Ecological Sites and State-and-Transition Models:

Concepts and Components

Threshold

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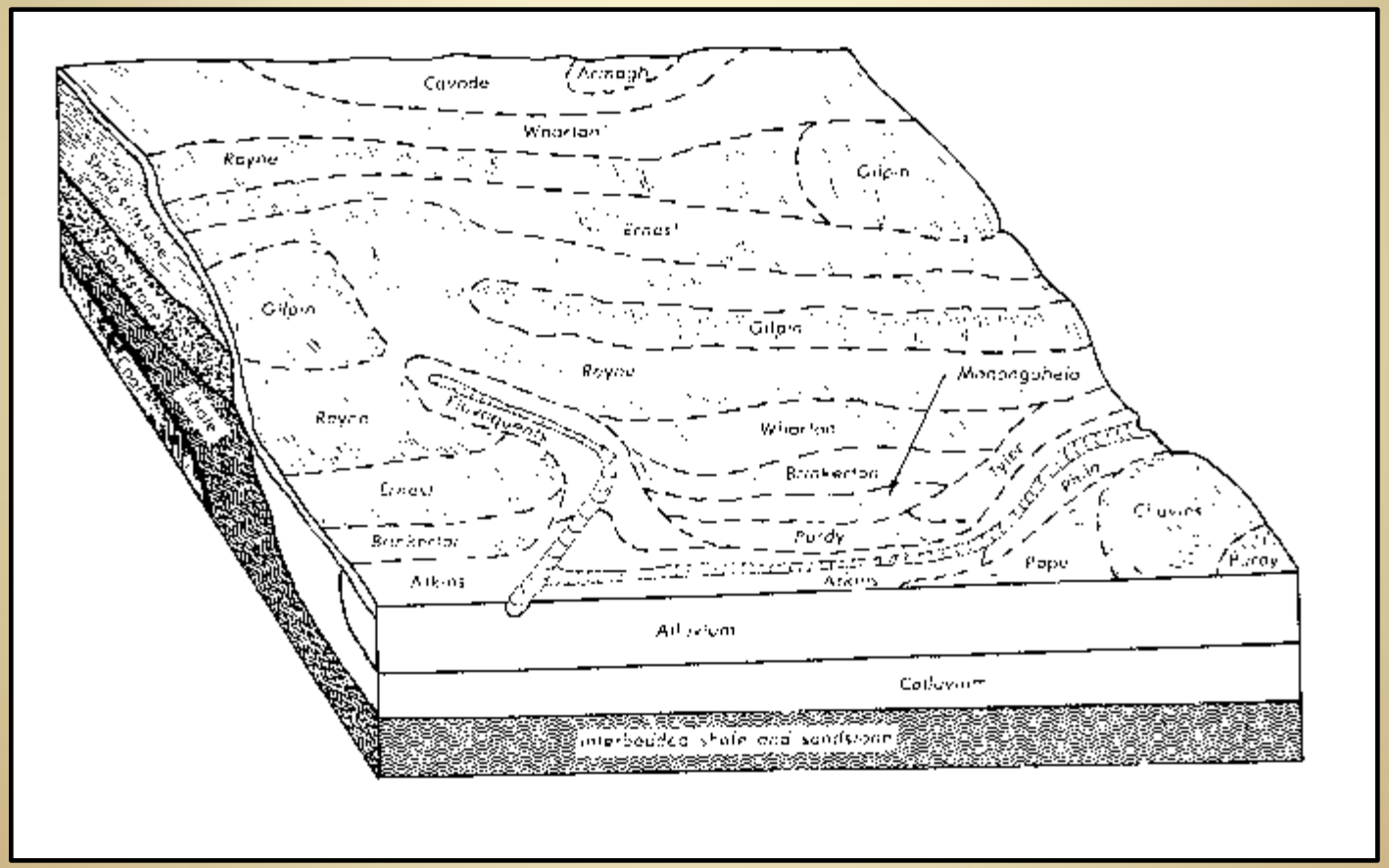
Looking across any landscape it is not difficult to recognize that...

...some parts are different from other parts in the kinds and amounts of vegetation.

ECOLOGICAL SITE



ECOLOGICAL SITE

DEFINITION:

"a **distinctive kind of land** based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its **ability to produce** distinctive kinds and amounts of vegetation and in its **ability to respond** similarly to management actions and natural disturbances" Interagency Ecological Site Handbook for Rangelands 2011

Each Ecological Site is the product of all the Environmental Factors responsible for its development.

Soils

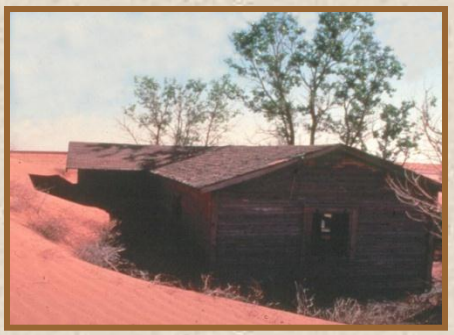
Topography

Climate

Other factors include Natural Disturbances such as:

Fire

Herbivory



Drought

ECOLOGICAL SITE

DIFFERENTIATION BETWEEN ECOLOGICAL SITES:

- **Significant differences in the species that are in the reference plant communities**
- **Significant differences in the relative proportion of species in the reference plant communities**
- **Significant differences in the total annual production of the reference plant communities**
- **Significant differences in the response of the reference state to natural disturbance or management actions**

Ecological Site Description

Reports with associated data that document the characteristics of an ecological site and the interpretations of its properties related to use and management.

ECOLOGICAL SITE DESCRIPTIONS

- **NON-EQUILIBRIUM ECOLOGY**
- **INTERPRETATIONS for MULTIPLE ECOLOGICAL SERVICES**

- **PLANT COMMUNITY SCALE**
- **SOIL MAP UNIT COMPONENTS**

EQUILIBRIUM SYSTEM DYNAMICS

CLEMENTS (1916)

vegetation as a 'superorganism' determined by climate

succession was predictable and had a predetermined outcome

vegetation change was an autogenic process driven by succession

DYKESTERHIUS (1949, 1958)

concept of functional edaphic units

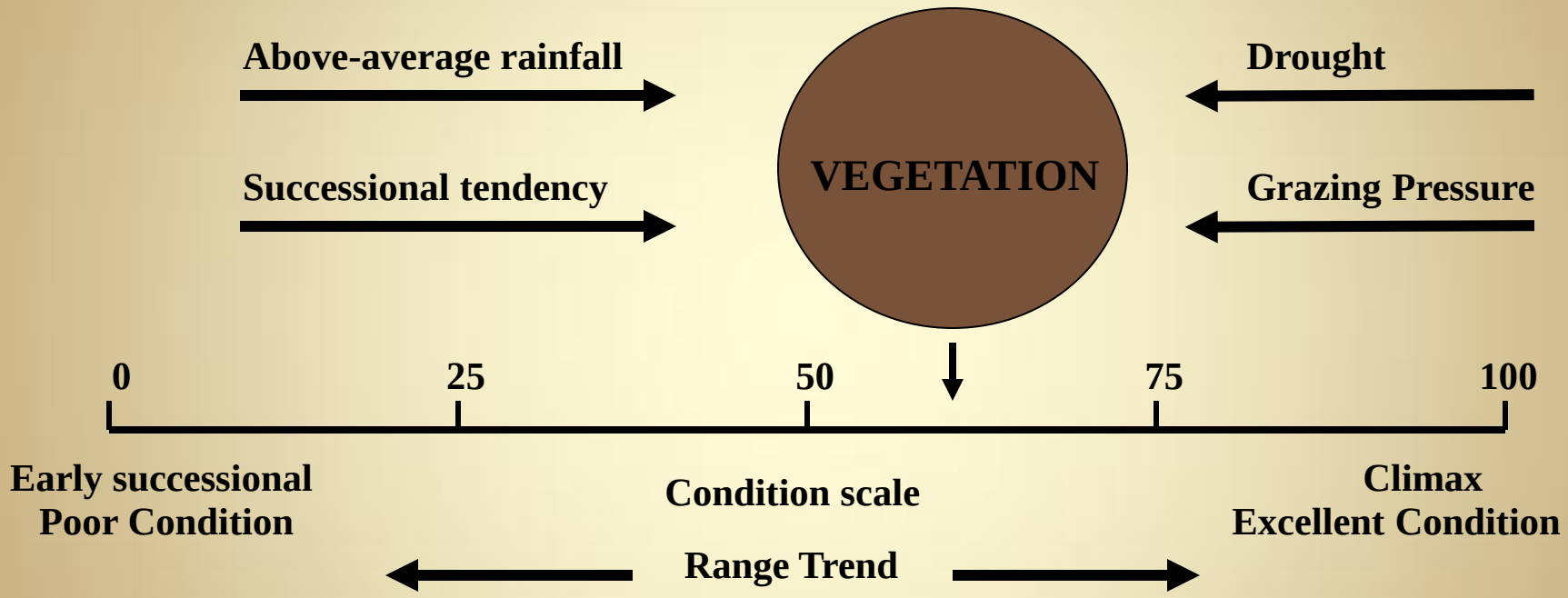
plant community/soil combination resulted in a unique (range) site

