

Vegetation Dynamics in State and Transition Models

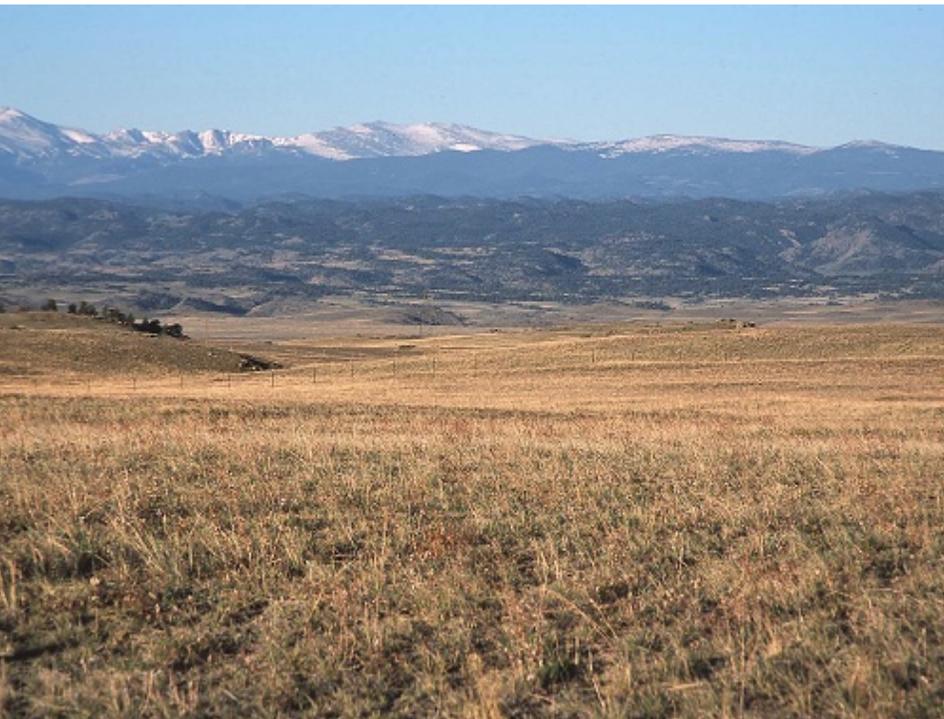
History, Concepts and Emerging Issues

Ecological Site Description Workshop
Jornada Experimental Range
15-18 Nov 2005

JOEL BROWN and BRANDON BESTELMEYER

Vegetation Dynamics in State and Transition Models

History, Concepts and Emerging Issues



History- *how did we get here?*

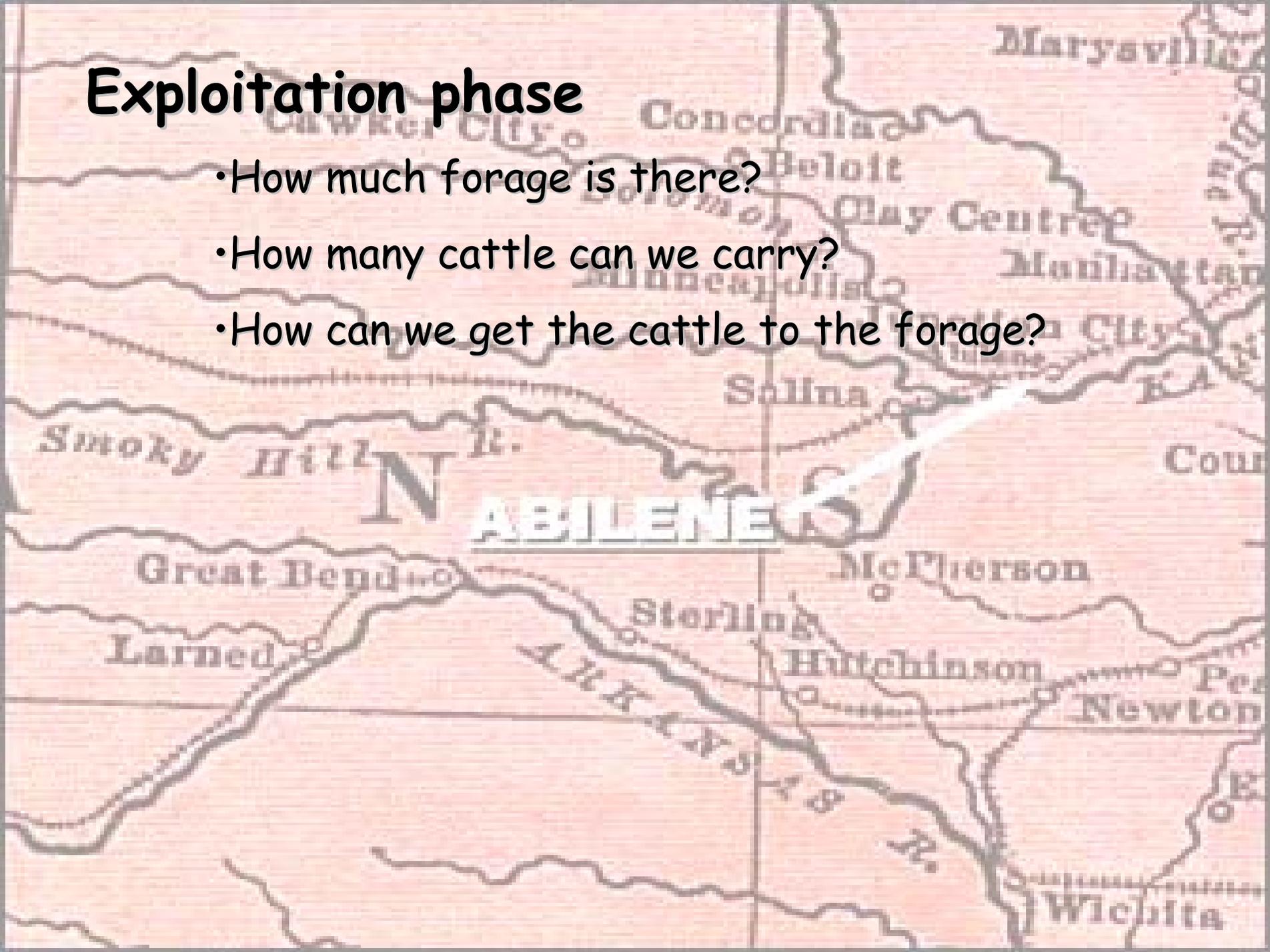
Emerging issues- *what is standing
in the way of progress?*

Resolving issues- *how do we
overcome challenges?*

Writing models- *general ideas*

Exploitation phase

- How much forage is there?
- How many cattle can we carry?
- How can we get the cattle to the forage?



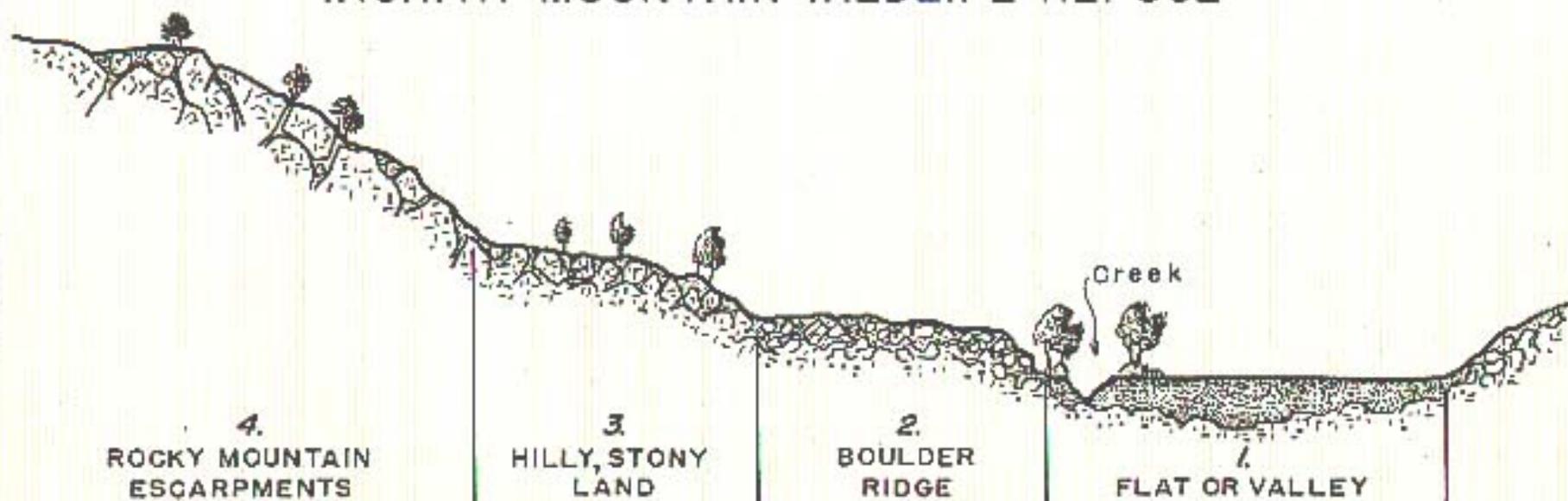
Sustainable Yield Phase

- Range Condition/Range Sites

- Long term carrying capacity
- Plant succession as a basis for assessment
- Included sources of forage loss other than direct consumption by livestock

Livestock production and performance remained the focus during this period, but from an ecological dynamics standpoint

FOUR RANGE SITES WICHITA MOUNTAIN WILDLIFE REFUGE



When each site is in excellent range condition, it requires about 5 to 8 acres of the flat or valley site for a cow to live on each year; 10 to 12 acres are needed on the boulder ridge site; 20 to 25 acres are required on the hilly, stony land site; and 40 to 50 acres per animal unit yearlong on the rocky mountain escarpment site.

