Threshold and state concepts used in ESDs: Needs and applications

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State and thresholds concepts lack empirical support and their utility and justification continues to be limited.

**Critical Issues**

A) How can model users recognize or measure thresholds?

B) How should we gather and use data to support the existence and nature of alternative states and land potential?
A) Thresholds as sequences of events, changes, and feedbacks

Pattern threshold
- grass connectivity
- shrub density
- habitat fragmentation

Process threshold
- erosion rate
- fire spread/frequency
- dispersal/colonization rate

Degradation threshold
- soil depth
- nutrient availability
- habitat occupancy

Classification thresholds
- recognized to prevent a transition
- recognized for restoration

Soil-climate conditionality

Bestelmeyer, Restoration Ecology, 2006
1) Pattern thresholds exist that can be quantitatively related to process
- Measures initiation of process that produces a transition
- Can be detected with cover values, stubble height, gap size

Ludwig et al., Ecological Indicators, in press
1b) Pattern may also be linearly related to process rates
• The lower the cover, the greater the erosion rate

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**Figure 6.4.** Water budgets and amount of interrill erosion, runoff, and interception from oak, bunchgrass, sodgrass, and bare ground dominated areas, Edwards Plateau, Texas. Based on 10 cm of rainfall in 30 minutes (from Blackburn et al. 1986).

Thurow, Grazing Management: an Ecological Perspective, 1991
2) Altered process rates have gradual or discrete environmental consequences
   • Process rates * duration = degree of change (e.g., in organic matter content)

Nickel series, MLRA 42, typic aridic Calcareous Gravelly

Recent grassland loss, A horizon present

Crossed a pattern-process threshold

Grassland absent for decades, A horizon lost

Has this crossed a degradation threshold?
3) At some critical values of an environmental/resource factor, the site becomes degraded, autogenic recovery does not occur, degradation may spread
4) Landscape processes (thresholds) may override local management
4b) Landscape processes may override local degradation and cause recovery

Middle piedmont slope
Gravelly loam ecological site, (gravelly) fine-loamy Calciargid

- Exclosure ungrazed since 1911
- Surrounding area is eroding
- 18 cm of sediment accumulation parallels grass recovery
5) The meaning of pattern and incidence of threshold behavior varies predictably with soil properties.

1. Fine-loamy, Calciargid

2. Coarse-loamy, Calciargid
Solutions for improving support of threshold concepts

• Concepts that use numbers rather than metaphors (no more cups)

• Funding to support threshold-oriented experimentation in different ecological site types (i.e., what patterns lead to vulnerability and change in different contexts?)

• Attention to landscape context in experiments

• Collection of within-site spatial pattern, indicator, and landscape context information in vegetation/soil inventory based on experiment-based threshold mechanisms

• Discussion of within-site spatial pattern and landscape context effects in state-and-transition model text referencing the experiments
Solutions for improving utility of threshold concepts

A. Key indicators of vulnerability to transition:

- Persistent high utilization of black grama, stubble heights < 3”, basal cover < 5%.
- Absence of stolons
- Bare patches interconnected and with many patches > 50 cm
- Evidence of soil movement, burial of grasses
- Proximity to eroding and expanding shrublands
Solutions for improving utility of threshold concepts

B. Key indicators of opportunity for restoration:

- Remnant grasses in shrub interspaces
- Grasses in shrub canopies
- Likelihood of two consecutive summers of high rain
- Darkened A horizon, minor erosion
- Proximity to seed sources
B. What kinds of data can NRCS and others gather to better understand alternative states and thresholds?

Grass dynamics in 123 trend plots: 1970-2003
1) Linked soil and vegetation data can improve S&T models.

- Shallow sandy sites resist invasion.
- Sandy sites vulnerable.

**Graph Description:**
- **Y-axis:** Depth to Calcic Horizon (0% to 150%)
- **X-axis:** Whitethorn cover along gradient

- Points:
  - 0% (North)
  - At sharp boundary
  - 21%
  - 68%
  - 0% (South)

- Notes:
  - Sandy sites vulnerable.
  - Shallow sandy sites resist invasion.
2) ESD classes must be able to distinguish land with different potential

Reagan series: Basin floor

Reagan series: Piedmont slope

Which one is closest to potential vegetation?
The solution: data gathering as part of soil survey and ESD development

Elements of a successful approach

1) One or more range cons working with soil scientists

2) Range cons that understand soils

3) A vegetation/soil surface sampling protocol that matches the pace of soil sampling

4) A coding system that relates vegetation measurements, soil measurements, and coordinates at points