established concept of 'dynamic equilibrium'

described in terms of species dominance

(from Brown and Tugel 2001)

RANGE SUCCESSION MODEL



(adapted from Westoby, Walker, Noy-Meir 1989)

NONEQUILIBRIUM SYSTEM DYNAMICS

HOLLING 1973: RESILIENCE AND STABILITY

MAY 1977: THRESHOLDS AND BREAKPOINTS

WESTOBY et al 1989: STATE AND TRANSITION

STRINGHAM et al 2003: DEFINITIONS & STRUCTURE

BRISKE et al 2008: RESILIENCE & S&T

multiple steady states-structural dominance, function may change

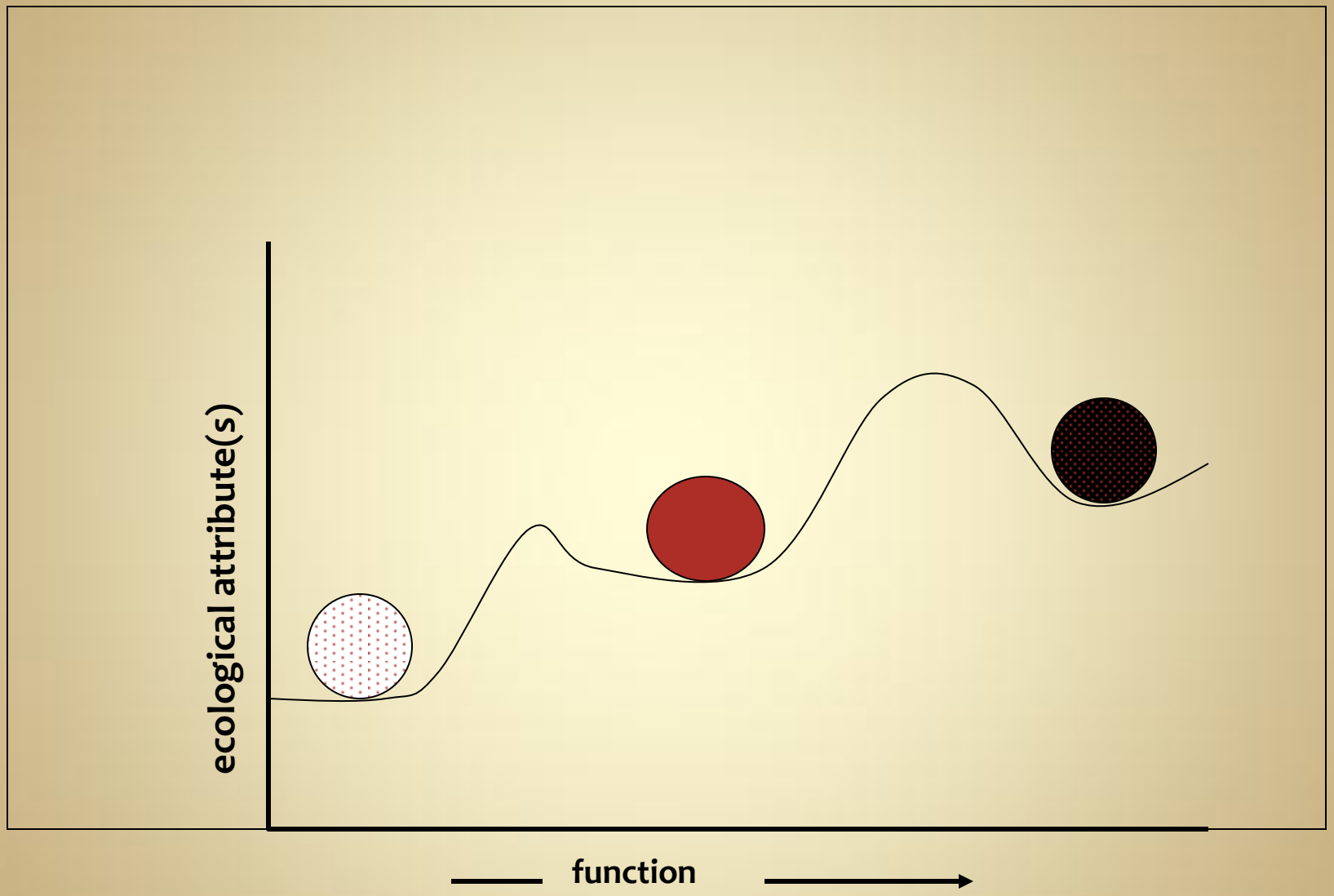
thresholds-point of entry into new domain (state)

hysteresis-lag times, failure to return to original system

feedbacks-positive feedback accelerates change

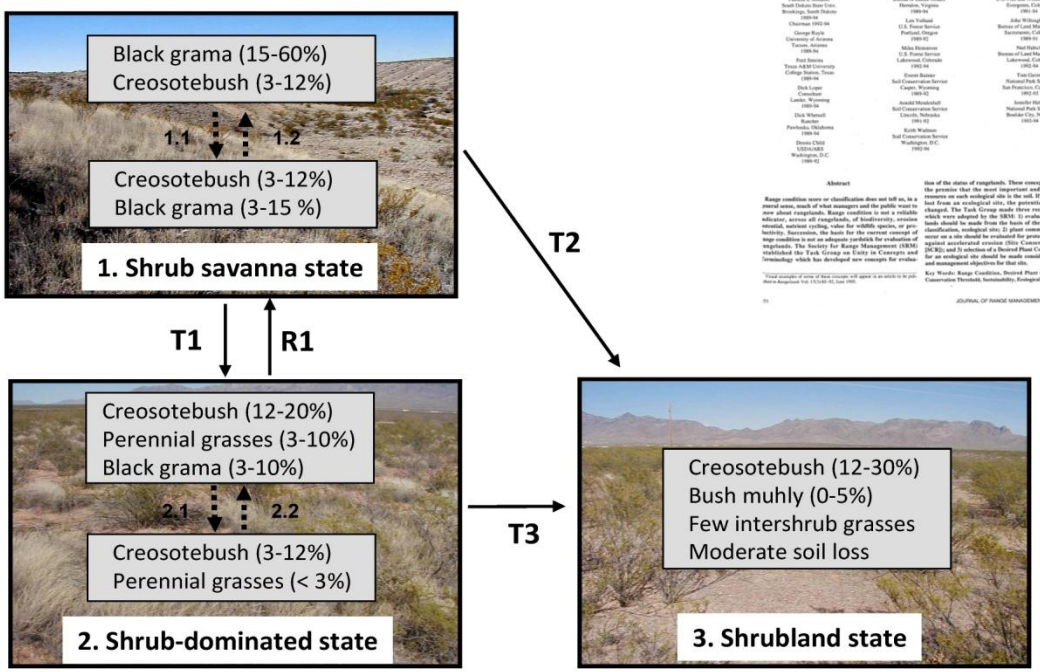
negative feedback suppresses change

(from Brown and Tugel 2001)


ecological attribute(s)
function

History of ecological sites

State-and-transition model

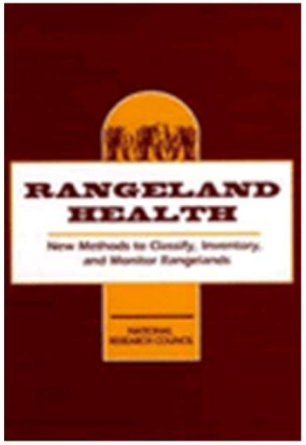


NEW CONCEPTS FOR ASSESSMENT OF RANGELAND CONDITION

TASK GROUP ON UNITY IN CONCEPTS AND TERMINOLOGY
COMMITTEE MEMBERS

Abstract

JOURNAL OF RANGE MANAGEMENT 48(3), May 1995



- **Alternative states potentially occupy a site**
- **Emphasis on dynamic soil properties as a basis for sustainability**
- **'Thresholds' of rangeland health and early warning indicators**

