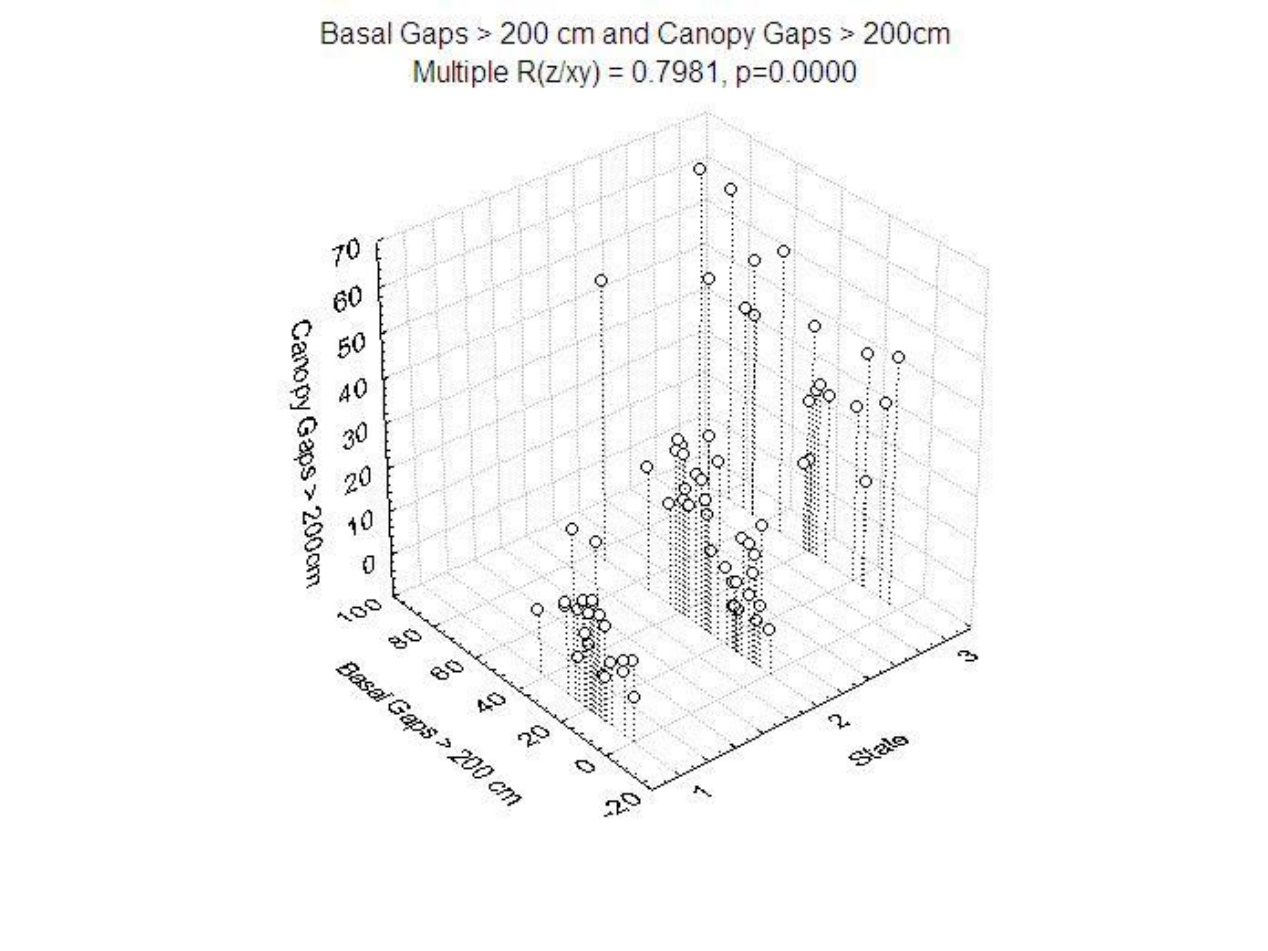
Litter

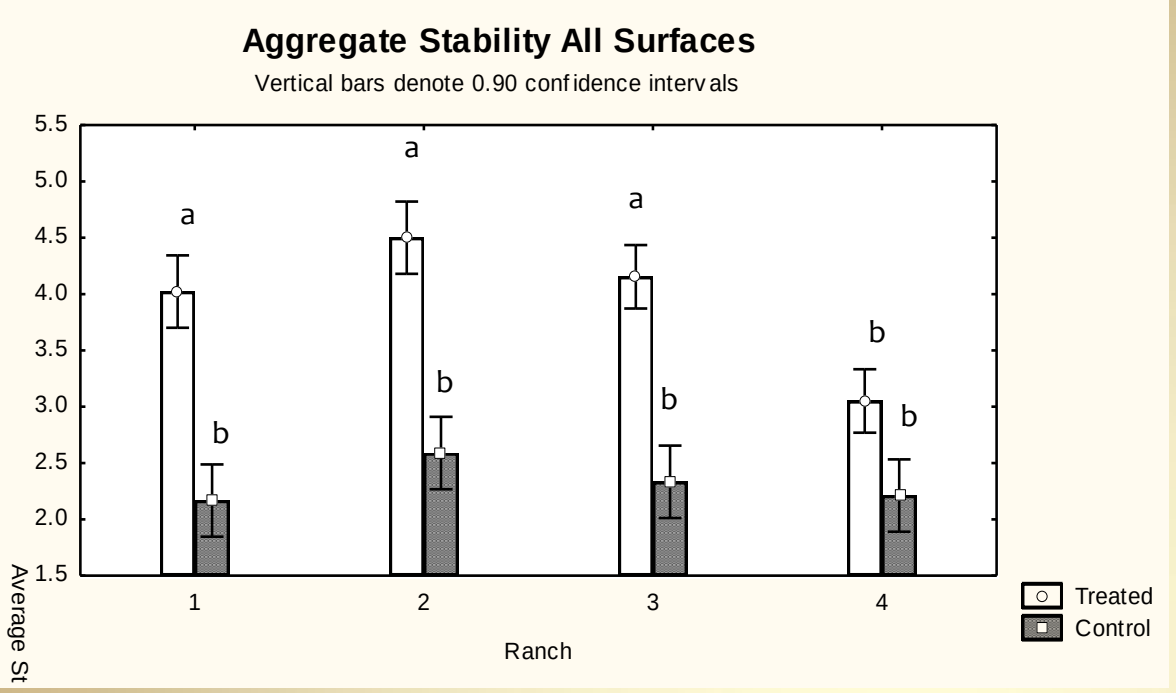
	Treated		Control	
	mean	p	mean	p
1985-1989	36.9		25.5	
1985-1985 & 2003	39.1	0.02	28.3	0.02