5) Many points with varying levels of detail at a regional scale, rather than a few points with unnecessarily high precision

6) A database to house these data and their relationships
A three-tiered sampling procedure

*Based on Presidio County, TX and White Sands, NM Soil Surveys*

Tier 1) “Traverse”—low intensity sampling, many points (100s)
   - arbitrary points, often along roads
   - soil to taxon or series or even prelim ecological site
   - vegetation community classes, state class id

**Purpose:** Concept building, locations for Tier 2 samples
A three-tiered sampling procedure

Tier 1) “Traverse”—low intensity sampling, many points (100s)

Tier 2) “Transect”—medium intensity sampling, fewer points
- intervals within replicate map unit representatives
- can be used to examine causes of vegetation differences within and between map units
- rapid soil profile information (mini-pit, auger holes)
- vegetation cover estimates by species, soil surface indicators

**Purpose**: Data used to create and test ESD concepts and to develop S&T models and model text
A three-tiered sampling procedure

Tier 1) “Traverse”—low intensity sampling, many points (100s)

Tier 2) “Transect”—medium intensity sampling, fewer points

Tier 3) “Characterization”—high intensity sampling, few points
- replicate, representative pedons and states
- full soil characterization (232) in trench or pit
- line-point intercept, production, soil stability test
  augmented by "tier 2" above

**Purpose**: Create data ranges to populate ESIS for benchmark data on vegetation and soils
A general strategy for sampling

1. Rapid survey of map units across LRU (Tier1)

2. How do map units differ, how many community types?

3. Use spatial digital data/remote sensing to stratify landscape/preliminary map units

4. Rapid survey of map unit delineations (Tier1)

5. “Transect” a subset of map unit delineations with different communities (at least 3 replicates/community/map unit), id map unit component (Tier2)

6. Evaluate data: important plant community differences are coupled with:
   a) no consistent soil differences = different states
   b) distinct soil or climate properties = different LRU and/or ecological sites

7. Select representatives of states within an Ecological Site for intensive measurement (Tier3)
## Tier 1: Traverse (ESD Quick data form)

<table>
<thead>
<tr>
<th>Date:</th>
<th>Observers:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Point</th>
<th>State/Community</th>
<th>MU</th>
<th>Landform</th>
<th>Soil family/characteristics</th>
<th>Series</th>
<th>Easting</th>
<th>Northing</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

Tobosa-honey mesquite community

Very rapid identification of plant community from catalog of types generated at S&T workshops or in databases (geolocation also important!)
Tier 2: Transect (Plant Composition and Pattern form)

Modified Domin-Krajina cover estimate in 20x20 m plot

<table>
<thead>
<tr>
<th>Woody Class</th>
<th>Grass Class</th>
<th>Forb Class</th>
<th>Other Class</th>
<th>Percent</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>+--few</td>
<td>1--&lt;0.1%</td>
<td>2--&lt;1%</td>
<td>3--1-4%</td>
<td>4--5-10%</td>
<td>5--10-25%</td>
</tr>
</tbody>
</table>

Litter

Cryptogram

20 m

20 m

= 1/10th acre plot

Cover estimated ocularly using cover scale within a 20x20 m area around pit, can be performed rapidly during soil survey transecting (15 minutes)
Tier 2: Transect (Plant Composition and Pattern form)

A simple measure of patch structure that relates to the potential for erosion

Relates to Rangeland Health Indicators, but does not compare to a standard (because it is not defined yet)

Used in S&T model text to describe states

from Reitkerk et al., 2004, Science 305: 1926
Tier 2: Transect (Plant Composition and Pattern form)

*Resource retention class in 20 x 20 m*

<table>
<thead>
<tr>
<th>Description</th>
<th>cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interconnected grass cover or dense bunchgrasses; and surrounding ellipsoid</td>
<td></td>
</tr>
<tr>
<td>bare patches &lt; 30 cm</td>
<td></td>
</tr>
<tr>
<td>Grass cover interconnected and surrounding ellipsoid bare ground patches</td>
<td></td>
</tr>
<tr>
<td>from 30-__cm</td>
<td>__</td>
</tr>
<tr>
<td>Grass cover fragmented by elongate bare ground areas to __ cm wide but</td>
<td></td>
</tr>
<tr>
<td>bounded in plot</td>
<td>__</td>
</tr>
<tr>
<td>Grass cover fragmented by elongate bare ground areas to __ cm wide that</td>
<td></td>
</tr>
<tr>
<td>across entire width of plot</td>
<td>__</td>
</tr>
<tr>
<td>Bare ground interconnected in several directions and isolated grass patches</td>
<td></td>
</tr>
<tr>
<td>up to __ cm</td>
<td>__</td>
</tr>
<tr>
<td>Bare ground interconnected with scattered or no grass plants</td>
<td></td>
</tr>
</tbody>
</table>

from Reitkerk et al., 2004, Science 305: 1926
Tier 2: Transect (Plant Composition and Pattern form)