ECOLOGICAL SYSTEM DYNAMICS

competing paradigms

CLEMENTS (1916)

DYKSTERHIUS (1949, 1958)

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climatic climax endpoint

CHANGE

linear

deterministic

disturbance unimportant

competition important

VON BERTALANFFY 1968

HOLLING 1973

MAY 1977

WESTOBY et al 1989

STRINGHAM et al 2003

BRISKE et al 2008

---

multiple steady states

CHANGE

nonlinear

disturbance important

competition-less important

thresholds

Key Concepts for ESDs

Disturbance ecology

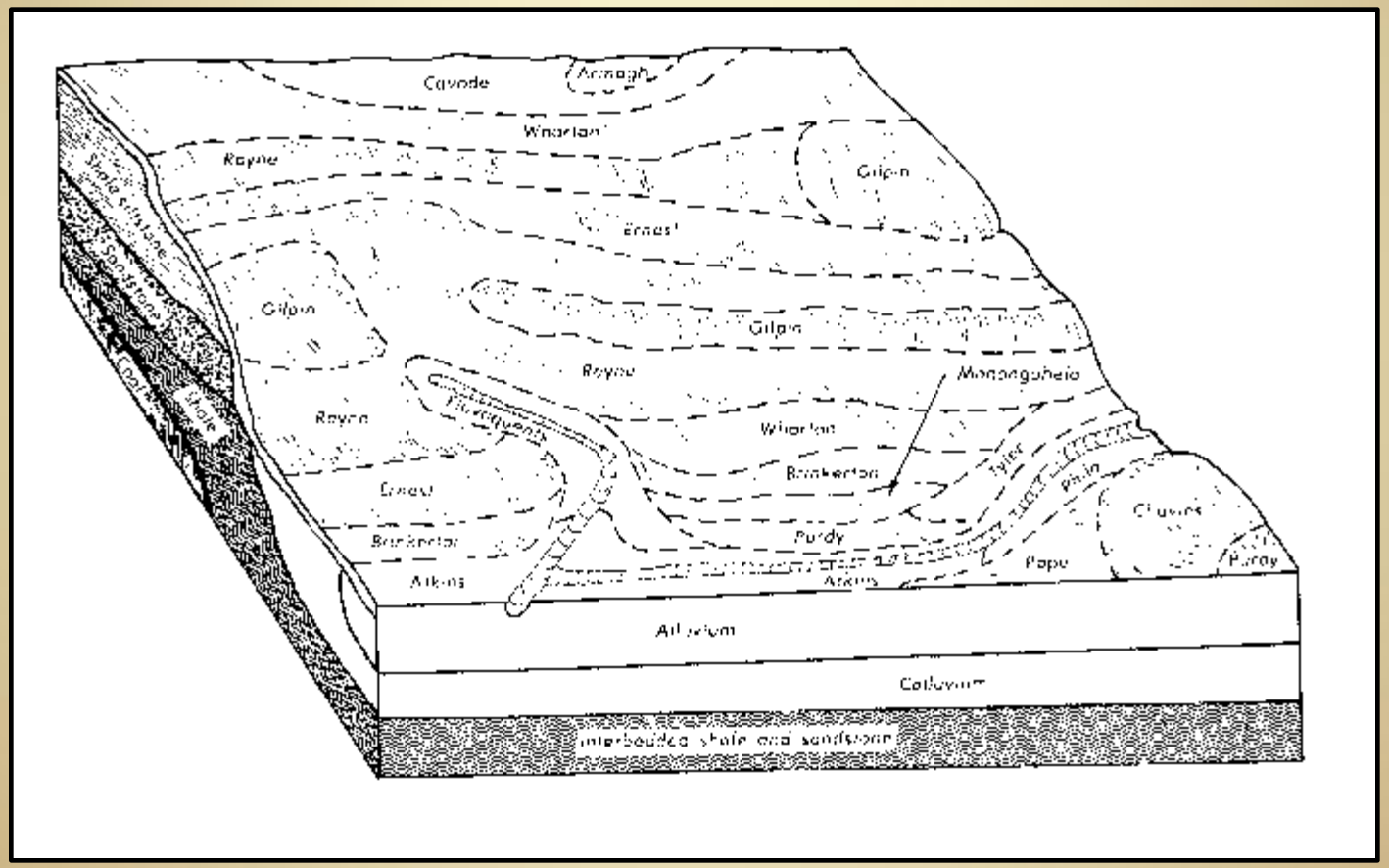
- Existence of multiple stable states
- State-and-Transition Models
  - Resistance and resilience (thresholds)
  - Soil plant systems (positive and negative feedbacks)

Archer 1989

Ecological Site Description Components

- SITE CHARACTERISTICS-ABIOTIC (distinguishing landscape position, climate, hydrology, soils including variability)
- ECOLOGICAL DYNAMICS-BIOTIC
  - STATE AND TRANSITION MODELS (soil/vegetation interactions, drivers of change-wildlife, weather, fire, management)
  - PLANT COMMUNITY COMPOSITION AND PRODUCTION
- INTERPRETATIONS-VARIETY OF ECOLOGICAL SERVICES
- REFERENCES

ECOLOGICAL SITE



Step 2. Soil-landscape variables used to classify ecological sites

Slope and aspect

Water table depth

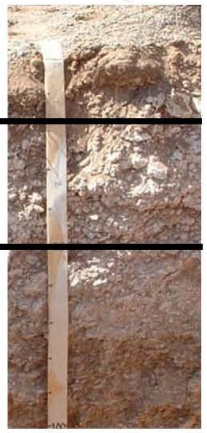
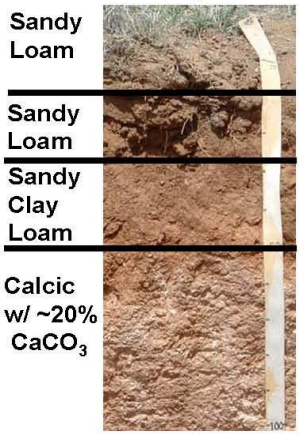
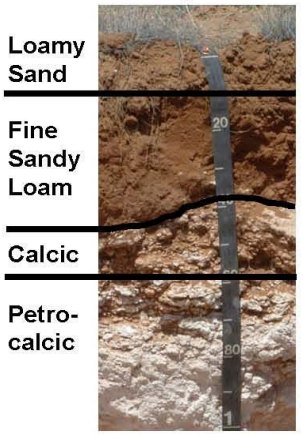
Flooding duration

Soil texture
(by depth)

Soil chemistry
(gypsum, sodium)

Soil depth
(kind of restrictive horizon)

“Concepts” for three ecological sites

	Gravelly	Loamy	Sandy
Profile characteristics			
Soil processes	Shallow rooting depth, high gravel, low water holding capacity	High water holding capacity plus run-on, susceptible to erosion/ compaction	High water holding capacity, susceptible to wind erosion
Potential vegetation	Low production of grasses and shrubs	Moderate-high production of mixed grasses	Moderate production of black grama grass
Dynamics	Shrub infill	Shrub invasion and scalding (bare ground)	Shrub invasion and dune formation

ECOLOGICAL DYNAMICS

STATE AND TRANSITION MODELS
(soil/vegetation interactions, drivers of change-wildlife, weather, fire, management)

Both diagram and narrative description of the ecological dynamics occurring on the ecological site.