Therefore land buyers could afford to pay thirty per cent more for the flats or valleys than for boulder ridge land; flats or valleys are worth three times as much as the hilly, stony land; and are worth about 6 or 7 times as much as the rocky mountain escarpments.

The sites do not always lie in the exact order as shown here. Their positions are sometimes changed about and rocky mountain escarpments or hilly, stony land may be in contact with the flats.

ECOLOGICAL SITE DESCRIPTIONS

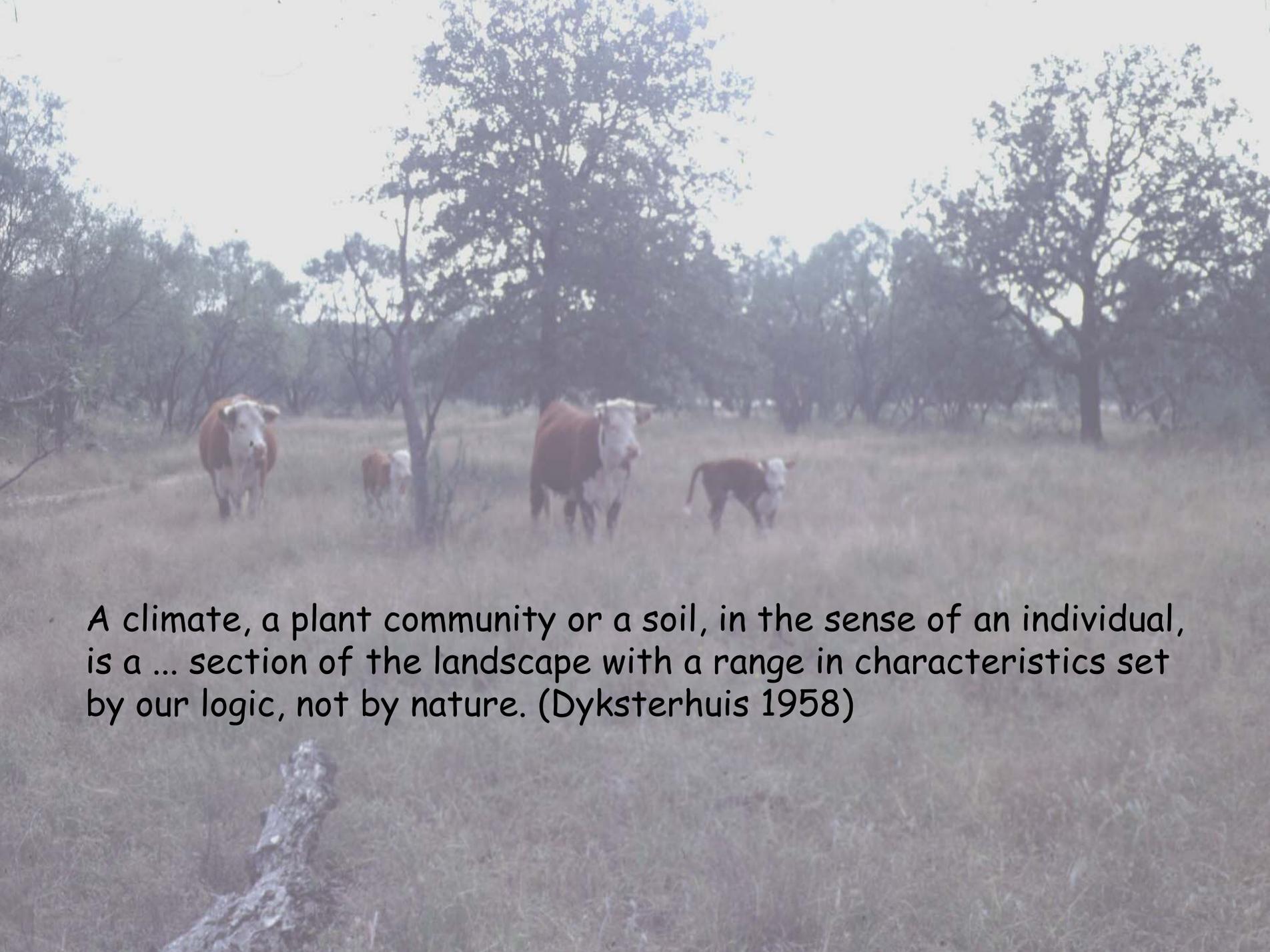
- Allows for multiple stable states and nonequilibrium dynamics
 - Includes multiple values
 - Recognizes multiple objectives for planning purposes

Livestock production is one of many potential uses of land...usually simultaneously with other uses

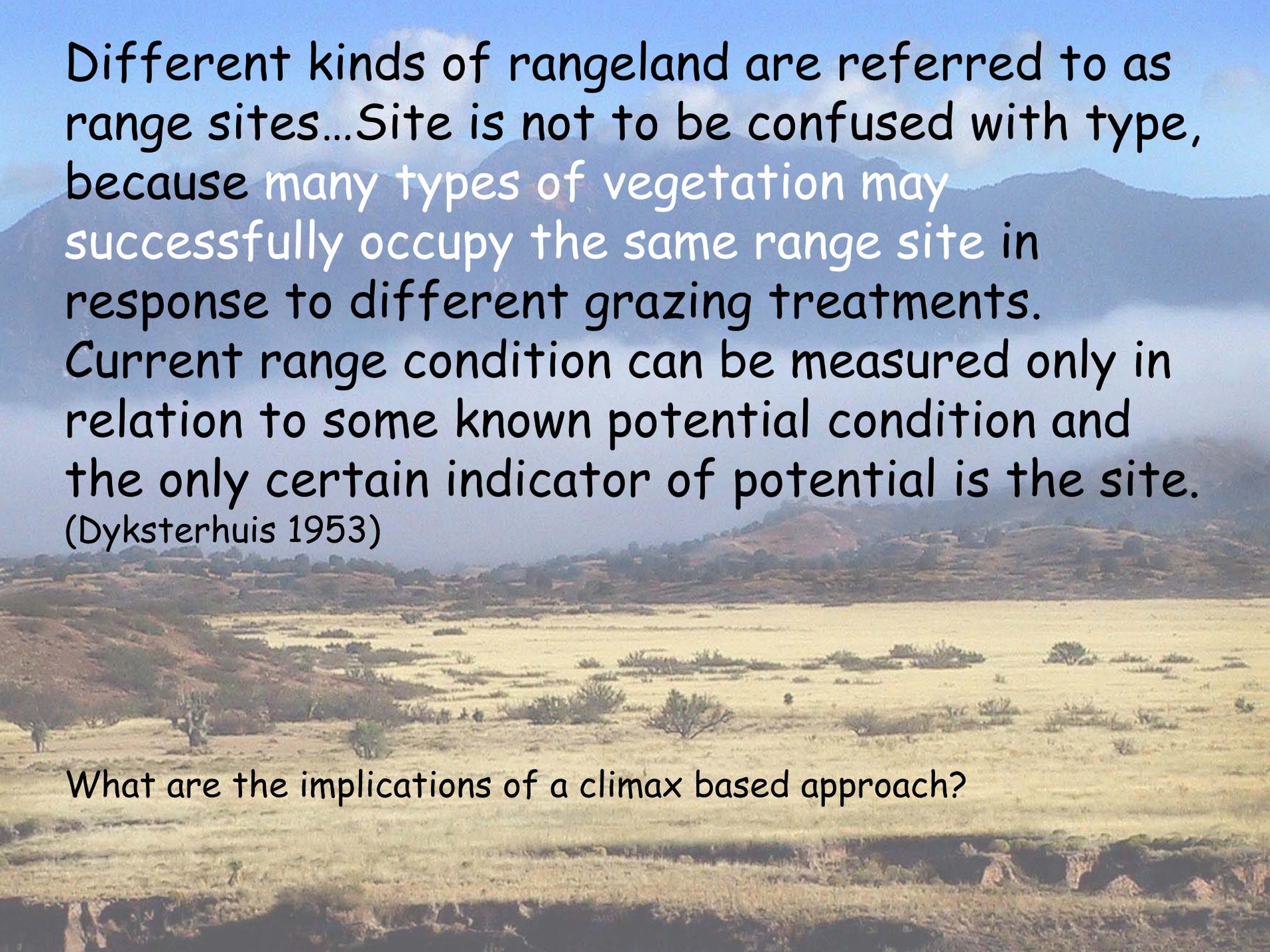
Derivation of the Site Concept

An early publication on forest sites by Korstian (1919) is thought to have provided the basic concept for range sites...The concept of "site" as an ecological or management entity **based on climax plant communities** was transposed from forestlands to rangelands in the 1930-40s...Range Site was first used in the literature without definition. Renner and Johnson (1942) implied different kinds of rangeland existed without defining the differences. Later, Renner (1949) referred to sites as kinds of rangelands with **inherently different soil and vegetation characteristics that result in different potential productivity**. (Shiflet 1973)