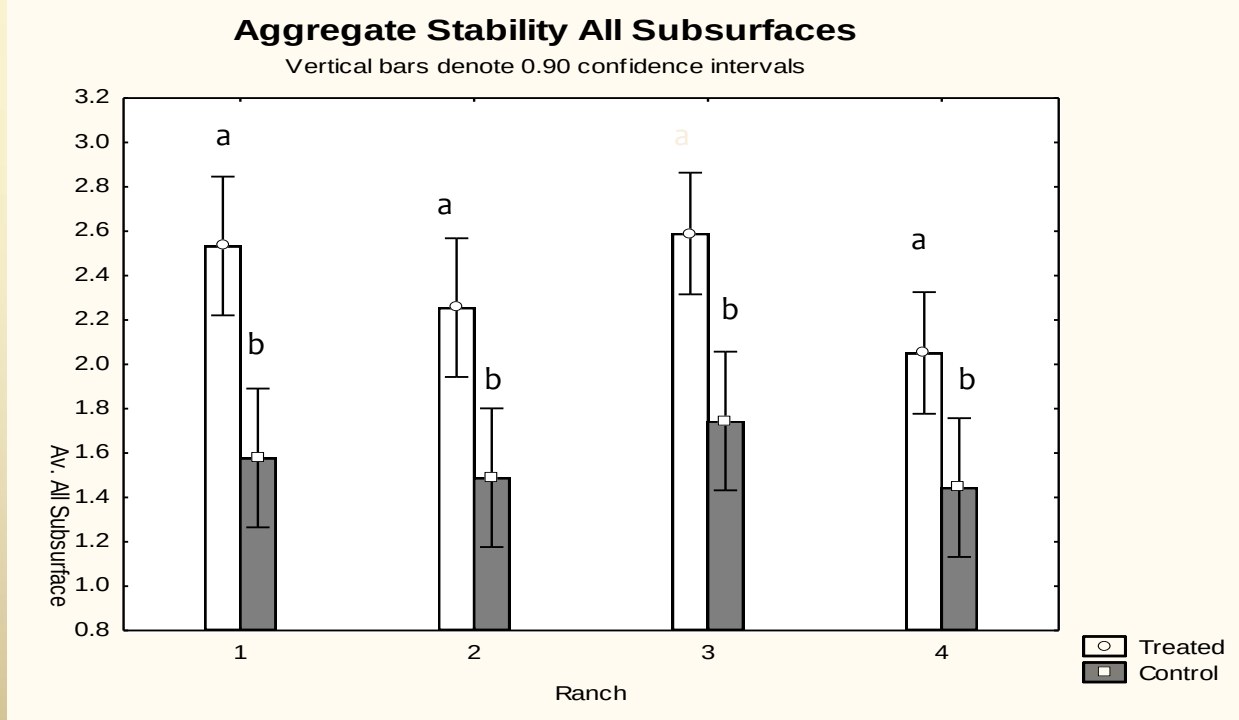
Dunnett's 1985 and 2003 p=0.966



Basal and Canopy Gaps




Aggregate Stability All Surfaces
Vertical bars denote 0.90 confidence intervals
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
a
b
a
b
a
b
b
b
1
2
3
4
Ranch
Treated
Control


Aggregate Stability All Subsurfaces
Vertical bars denote 0.90 confidence intervals
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
Av. All Subsurface
a
b
a
b
a
b
a
b
1
2
3
4
Ranch
Treated
Control

State-and-Transition Model Testing

- Nonhierarchical multivariate exploratory method
  k-means clustering was used to test the proposed model.
- All data elements used except surface soil stability
- Clustering was preformed with 2, 3, 4 and 5 clusters.
- Highest average Euclidean distance determined the optimum number of clusters