State and Transition Models

- Westoby,Walker, Noy-Meir (1989) – Management 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*

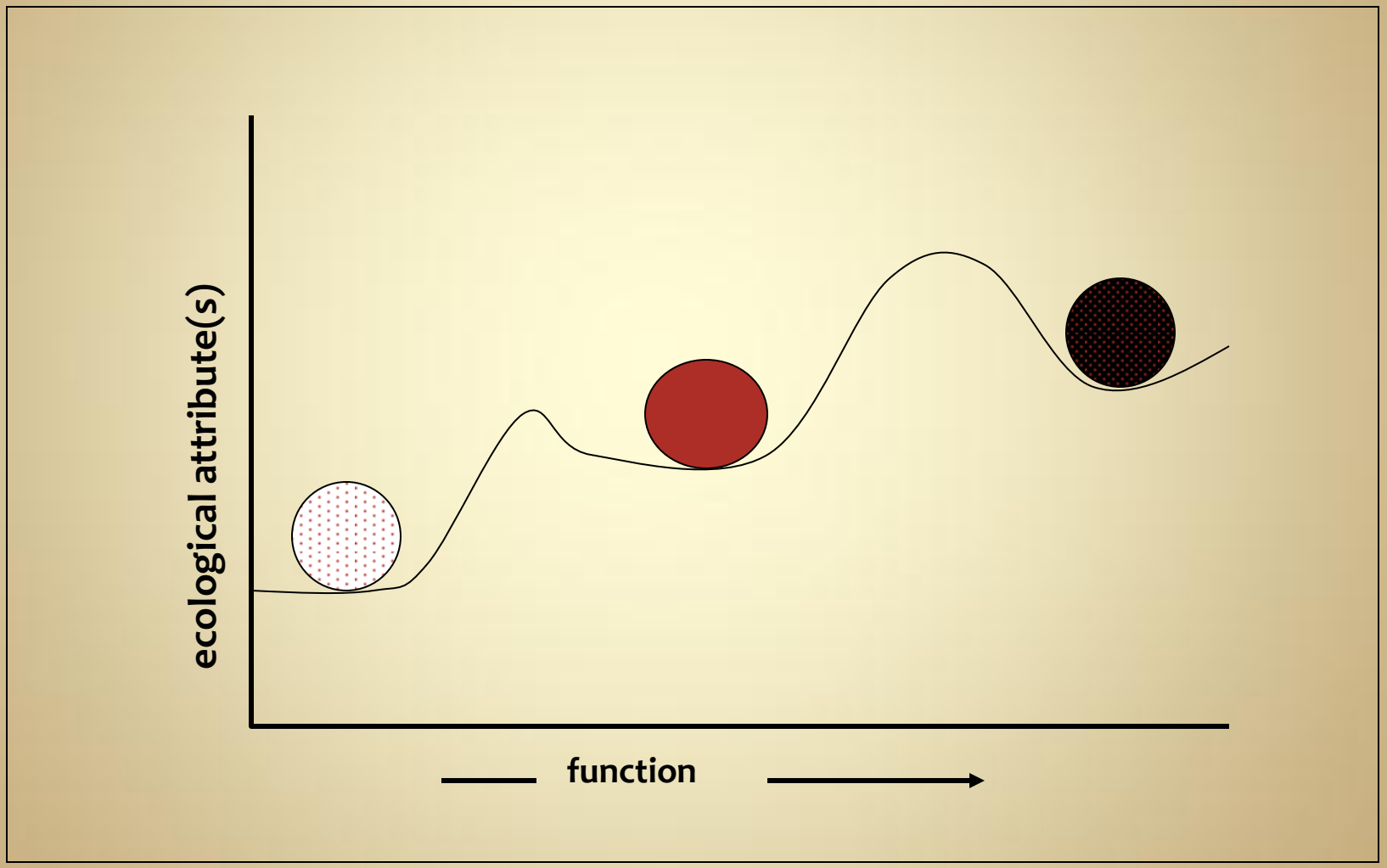
- *soil - developed through time from specific parent material, climate, landscape position and interaction with biota*

  - 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

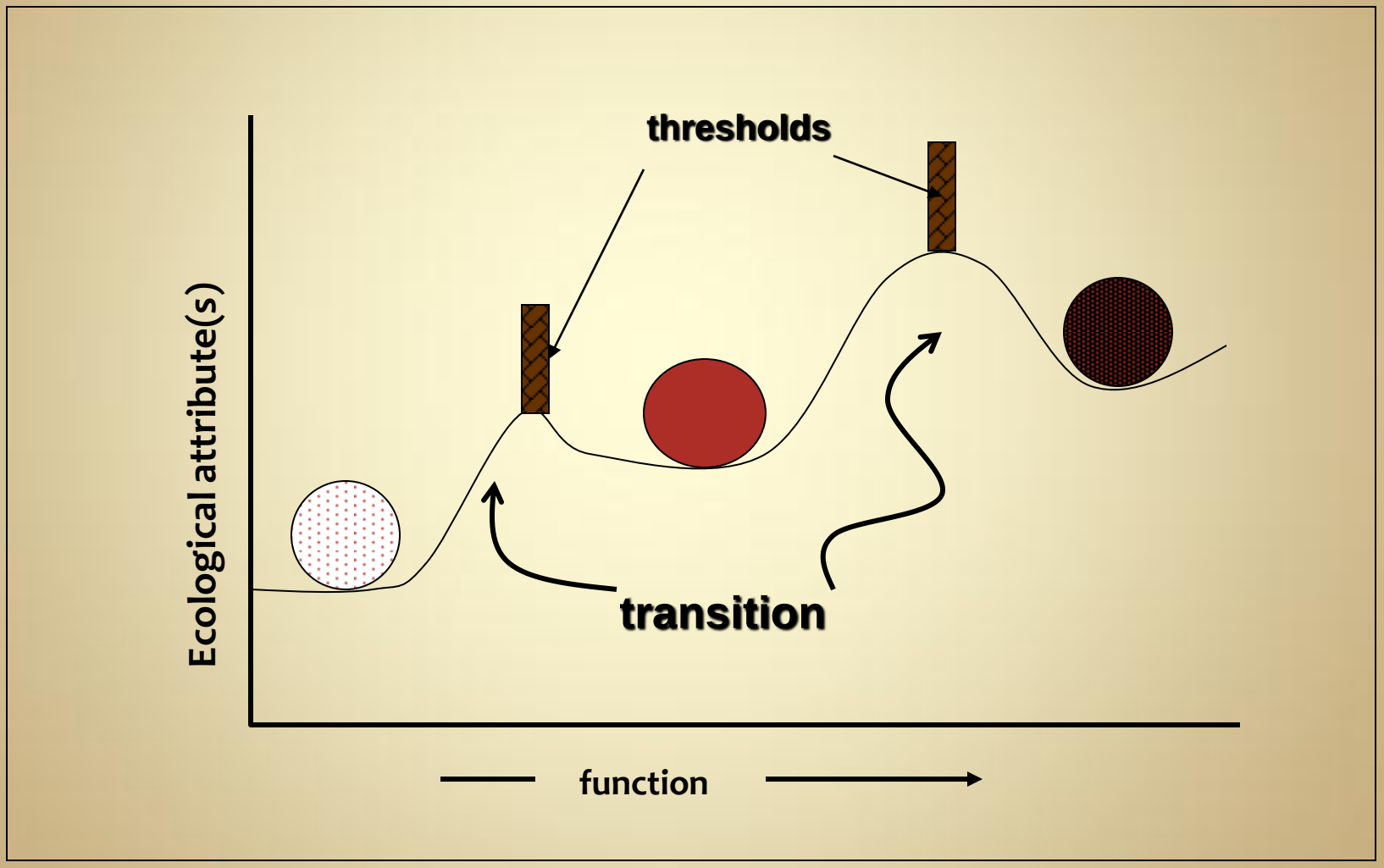
- degrades the integrity of one or more of the state's primary ecological processes beyond the point of self repair