A more definitive description was used by Dyksterhuis (1949) characterizing range sites as types of rangeland that differ from each other in their **ability to produce a significantly different kind or amount of climax ... vegetation**...A similar concept was presented later in which sites were described as different kinds of rangeland resulting from **complexes** of soil and climate whose **functional differences** are based on measurable differences in kind or amount of **climax vegetation**. (Shiflet 1973)



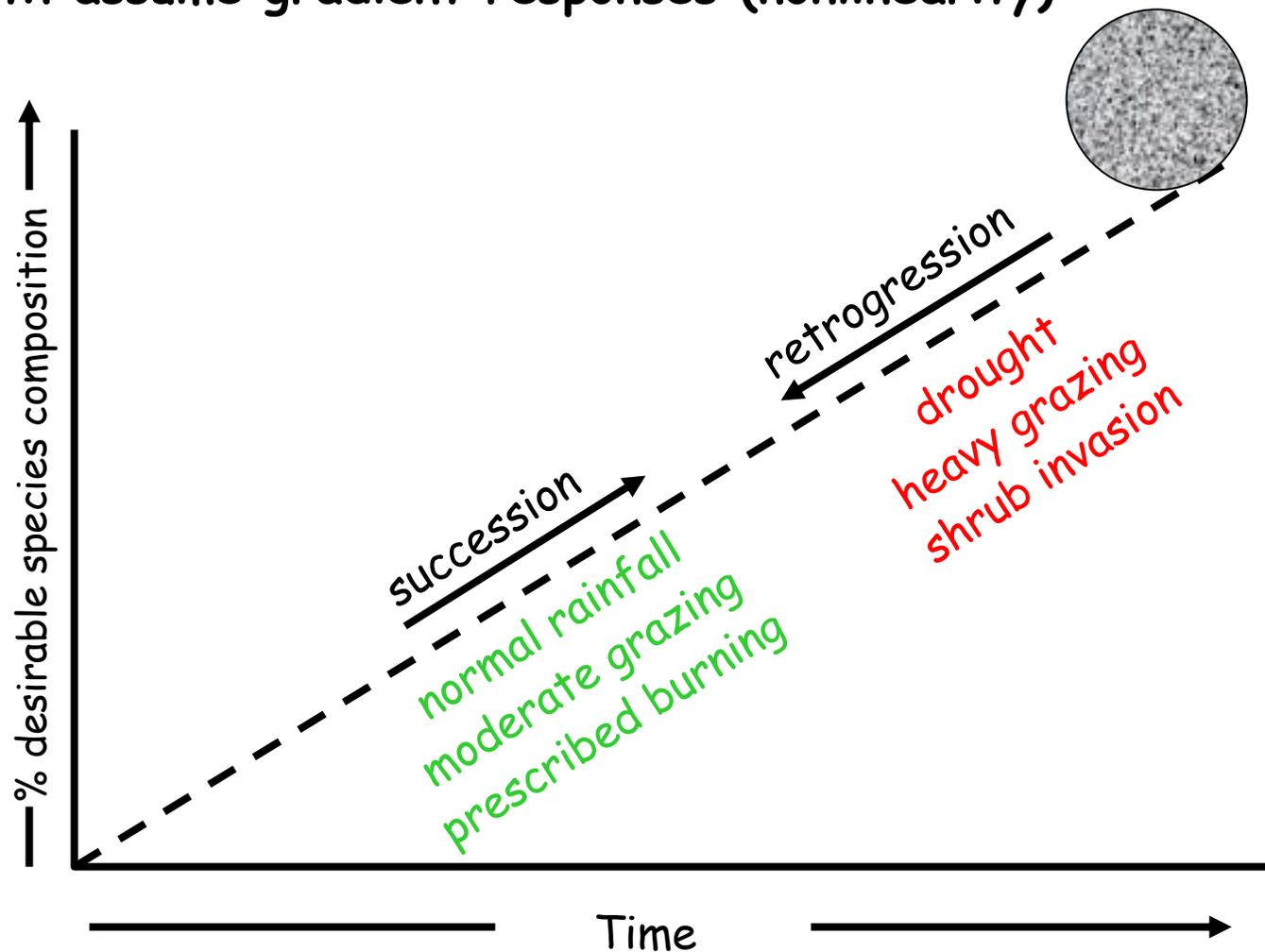
A climate, a plant community or a soil, in the sense of an individual, is a ... section of the landscape with a range in characteristics set by our logic, not by nature. (Dyksterhuis 1958)

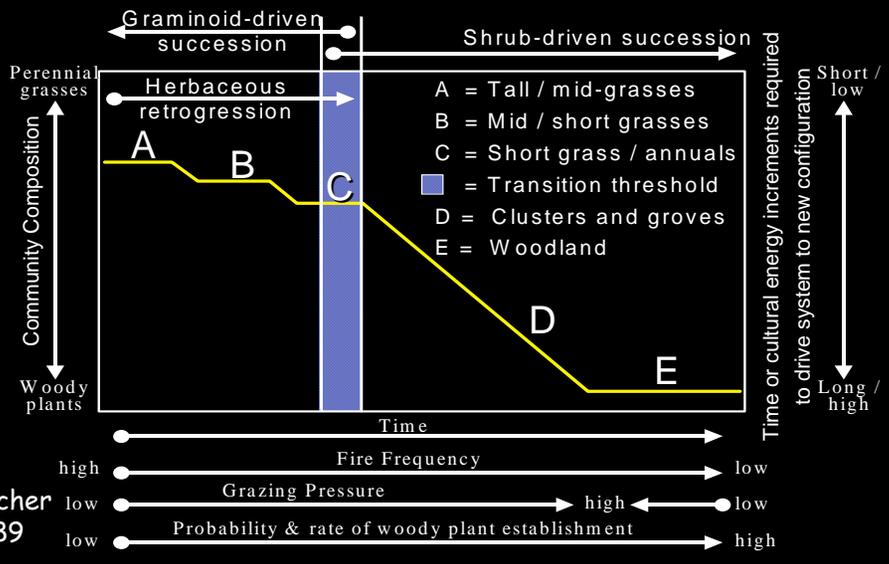


Different kinds of rangeland are referred to as range sites...Site is not to be confused with type, because many types of vegetation may successfully occupy the same range site in response to different grazing treatments. Current range condition can be measured only in relation to some known potential condition and the only certain indicator of potential is the site. (Dyksterhuis 1953)

What are the implications of a climax based approach?

1. Allows for grouping soils in response to lack of disturbance
2. Allows for assuming change is linear
3. Both assume gradient responses (nonlinearity)





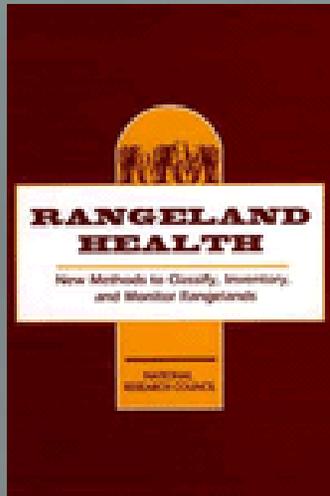
Holling 1973 'Stability and resilience of ecological systems'

May 1977 'Multiple stable states in ecological system'

Westoby et al 1989 'Opportunistic management for rangelands not at equilibrium'



National Research Council (1994)



NEW CONCEPTS FOR ASSESSMENT OF RANGELAND CONDITION

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Abstract

Rangeland condition refers to classification that can tell us, in general terms, much of what managers and the public want to know about rangelands. Rangeland condition is not a reliable indicator across all rangelands, of biodiversity, resource potential, aesthetic value, or wildlife species, or game habitat. Nevertheless, the basis for the current concept of rangeland condition is not an adequate paradigm for evaluation of rangelands. The Society for Range Management (SRM) established the Task Group on Rangeland Concepts and Terminology which has developed new concepts for evaluation of the status of rangelands. These concepts were based on the premise that the most important and basic physical concepts on each ecological site is the soil. If sufficient soil is lost from an ecological site, the potential of the site is changed. The Task Group made three recommendations, which were adopted by the SRM: 1) evaluation of rangelands should be made from the basis of the same land unit classification, ecological site; 2) plant communities likely to occur on a site should be evaluated for protection of the site against accelerated erosion (Site Conservation Rating, SCR); and 3) selection of a Desired Plant Community (DPC) for an ecological site should be made considering both SCR and management objectives for that site.