State-and-Transition Model

Based on the data used, k-means clustering shows that a 3 state model is optimal

	2 Clusters	3 Clusters	4 Clusters	5 Clusters
Distance	0.140124	0.172404	0.160947	0.158287

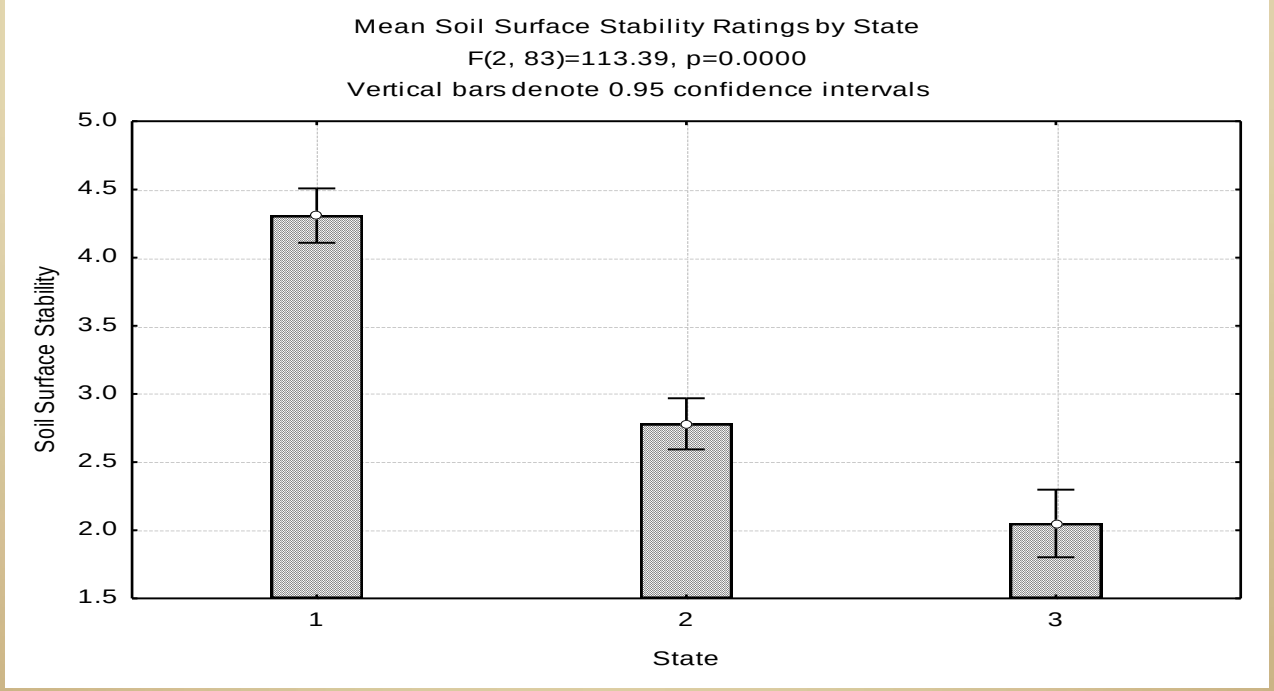
Number of treated and control transects in the resulting 3 states

	Total	Treated	Control
State 1	31	31	0
State 2	35	13	22
State 3	20	2	18

State-and-Transition Model

Surface soil stability data used to validate the k-means clusters.

State	Mean	Stnd Dev	Stnd Error	C.I. -95%	C.I. +95%
1	4.3	0.6	0.1	4.1	4.5
2	2.8	0.6	0.1	2.6	3.0
3	2.0	0.4	0.1	1.9	2.3