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

- irreversible for practical purposes without input of outside energy

Stringham, et al., 2003

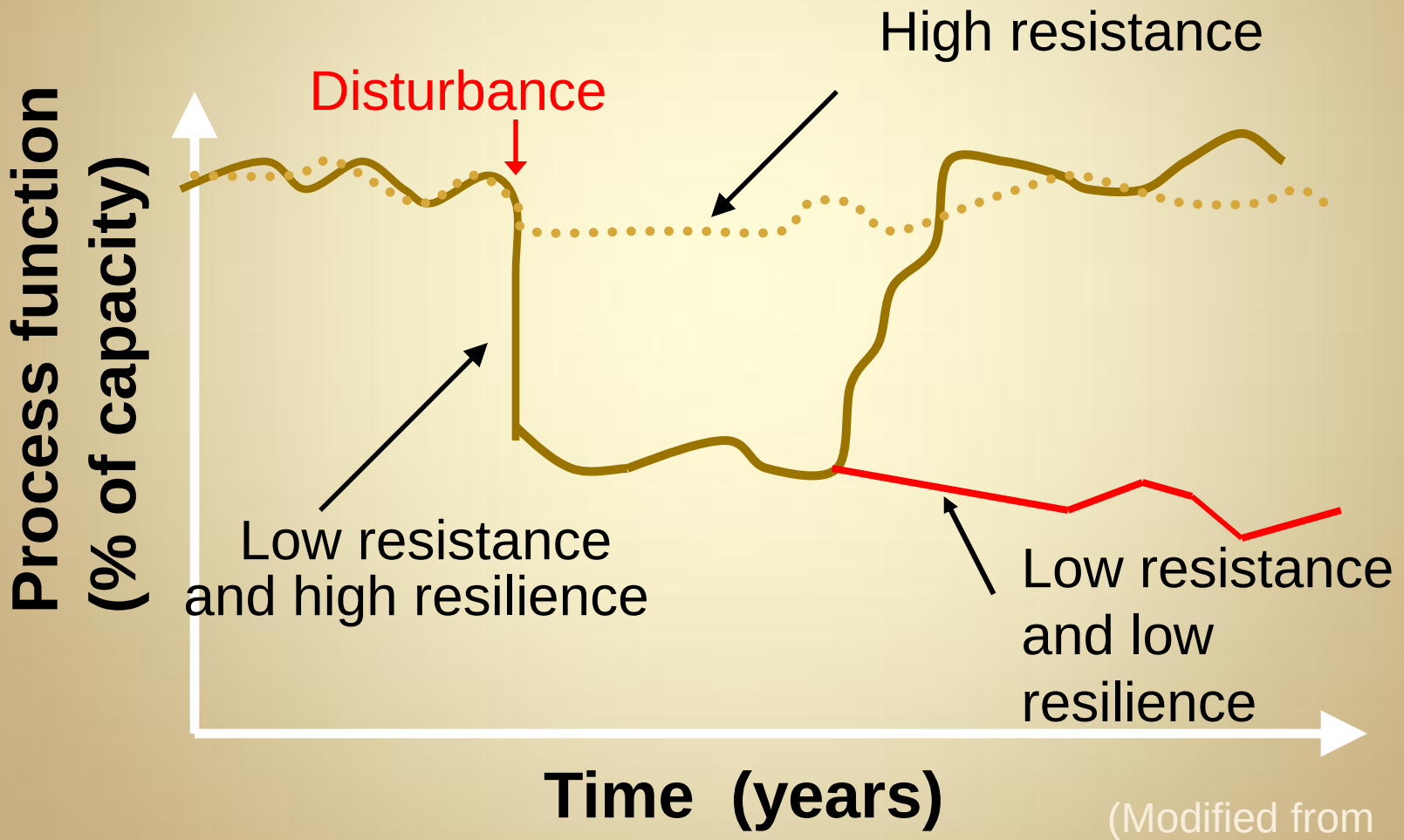
TRANSITIONS



- **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.

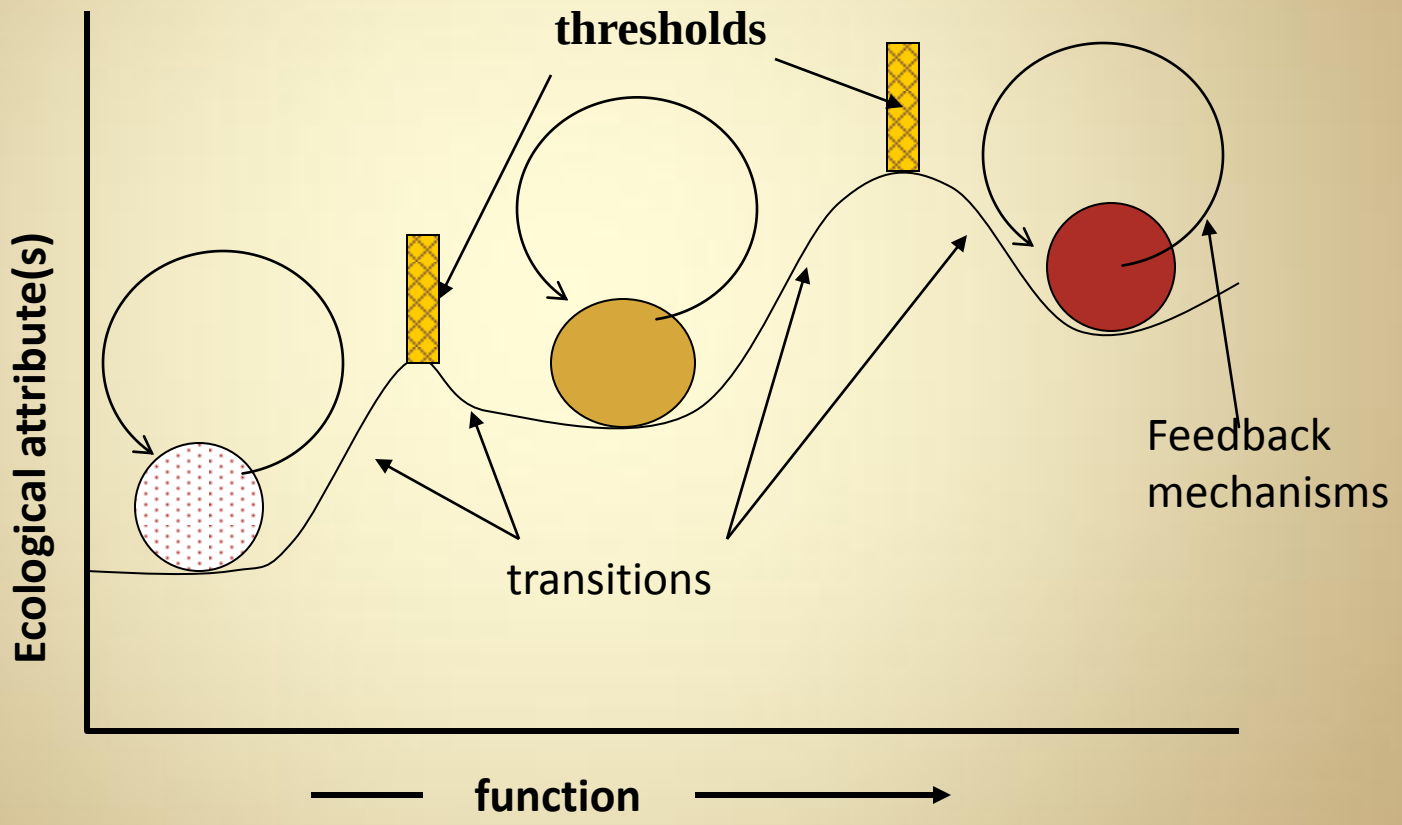
(Briske et al 2008)