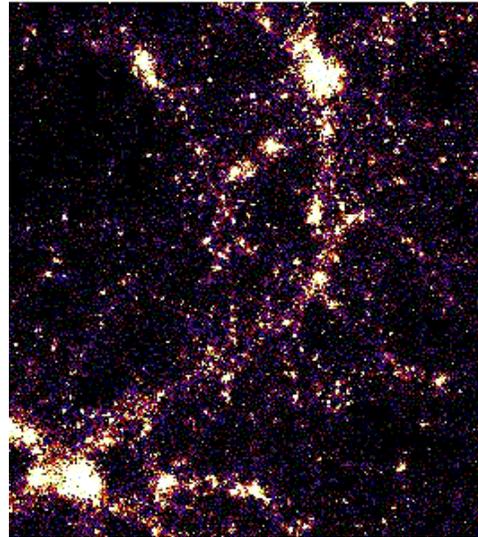
Key Words: Range Condition, Desired Plant Community, Site Conservation Threshold, Sustainability, Ecological Site, Soil Erosion

SRM Unity in Concepts and Terminology (1994)

- Multiple plant communities occupying a site may have similar ability to protect a site from accelerated erosion
- Plant communities may have a variety of values in addition to offering the same site protection
- Included phrases 'early warning line' and 'threshold' of rangeland health

- Evaluations of rangelands should be made from the basis of the same land unit classification
- Plant communities likely to occur on a site should be evaluated for protection against erosion
- Selection of a Desired Plant Community for an Ecological Site should be made considering site protection and objectives

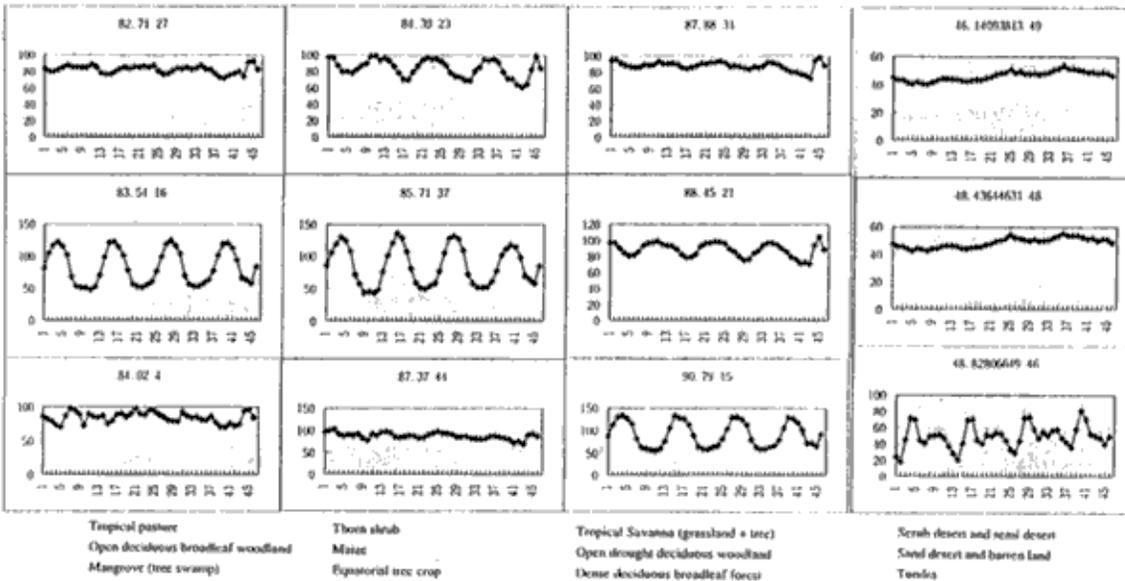
The world is lumpy in both time and space



Distribution of disturbance in space



Distribution of resources in space



Distribution of NPP in time



CHANGE

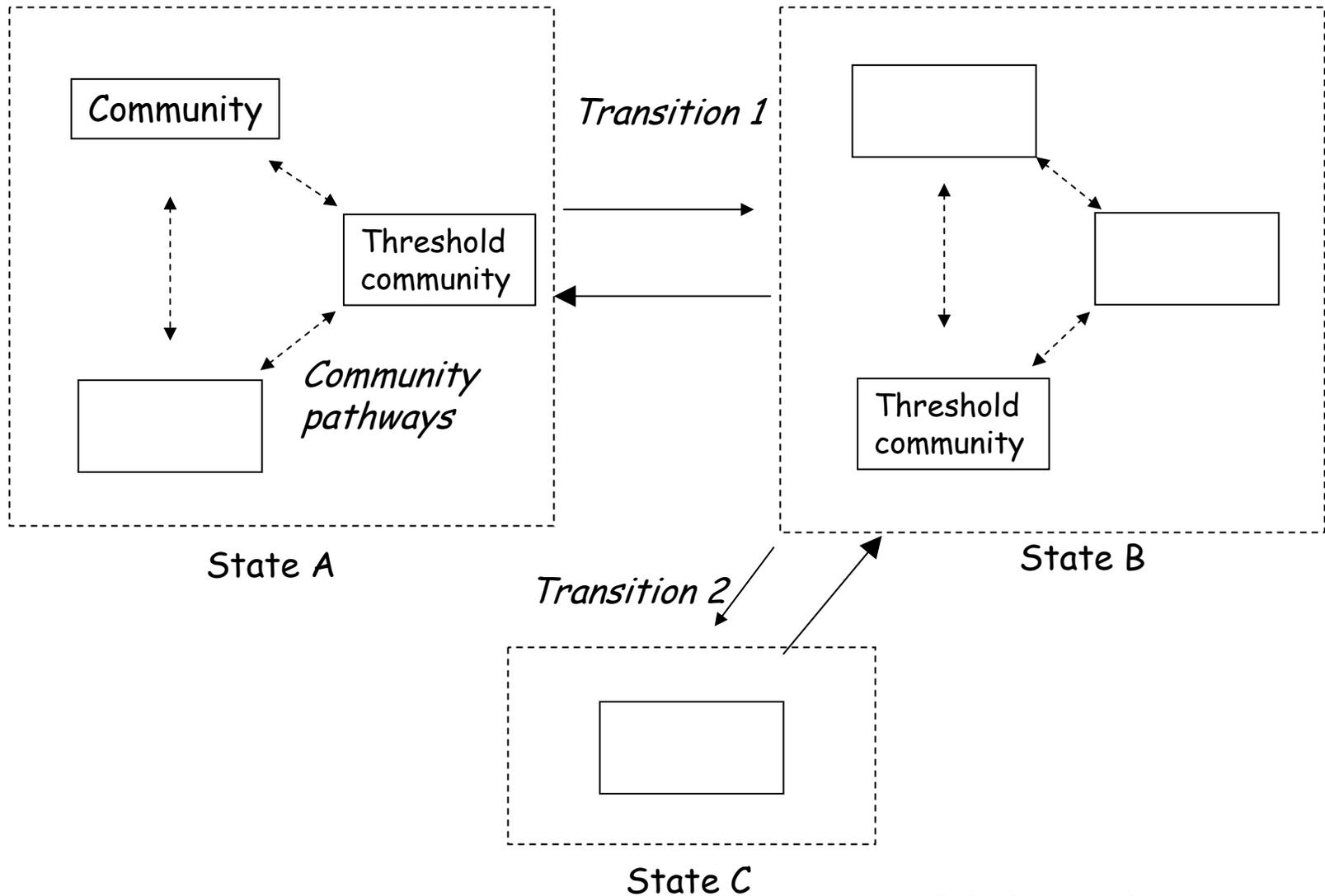
WHEN THE WINDS OF CHANGE BLOW HARD ENOUGH,
THE MOST TRIVIAL OF THINGS CAN TURN INTO DEADLY PROJECTILES.

www.despair.com



NWS La Crosse

Using state and transition models allow us to better organize information



Emerging issues in the development of Ecological Site Descriptions

1. Artificial separation of forest and range sites

Variation in shrub and tree cover

2. Grouping soil map units into ecological sites

New soil surveys-lower order includes more variability

Existing surveys need to be reexamined

3. Lack of transparent, logical decision making

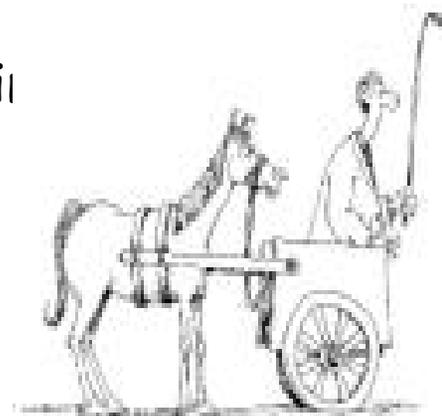
Extant examples of reference states (HCPC)