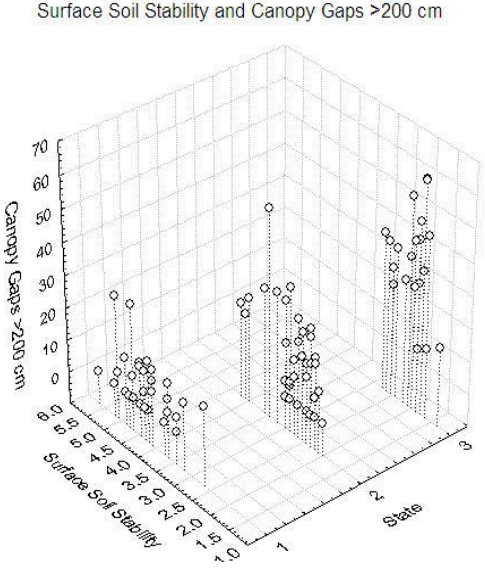


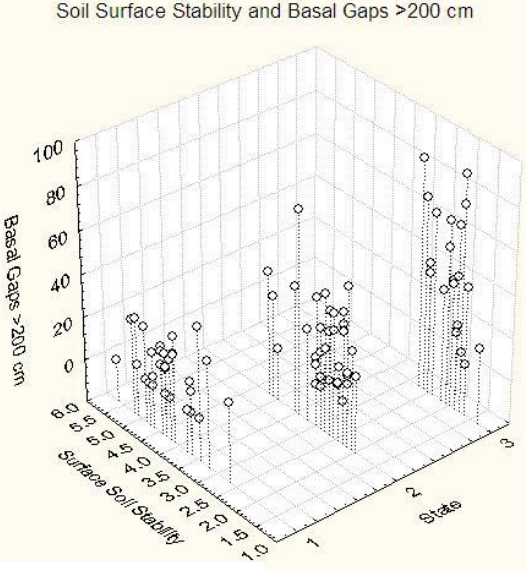
State-and-Transition Model

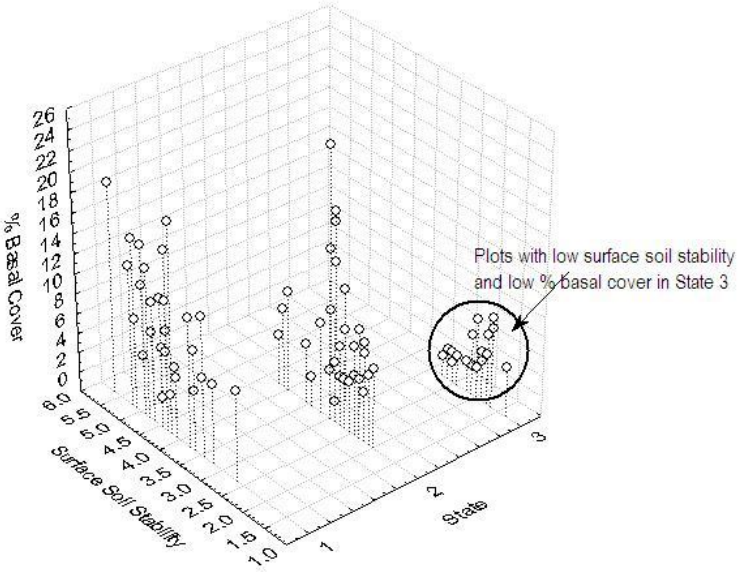
	Reference State 1.0	Juniper State 2.0	Eroded State 3.0
Surface Soil Stability	>4.0	2.6 – 3.0	< 2.4
Subsurface Soil Stability	>2.4	1.6 – 1.8	< 1.6
Canopy Gaps > 200cm	<10%	10% - 20%	> 28%
Basal Gaps > 200cm	< 17%	17% - 29%	> 33%
Basal Cover	>7%	5% - 9%	< 4%
Juniper Foliar Cover	<17%	18% - 27%	>20%
Herb. Foliar Cover	>45%	>45%	<41%
Bare Ground	<33%	28% - 37%	>39%

Values are within 95% C.I. of the mean.