Function, Resistance and Resilience



(Modified from Seybold, et al, 1999)

STATES


thresholds
Ecological attribute(s)
transitions
Feedback
mechanisms
function

PLANT COMMUNITY PHASES

COMMUNITY PHASES

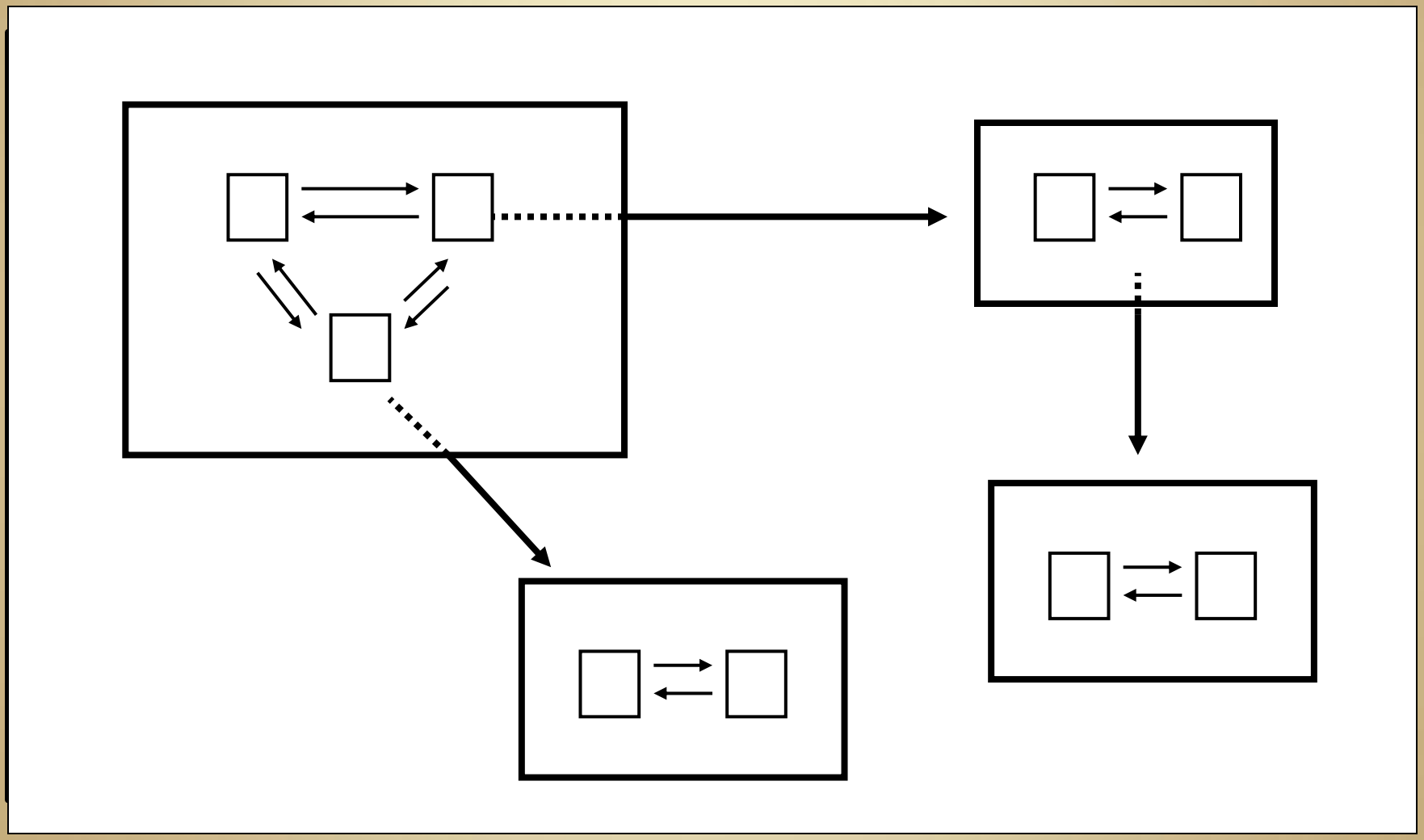
-Different assemblages within a state that do not represent a state change since a threshold has not been crossed

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

COMMUNITY PATHWAYS

- Causes of change between plant communities

BUILDING STATE and TRANSITION MODELS



thresholds

Ecological attribute(s)

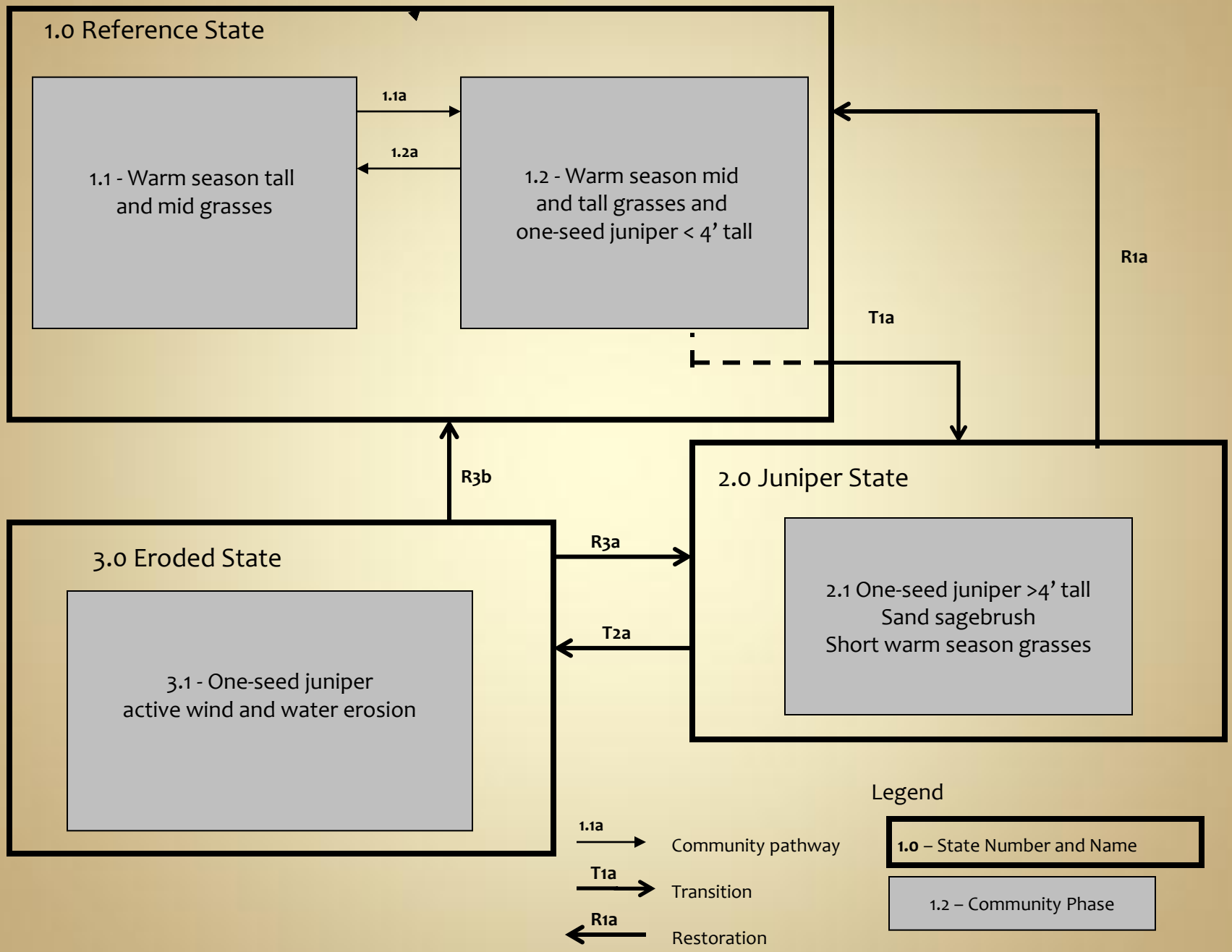
Feedback mechanisms

transitions

function

Deep Sand Savannah

Deep Sand Savannah


1.0 Reference State
1.1 - Warm season tall and mid grasses
1.1a
1.2a
1.2 - Warm season mid and tall grasses and one-seed juniper < 4' tall
R1a
T1a
R3b
2.0 Juniper State
2.1 One-seed juniper >4' tall
Sand sagebrush
Short warm season grasses
R3a
T2a
3.0 Eroded State
3.1 - One-seed juniper active wind and water erosion
Legend
1.1a
Community pathway
T1a
Transition
R1a
Restoration
1.0 – State Number and Name
1.2 – Community Phase