Relevant supporting data

Distribution of reference and sampling sites

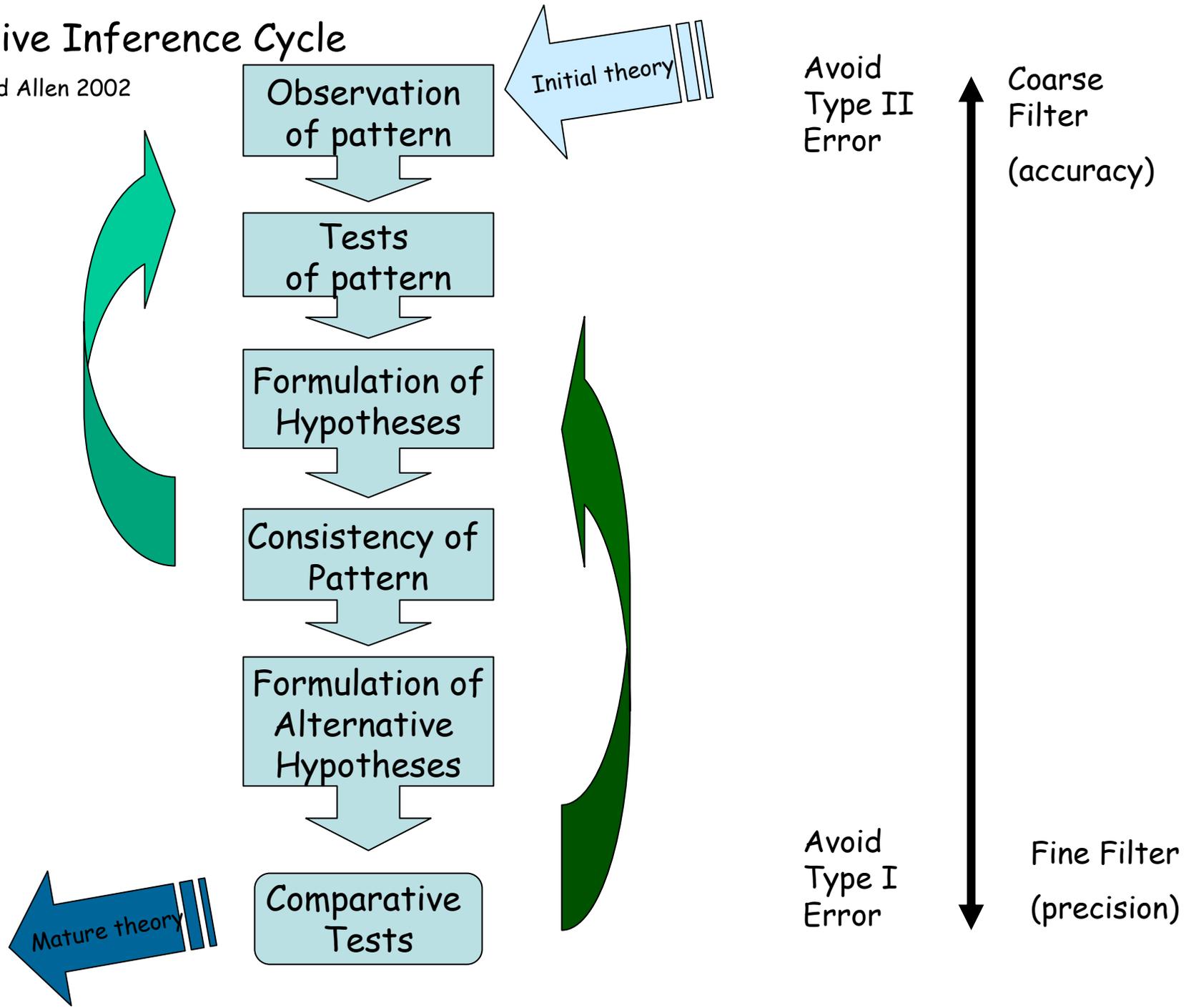
4. Reliance on non-spatially explicit species composition and productivity data

Importance of spatial distribution of attributes-scale



Adaptive Inference Cycle

Holling and Allen 2002



Type I vs Type II Errors

Type I error-false positives (something is true when it isn't)

Type II error-false negatives (something isn't true when it is)

Avoiding Type I error limits chances of finding new explanations in favor of certainty about previously identified causes

Avoiding Type II error can lead to an inability to exclude any causes for anything

Avoiding Type II error is a good way to find organizing principles (we're sure we're right, but only within a broad range)

Avoiding Type I error is a good way to confirm if our ideas were right (we're positive we're right about a very small portion of the model)

Observe Pattern

General Soil Map, STATSGO

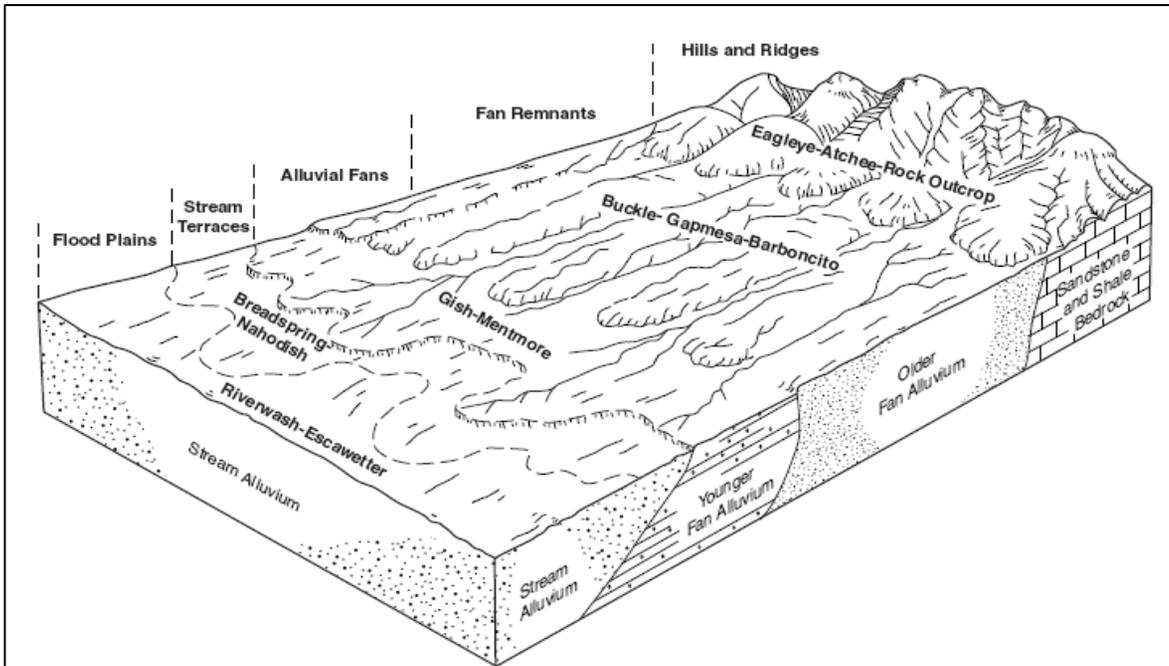
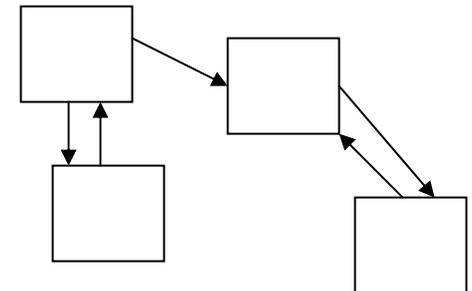


Figure 21 Generalized relationship of some soils in the survey area.

McKinley County, New Mexico

• Each landform can be represented by a general state and transition model (one model per landform)

Lifeform (species) relationships, driving variables, feedback mechanisms are similar within a landform