State-and-Transition Model





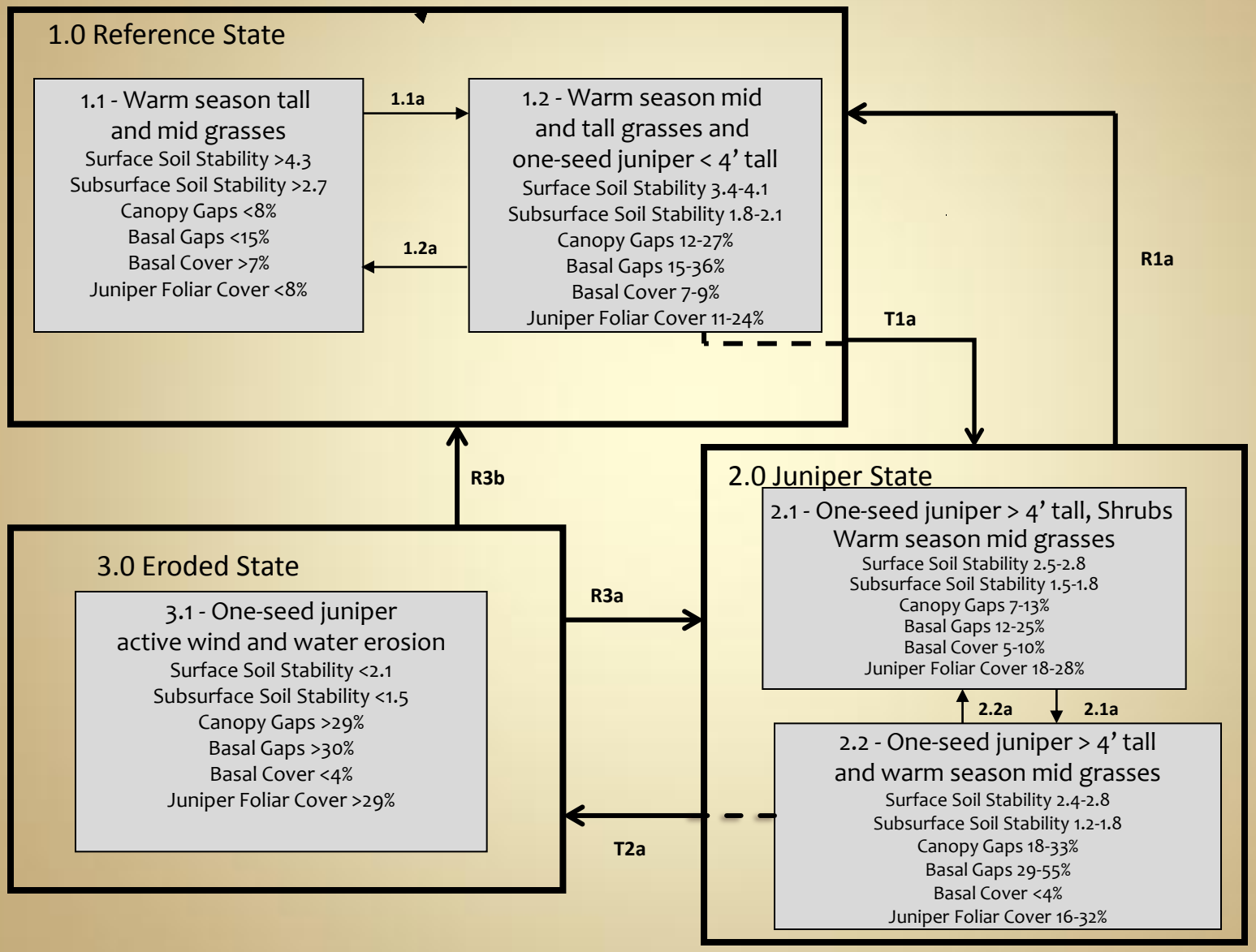


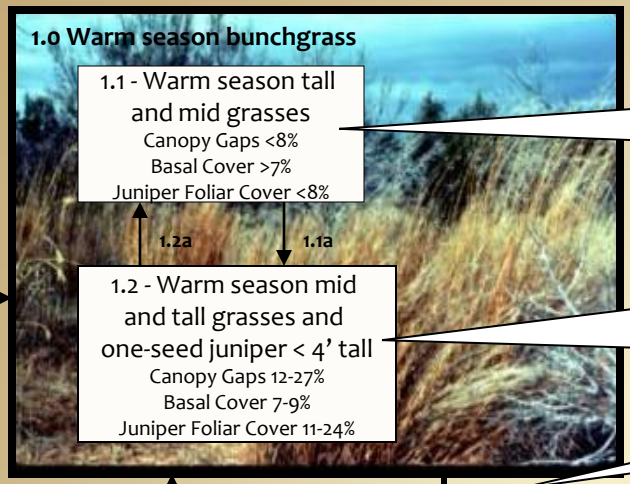
State-and-Transition Model

State	Reference State		Juniper State		Eroded State
Community Phase	1.1	1.2	2.1	2.2	3.1
Surface Soil Stability	>4.3	3.4 – 4.1	2.5 – 2.8	2.4 – 2.8	<2.1
Subsurface Soil Stability	>2.7	1.8 – 2.1	1.5 – 1.8	1.2 – 1.8	<1.5
Canopy Gaps > 200cm	<8%	12 – 27%	7 – 13%	18 – 33%	>29%
Basal Gaps > 200cm	<15%	15 – 36%	12 – 25%	29 – 55%	>30%
Basal Cover	>7%	5 – 9%	5 – 10%	<4%	<4%
Juniper Foliar Cover	<8%	11 – 24%	18 – 28%	16 – 32%	>29%
Herb. Foliar Cover	>46%	40 – 54%	47 – 57%	32 – 46%	<30%
Bare Ground	<32%	24 – 42%	27 – 37%	33 – 47%	>39%