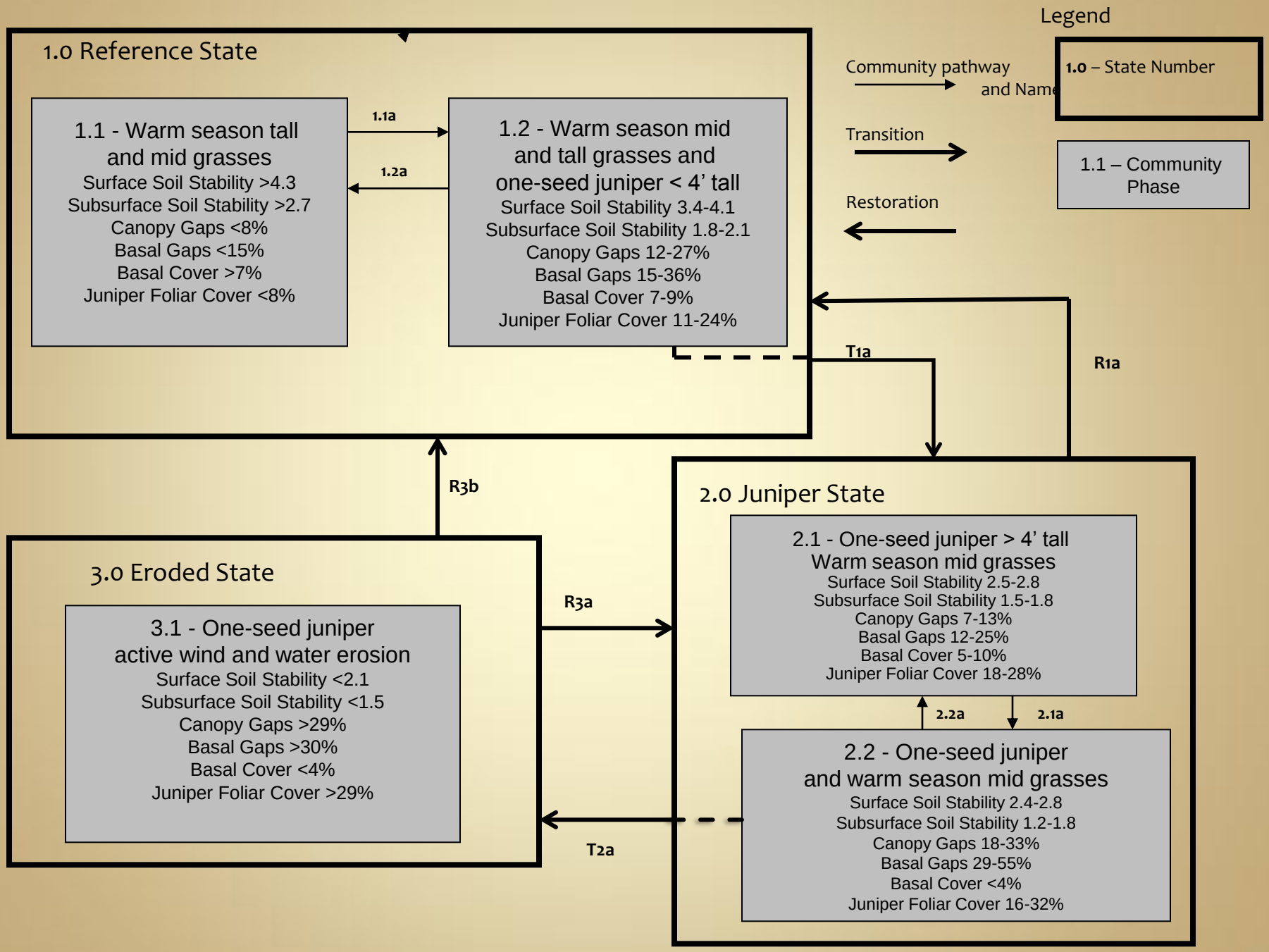
State-and-Transition Model

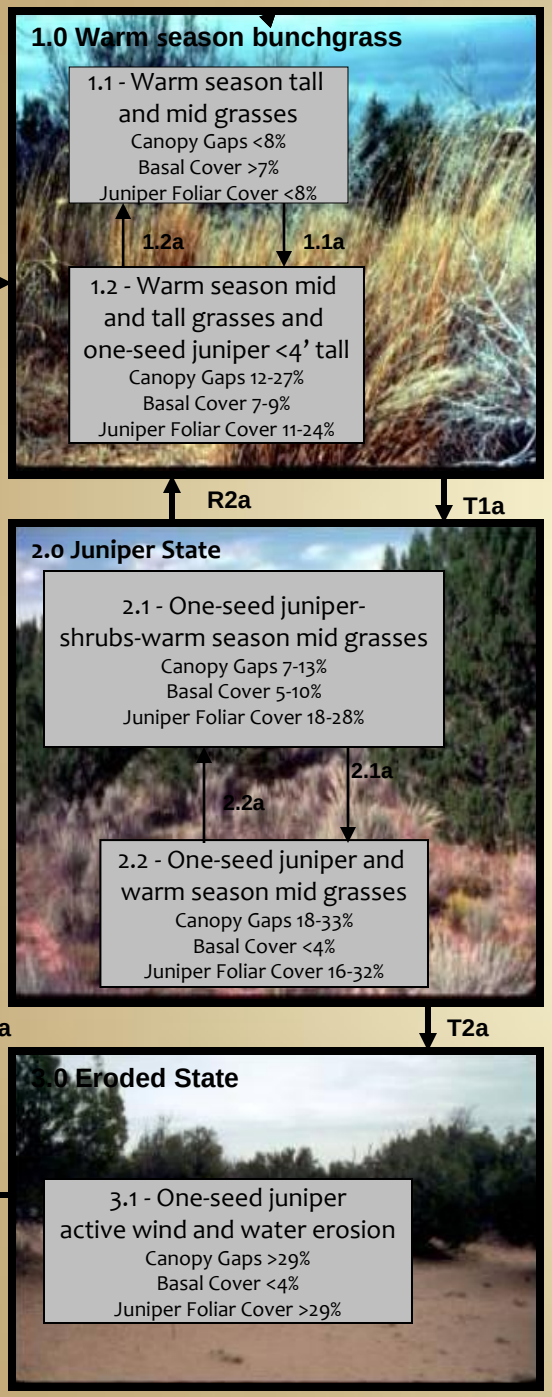
	Reference State 1.0	Juniper State 2.0	Eroded State 3.0
Species	Lbs./ac.	Lbs./ac.	Lbs./ac. 0
Sand Bluestem	400 - 500	100-150	0
Little Bluestem	300 - 400	150 - 300	0 - 50
Sideoates Grama	100 - 150	100 - 150	0 - 20
Indian Ricegrass	80 - 150	50 - 75	0 - 10
Sandhill Muhly	0 - 25	20 - 80	100 - 120
Sand Sagebrush	0 - 20	50 - 150	0 - 20
One-seed Juniper	0 - 50	230 - 350	400

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.