Test Pattern

General Soil Map, STATSGO

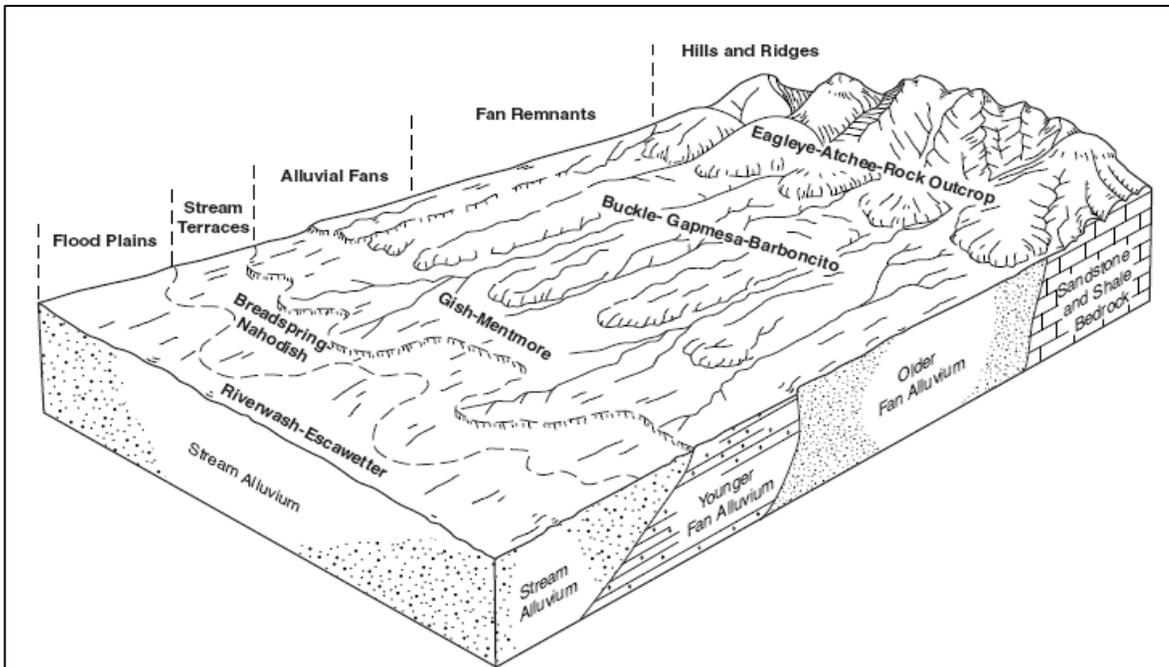


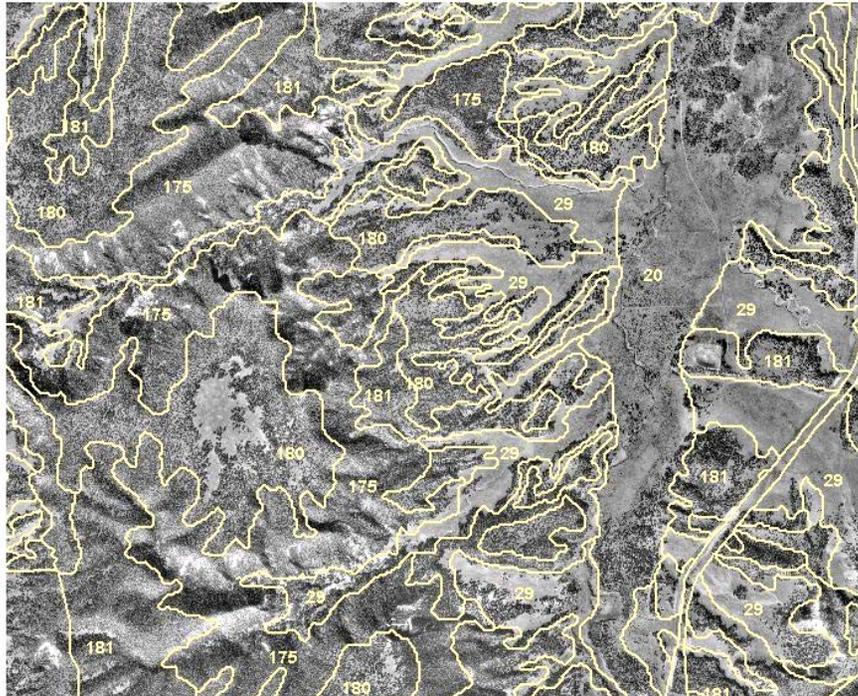
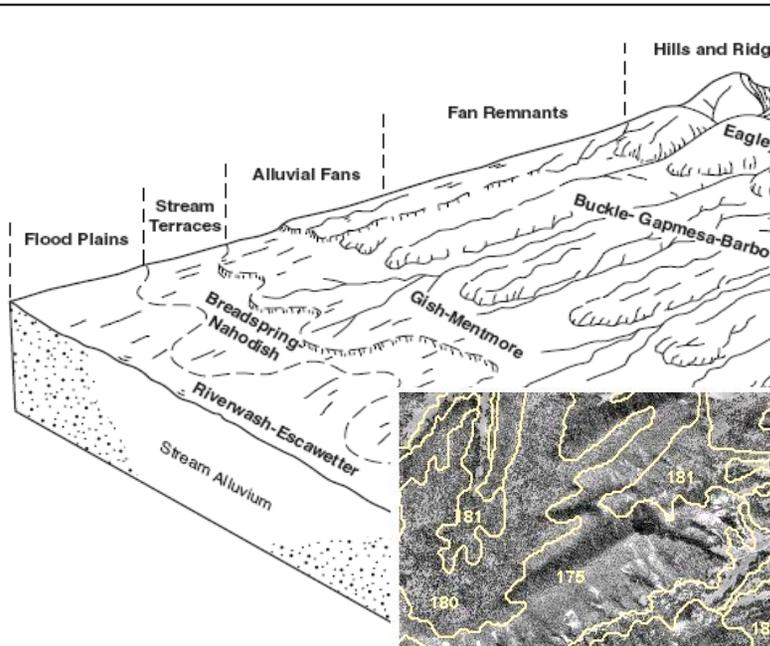
Figure 21 Generalized relationship of some soils in the survey area.

•Do I see any states on a landform that don't conform to my model?

Observations
Literature
Expert knowledge
Examine states, not transitions

Formulate Hypotheses

General Soil Map, Soil Maps



•What governs the transitions?

What processes are important?

How are processes affected by

Landscape Position

Texture

Depth

Aspect

History

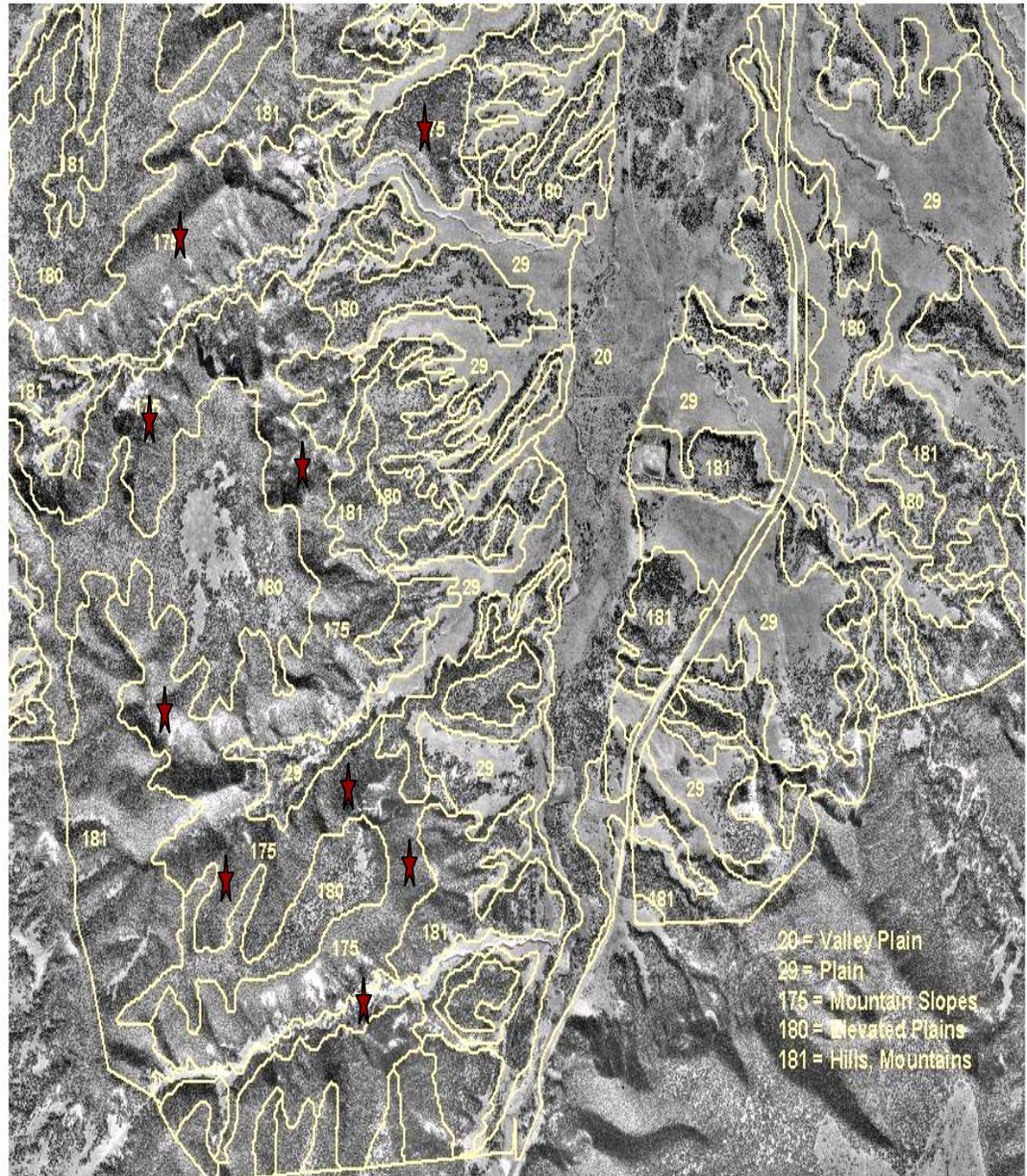
Disturbance

Still emphasizing lots of locations over lots of data, look for variability

Consistency of pattern

Identify multiple plots within the same ESD for sampling and intensively collect information

Clearly identify how much (and what kind of) variability will be encompassed within an ESD STM before creating a new one