Value ranges within 95% C.I. of the mean

State-and-Transition Model





1.1a: " … time since last fire or by a series of dry years followed by wet years. … opportunity for juniper seedling establishment increases. … decreases herbaceous production, crown cover and organic matter input into the soil, … allow juniper seed germination and establishment…"

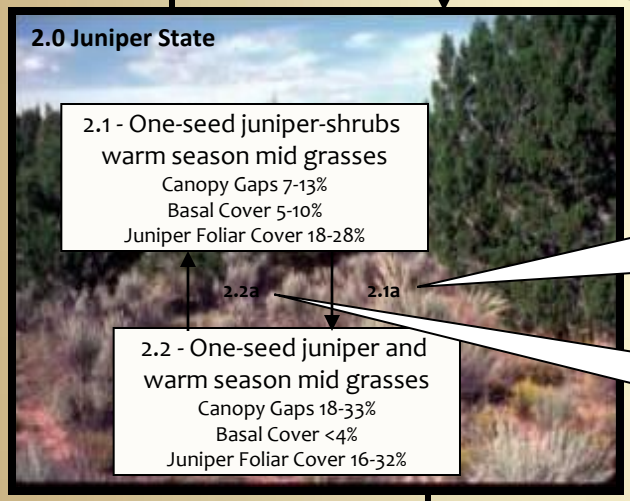
1.2a:"… fire frequency allows for ground fires that remove juniper seedlings and established plants less than 1.5 meters tall…"

T1a: "… slow variables and triggers for this transition are the elimination of fire due to decrease in fine fuels allowing juniper canopy. The threshold values… surface soil stability < 3.4, basal cover <7%, juniper foliar cover >24%, juniper >4' tall…"

R2a

T1a

R2a:"… removal of juniper canopy cover to < 5% with minimal soil surface disturbance… management actions that increases herbaceous production and favors the establishment and growth of warm season tall and mid grasses…"

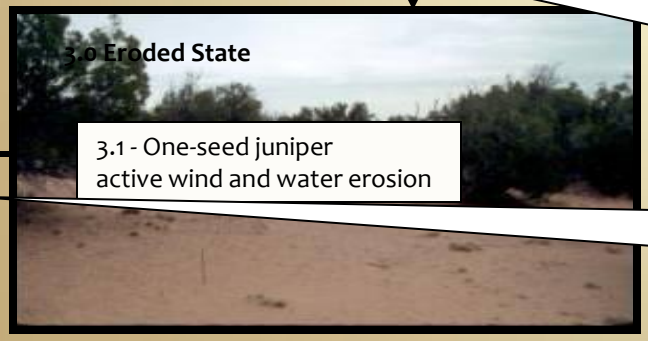


2.1a:"… juniper canopy increases with time since last fire …other management action to reduce juniper canopy… increase in juniper canopy decreases shrub and herbaceous production and cover… shrubs and tall grasses decrease or are eliminated… drought years followed by wet years will allow for increase in juniper establishment…"

2.2a:"… management actions that decrease juniper canopy and increase herbaceous and shrub production… can include prescribed burning, chemical or mechanical brush management, while other management actions are aimed at increasing herbaceous production… "

T2a

T2a:"… slow variables and trigger for this transition are increase in juniper seedling establishment and juniper cover… caused by management actions that lead to decreased herbaceous production and decreased organic matter inputs… by lack of management actions that actively reduce juniper canopy cover… threshold values…surface soil stability <2.4, bare ground >40%, canopy gaps >30%, basal cover <4%. …"



R3a

R3a:"… management and restoration planned must decrease juniper canopy to <5%…little or no surface disturbance, management actions must increase herbaceous production… allow for litter accumulation… improve organic matter inputs to stabilize soil surface… "


Thank You