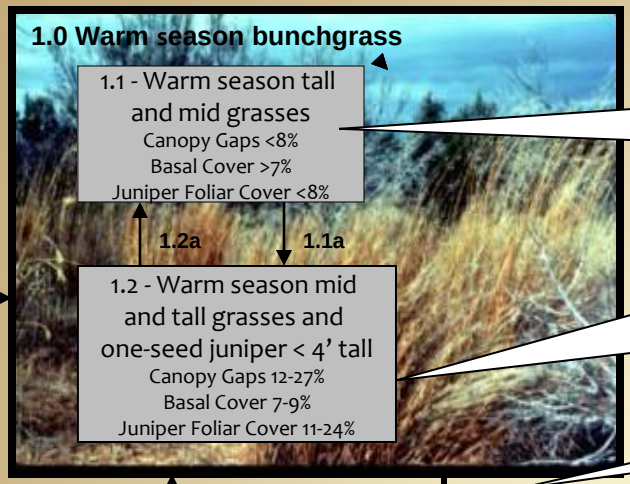

Legend
1.0 – State Number
Community pathway and Name
Transition
Restoration
1.1 – Community Phase
1.0 Reference State
1.1 - Warm season tall and mid grasses
Surface Soil Stability >4.3
Subsurface Soil Stability >2.7
Canopy Gaps <8%
Basal Gaps <15%
Basal Cover >7%
Juniper Foliar Cover <8%
1.1a
1.2a
1.2 - Warm season mid and tall grasses and one-seed juniper < 4' tall
Surface Soil Stability 3.4-4.1
Subsurface Soil Stability 1.8-2.1
Canopy Gaps 12-27%
Basal Gaps 15-36%
Basal Cover 7-9%
Juniper Foliar Cover 11-24%
T1a
R1a
R3b
2.0 Juniper State
2.1 - One-seed juniper > 4' tall Warm season mid grasses
Surface Soil Stability 2.5-2.8
Subsurface Soil Stability 1.5-1.8
Canopy Gaps 7-13%
Basal Gaps 12-25%
Basal Cover 5-10%
Juniper Foliar Cover 18-28%
2.2a
2.1a
2.2 - One-seed juniper and warm season mid grasses
Surface Soil Stability 2.4-2.8
Subsurface Soil Stability 1.2-1.8
Canopy Gaps 18-33%
Basal Gaps 29-55%
Basal Cover <4%
Juniper Foliar Cover 16-32%
3.0 Eroded State
3.1 - One-seed juniper active wind and water erosion
Surface Soil Stability <2.1
Subsurface Soil Stability <1.5
Canopy Gaps >29%
Basal Gaps >30%
Basal Cover <4%
Juniper Foliar Cover >29%
R3a
T2a



1.0 Warm season bunchgrass (reference state): Two community phases
Diagnosis & Indicators: High perennial grass cover and production. Surface soil stability >3.4, one-seed juniper less than 4'tall.
Feedbacks & Ecological Processes: Organic matter inputs allows for increased soil moisture, herbaceous production, root turnover and litter increasing soil surface stability, infiltration and nutrient cycling.
1.1 Warm season tall and mid grasses (reference phase): Canopy gaps <8%, basal cover >7% and juniper foliar cover <8%, surface soil stability >4.3, subsurface soil stability >2.7, bare ground <32%.
1.2 Warm season mid & tall grasses and one-seed juniper <4' tall (at-risk phase): Canopy gaps 12-27%, basal cover 7-9%, juniper foliar cover 11-24%, juniper <4' tall, surface soil stability 3.4-4.1, subsurface soil stability 1.8-2.1, bare ground 24-42%.
Management: Management actions focus on activities that maintain herbaceous production and organic matter inputs. Prescribed burning or other actions to limit juniper establishment and growth are necessary.
Transition-1a: *Slow variables and triggers*: Elimination of fire and overgrazing causing increase juniper establishment and growth.
Thresholds: Surface soil stability <3.4, basal cover <7%, juniper foliar cover >24%, juniper >4' tall.
Restoration Pathway-R2a: Decrease juniper canopy cover and height, increase organic matter inputs.

2.0 Juniper State (alternative state 2): Two community phases
Diagnosis & Indicators: Juniper canopy cover controls the soil moisture, herbaceous production and organic matter inputs. Juniper >4' tall, Surface Soil Stability 1.2-1.8.
Feedbacks & Ecological Processes : Juniper use of moisture, decreasing herbaceous production, decreasing organic matter inputs, and nutrient cycle, decreasing infiltration and surface soil stability.
2.1 One-seed juniper-shrubs-warm season mid grasses: Juniper >4' tall, with foliar cover 18-28%, understory shrubs common, canopy gaps 7-13%, basal cover 5-10%, surface soil stability 2.5-2.8, subsurface soil stability 1.5-1.8, bare ground 27-37%.
2.2 One-seed juniper warm season mid grasses (at-risk phase): Juniper >4' tall, with foliar cover 16-32%, understory shrubs missing, canopy gaps 18-33%, basal cover <4%, surface soil stability 2.4-2.8, subsurface soil stability 1.2-1.8, bare ground 33-47%.
Management: Management actions focus maintaining understory shrub and herbaceous production and ground cover. Manipulation of brush species, prescribed burning and other management focused to maintain or improve herbaceous production and shrub cover.
Transition-2a: *Slow variables and triggers*: Juniper canopy increase causing decrease in shrubs understory and herbaceous production and cover causing decrease in organic matter inputs.
Thresholds: Surface soil stability <2.4, bare ground >40%, canopy gaps >30%, basal cover <4%.

3.0 Eroded State (alternative state 3) one community phase-3.1: Active wind & water erosion .
Diagnosis & Indicators: Juniper foliar cover >29%, surface soil stability <2.1, subsurface soil stability <1.5, canopy gaps >29%, basal cover <4%, bare ground >39%.
Feedbacks & Ecological Processes: Juniper use of all available moisture, eliminates organic matter inputs, decreases soil surface stability, increases wind and water erosion.
Restoration Pathway-R3a: Restoration practices planned must decrease juniper canopy with little or no surface disturbance, increase herbaceous production and allow for litter accumulation to improve organic matter inputs to stabilize soil surface.



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…"

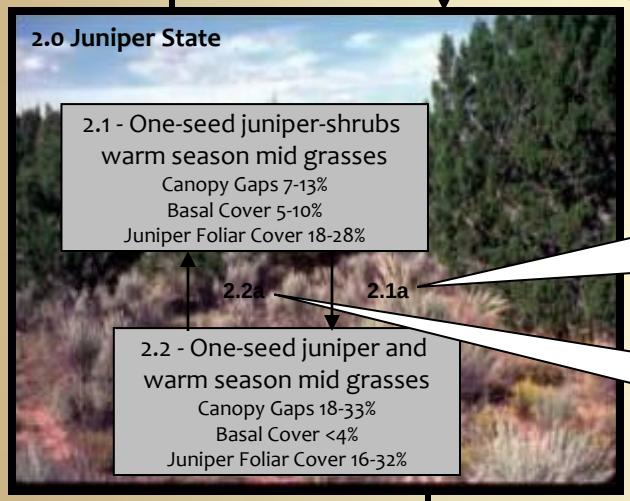
1.2a:"…fire frequency allows for ground fires that remove juniper seedlings and established plants less than 1.5 meters tall…"

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…"

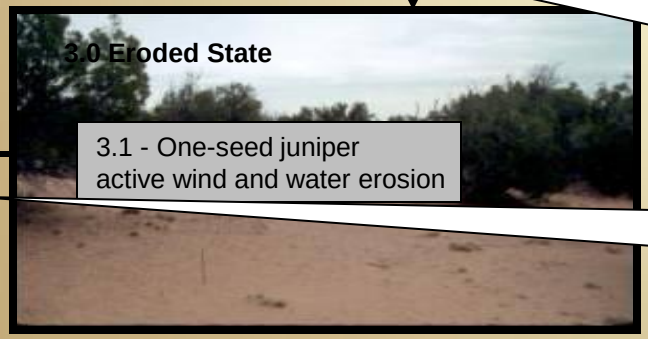


2.1a:"…juniper canopy increases with time since last fire …other management action to reduce juniper canopy…increase in juniper canopy decreases shrub and herbaceous production and cover…shrubs and tall grasses decrease or are eliminated…drought years followed by wet years will allow for increase in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