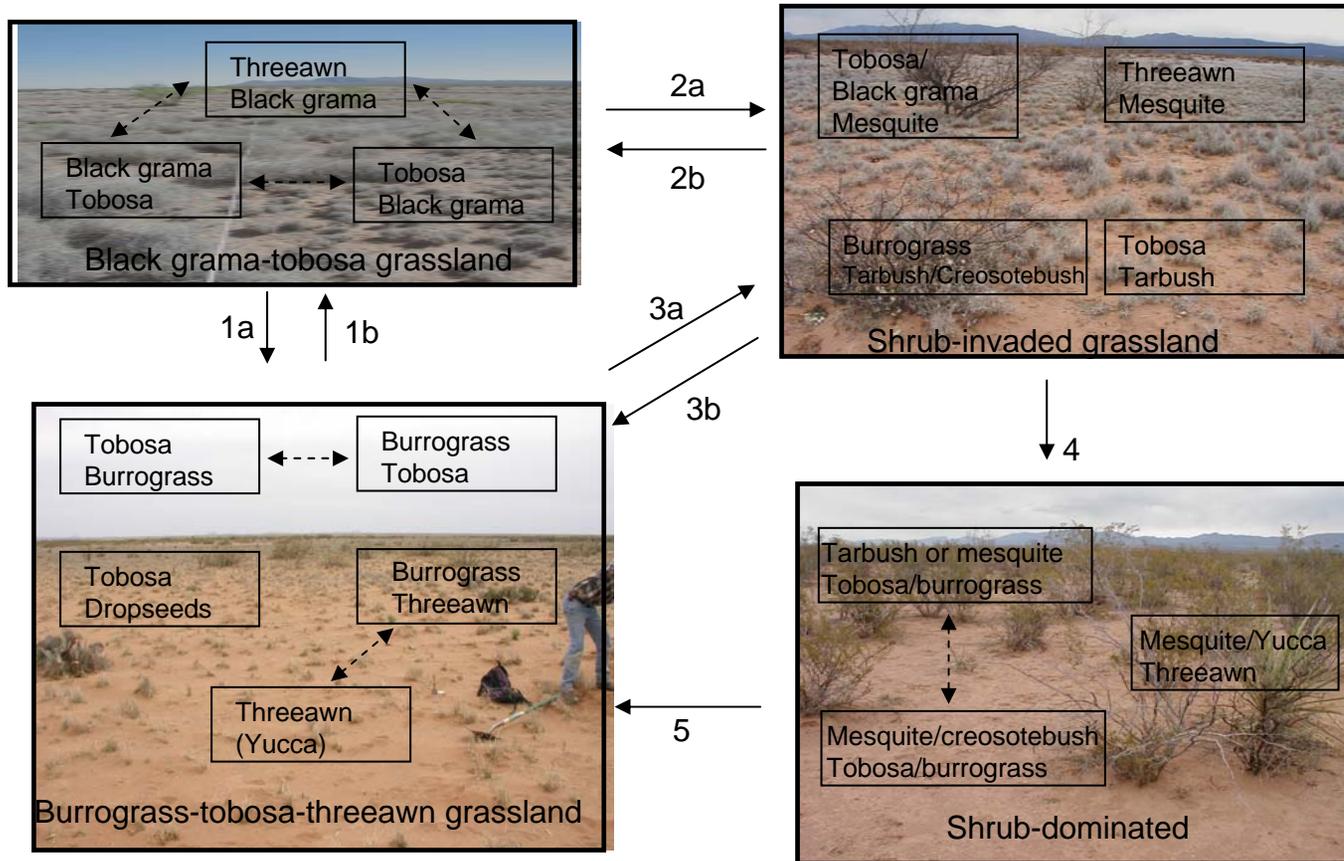


1 0 1 Miles



Formulation of Alternative Hypotheses

Loamy SD-2



- 1a-Overgrazing, soil fertility loss, erosion and sand loss; 1b-Soil stabilization or modification
 2a-Shrub invasion due to overgrazing and/or lack of fire; 2b-Shrub removal, restore cover
 3a-Shrub invasion; 3b-Shrub removal with grass recovery
 4. Persistent reduction in grasses, competition by shrubs, erosion and soil truncation
 5. Shrub removal with soil addition?
 (Bestelmeyer et al 2003)

Information in an Ecological Site Description

Site Characteristics -- Identifies the site and describes the physiographic, climate, soil, and water features associated with the site.

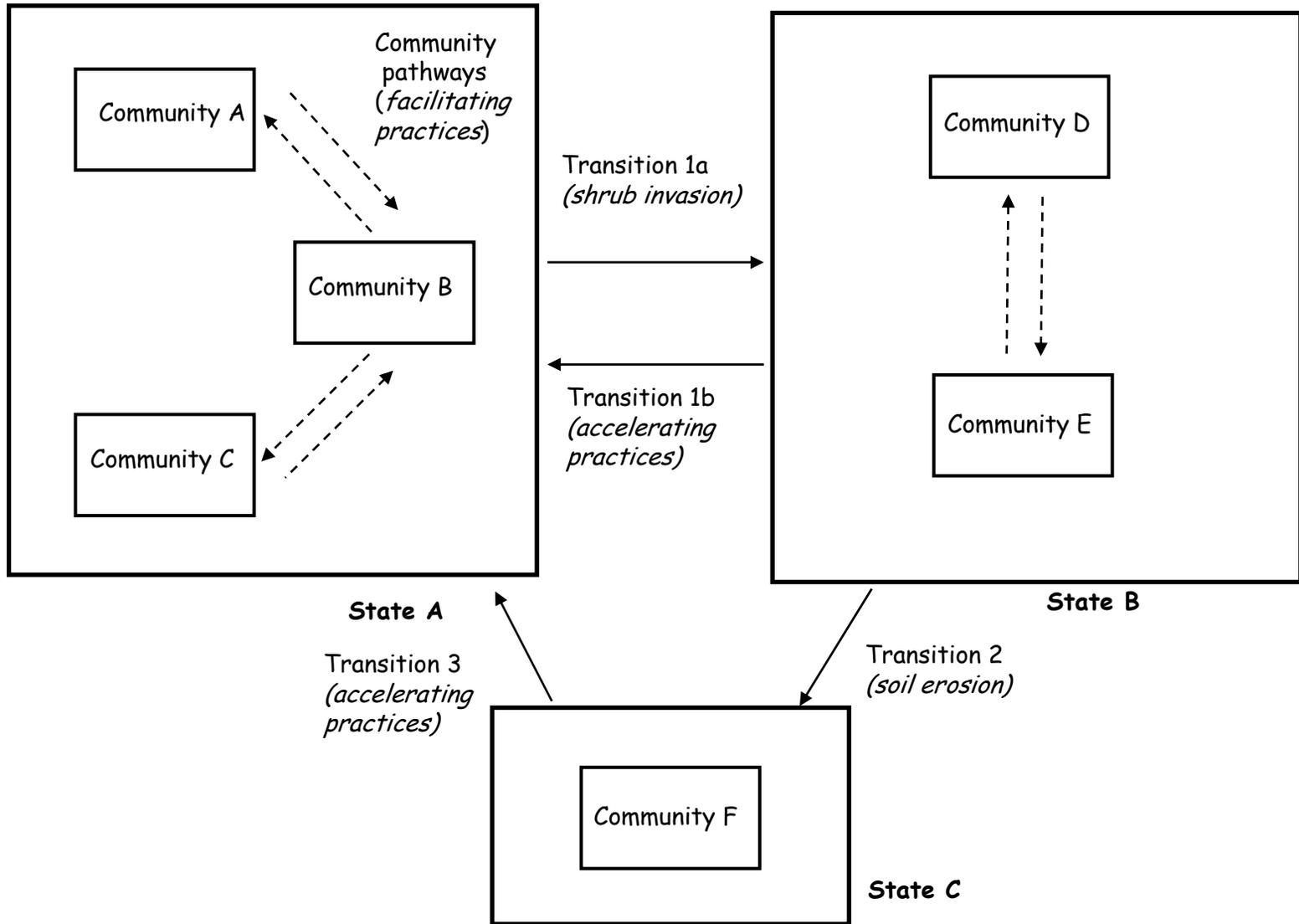
Plant Communities -- Describes the ecological dynamics and the common plant communities comprising the various vegetation states of the site. The disturbances that cause a shift from one state to another are also described.

Site Interpretations -- Interpretive information pertinent to the use and management of the site and its related resources.

Supporting Information - Provides information on sources of information and data utilized in developing the site description and the relationship of the site to other ecological sites.

<http://esis.sc.egov.usda.gov/>

A idealized state and transition model



This model has 16 elements that should be described

Building a Box & Arrow Diagram

- Components of a state and transition model
 - States and Communities
 - Differing types of change
 - Transitions
 - Thresholds
 - How do you write the information?

Defining states and communities

A) *States* are defined and named by distinct structural attributes (e.g., eroded shrubland state) that are related to ecological processes

B) There are different philosophies for defining *communities*:

- Usually differ in functional significance
- Functional groups: e.g. "mid-grass dominated community"
- Dominant or significant species: e.g. "Ricegrass-Big Sage-Cheatgrass"
- May differ from an economic perspective
- May be able to link communities in ST models with National Vegetation Classification community types and mapping efforts

<http://www.natureserve.org/explorer/index.htm>

Two types of change in S&T models

A. "Community pathway *within* states"

Changes in plant abundance that are promoted or reversed with changes in *rainfall* or *management* or *facilitating practices* (e.g., grazing management)

B. "Transition *between* states"

Changes in plant cover that cannot be reversed until competitors or fire-adapted exotic species are removed

OR

erosion is stabilized and soil fertility, soil physical properties, or previous hydrology is restored (both are *accelerating practices*)

Mechanisms of change (examples)

Community pathways within states

1. Continuous heavy grazing reduces cover of black grama relative to dropseeds and threeawns
2. Early season rainfall favors establishment of snakeweed
3. Prescribed grazing allows seeding by dropseeds in late summer

Transitions among states

4. Continuous heavy grazing eliminates cover of vine mesquite
5. Reduced grass cover reduces fire frequency and permits mesquite establishment and growth to a size that is resistant to fire damage
6. Reduced grass cover leads to accelerated erosion and truncation of the A horizon, creating soil conditions favorable only to establishment of hairy grama
7. High intensity storms during periods of low grass cover produce deep gullies, channelizing subsequent run-on water and reducing moisture below that required by giant sacaton

Choosing and describing mechanisms of change

- Mechanisms should make sense to the reader and should be adequately described so that the reader can make a judgment
- Mechanisms seldom involve just one process (e.g., "shrub invasion" or "non-use" or "cultivation" involve several)
- Mechanisms often require consideration of the ecology of particular plant species as well as plant community
- Mechanisms should have been described somewhere in the literature or have some documentation
- There are often several plausible mechanisms

Describing thresholds: risk and consequences



1) Inappropriate grazing, low soil protection, low rainfall



2) Grazing management, good rainfall, high soil protection



In some periods, you take a risk and get lucky---succession leads to recovery

In some periods, you take a risk and get unlucky---things don't work

What is the probability of each?

'You have to ask yourself, punk "do I feel lucky today?"

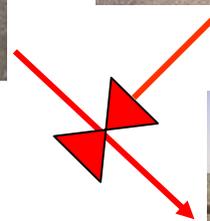


Transitions must be matched with an appropriate management response (or lack thereof)

1) Inappropriate grazing, low soil protection



2) Trigger and threshold: large storm produces gully



5) Shrub control with herbicide: soils already degraded



4) Gully repair: shrubs maintain low grass cover, soils degrade



3) Time passes without management: Gully deepens, adjacent soils dry, shrubs invade



Transitions may not involve dramatic changes in vegetation

Nickel series, MLRA 42, typical aridic Gravelly



Recent grassland loss,
potential
for recovery

Crossed a biotic
threshold, soils not yet
degraded (abiotic
threshold not yet
crossed)

Dark A



Light A



Grassland absent for
decades, recovery
unlikely

Already crossed a
soil degradation
threshold (both
biotic and abiotic
thresholds crossed)

The dynamic relationship between soil and vegetation is key to defining thresholds

Common mechanisms of transitions

Cause of transition

Loss of fire disturbance
regime change

Soil degradation
physical/biological

Altered hydrology
sub/surface

Undesired establishment
invasive species

Depletion of seed pool

Accelerating/restoration practice

Restore fuel loads and fire regime
grazing management/prescribed
burning

Soil stabilization/amendments
pitting, contour furrowing,
fertilizer

Gully plugs, create meanders
stream restoration

Reduce target species
mechanical/herbicide treatment

Seeding/practices to favor
establishment

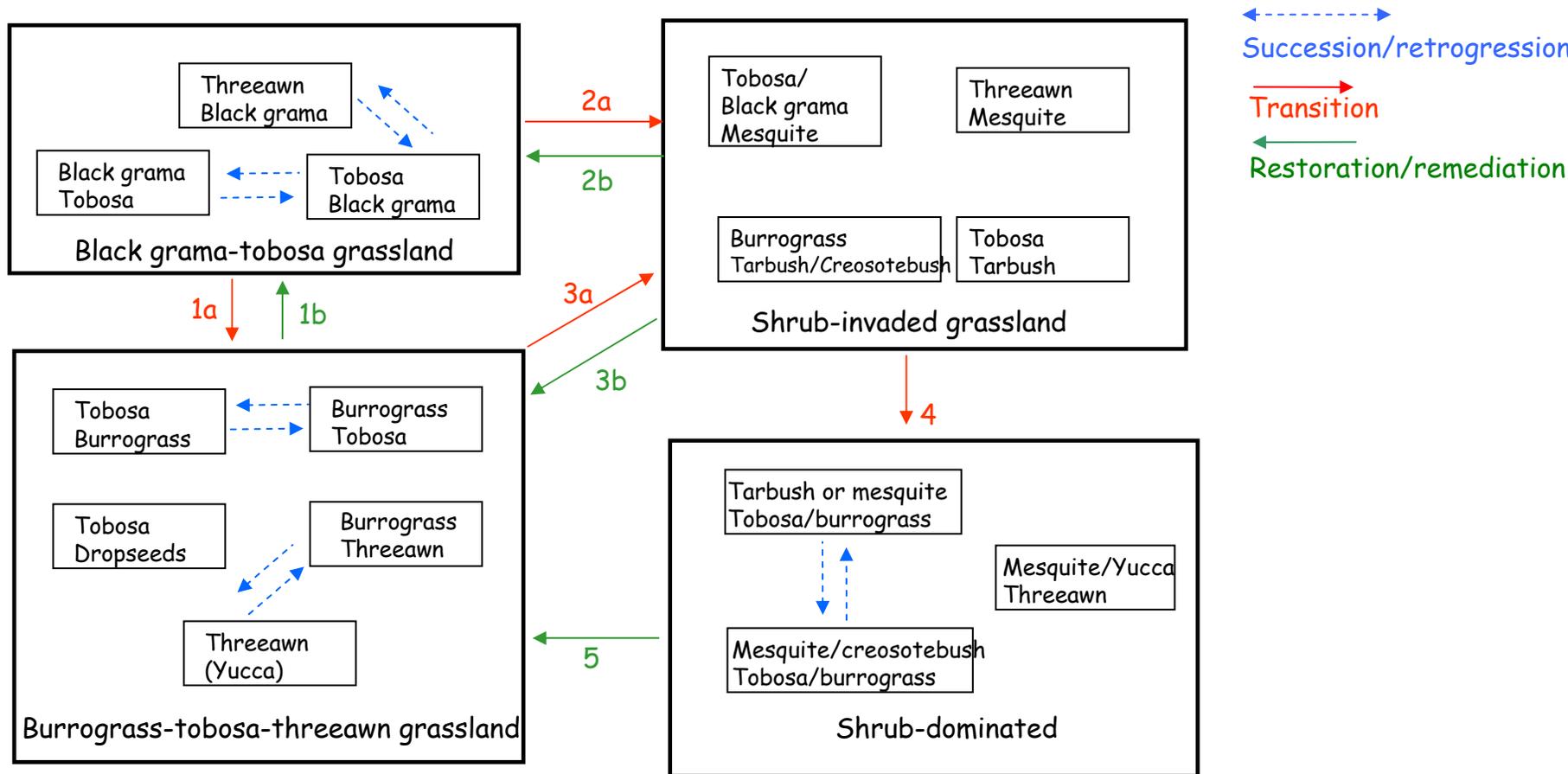
When is a transition so severe that a new ecological site should be created?

Never: because then a rangeland can be degraded into a healthy state with a new potential. For instance, mesquite and juniper dominance could be the 'potential' for a new site.

Alternative: When soil morphology is severely altered, establish a new site but maintain its connection as a degraded state of its ancestral site

Danger: When is soil morphology "severely altered" --and isn't this a value judgment?

A state and transition model from the messy real world



- 1a.** Continuous heavy grazing, soil fertility loss, erosion and sand loss. **1b.** Soil stabilization, soil amendments
- 2a.** Shrub invasion due to overgrazing and/or lack of fire. **2b.** Shrub removal, restore grass cover
- 3a.** Shrub invasion. **3b.** Shrub removal
- 4.** Persistent reduction in grasses, competition by shrubs, erosion and soil truncation
- 5.** Shrub removal with soil addition??

Strategies for the Text

Ecological Dynamics of the Site

Summarize the causes and constraints to community change within the historic state, and causes and constraints to transitions among states

Catalog of States and Transitions (a proposal)

State 1 (state containing historic community): Describe attributes that define this state, how to distinguish state from other states

Transition 1A: Describe the mechanisms of transition in detail

Transition 2A: Describe the mechanisms of transition to another state

Transition 1B: Describe the accelerating practice to get back in detail

Community A: Describe attributes of community

Pathway 1A...

Pathway 1B (facilitating practices)

State 2 (alternative state):...

This structure will allow links to Web Soil Survey

Strategies for the Text

How do we distinguish the states and communities?

Diagnosis: Grass cover is fairly uniform with few large bare areas present. Mature piñon and/or juniper are an important component of the site with canopy averaging 25 percent. Evidence of erosion such as pedestalling of grasses, rills and gullies are infrequent.

From MLRA-36, WP-2: Savannah, David Trujillo, author

Why we think this is good:

- 1) Descriptive
- 2) Refers to data
- 3) Refers to rangeland health indicators

Strategies for the Text

How much detail on transitions is enough?

Transition to Piñon-Juniper State (1a) Persistent loss of grass cover, the associated decreased competition by grasses, and lack of fire are believed to facilitate the encroachment of piñon/juniper.^{1,2, 5, 7} Loss of herbaceous cover due to overgrazing and drought can provide competition free areas for piñon/juniper seedling establishment, and afford a competitive advantage to established woody species. However, the natural spatial variability of ground cover may also allow woody species to establish on existing bare areas.³ As piñon/juniper canopy cover increases, total herbaceous biomass decreases.⁶ Loss of herbaceous cover can also reduce fuel levels beyond the point capable of carrying fire. It is believed that periodic fire was historically important in limiting reproduction of piñon/juniper on Savannah ecological sites by suppressing piñon/juniper seedlings. The disruption of natural fire frequency may be a key factor in facilitating piñon/juniper encroachment.⁵ Favorable climatic periods of mild winters and wet summers have also been cited as possible causes of piñon/juniper encroachment.⁵

From MLRA-36, WP-2: Savannah, David Trujillo, author, embarrassed again

Why we think this is good:

- 1) Mechanisms are detailed
- 2) Uncertainty and alternatives are described
- 3) References to the literature

Photos and indicators summary

Shrub-invaded state, threeawn-mesquite



- Threeawn dominant, some burrograss and fluffgrass. Mesquite and tarbush present
- Cover of grasses low (18/3%)
- Evidence of wind erosion and pedestalling, large bare patches.
- Algerita sandy loam, eroded phase, Jornada Exp. Range, Dona Ana Co.

Shrub-invaded state, burrograss-creosotebush



- Burrograss dominant, some tobosa. Creosotebush at moderate density
- Cover of grasses low-moderate (28/6%)
- Evidence of wind erosion and pedestalling, large bare patches.
- Dona Ana fine sandy loam, Jornada Exp. Range, Dona Ana Co.

Shrub-dominated state, creosotebush-tarbush



- Creosotebush dominant, some bush muhly among shrubs. Borders gravelly site.
- Cover of grasses very low (<1%)
- Evidence of wind erosion and pedestalling, nearly continuous bare ground, physical crusts.
- Dona Ana fine sandy loam, Jornada Exp. Range, Dona Ana Co.