**Resource retention class in 20 x 20 m**

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</tr>
<tr>
<td>Grass cover interconnected and surrounding ellipsoid bare ground patches from 30-__ cm</td>
<td></td>
</tr>
<tr>
<td>Grass cover fragmented by elongate bare ground areas to __ cm wide but bounded in plot</td>
<td></td>
</tr>
<tr>
<td>Grass cover fragmented by elongate bare ground areas to __ cm wide that across entire width of plot</td>
<td></td>
</tr>
<tr>
<td>Bare ground interconnected in several directions and isolated grass patches up to __ cm</td>
<td></td>
</tr>
<tr>
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</tr>
</tbody>
</table>

from Reitkerk et al., 2004, Science 305: 1926
## Tier 2: Transect (Plant Composition and Pattern form)

**Erosion pattern class in 20 x 20 m**

<table>
<thead>
<tr>
<th>Description</th>
<th>Check one</th>
</tr>
</thead>
<tbody>
<tr>
<td>No evidence of erosion or deposition</td>
<td></td>
</tr>
<tr>
<td>Erosion limited to small (&lt; 50 cm) blowouts or rills, few pedestals</td>
<td></td>
</tr>
<tr>
<td>Erosion across large (&gt; 50 cm) bare patches, gullies, flow patterns, but low soil loss</td>
<td></td>
</tr>
<tr>
<td>Erosion across large areas with minor deflation, coppicing, flow patterns, pedestals</td>
<td></td>
</tr>
<tr>
<td>Erosion across large areas with deflation, coppicing, and truncation of horizons</td>
<td></td>
</tr>
<tr>
<td>Deposition across large areas, may have rills, flow patterns.</td>
<td></td>
</tr>
</tbody>
</table>

A simple measure of erosion pattern that describes the *consequences of erosion processes for soils*

Relates to Rangeland Health Indicators, but does not compare to a standard (because it is not defined yet)

Used in S&T model text to describe states
## Tier 2: Transect (Plant Composition and Pattern form)

**Erosion pattern class in 20 x 20 m**  

<table>
<thead>
<tr>
<th>Erosion Pattern Class</th>
<th>Check one</th>
</tr>
</thead>
<tbody>
<tr>
<td>No evidence of erosion or deposition</td>
<td></td>
</tr>
<tr>
<td>Erosion limited to small (&lt; 50 cm) blowouts or rills, few pedestals</td>
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<td></td>
</tr>
<tr>
<td>Deposition across large areas, may have rills, flow patterns.</td>
<td></td>
</tr>
</tbody>
</table>

Another simple measure related to rangeland health indicators and used in text
## Tier 2: Transect (Soil form)

### Surface soil properties

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>No crust; may be plant base or soil without any other surface feature</td>
</tr>
<tr>
<td>WP</td>
<td>Weak physical or biological crust, may have few cyanobacterial sheaths dangling from ped, no darkening from cyanobacteria.</td>
</tr>
<tr>
<td>SP</td>
<td>Strong physical crust</td>
</tr>
<tr>
<td>PDB</td>
<td>Poorly developed biological crust assemblage, few to many cyanobacterial sheaths, may be slightly dark, can include some other morphological group (algal crust, lichen, moss)</td>
</tr>
<tr>
<td>SDB</td>
<td>Strongly developed biological crust assemblage, obvious dark cyanobacteria, rubbery algal moss or lichen crust.</td>
</tr>
<tr>
<td>CB</td>
<td>Cracking or curling, rubbery algal crusts, with or without lichen</td>
</tr>
<tr>
<td>RA</td>
<td>Uniform rock armor</td>
</tr>
<tr>
<td>CEM</td>
<td>Cemented</td>
</tr>
<tr>
<td>D</td>
<td>Duff</td>
</tr>
<tr>
<td>EL</td>
<td>Embedded litter</td>
</tr>
</tbody>
</table>

These classes are estimated visually in Tier 2 plots or can be used with more intensive techniques.
Tier 3: Intensive characterization: line point intercept vegetation, quantitative soil surface properties, production

LPI design yields 200 points for basal and canopy cover but maintains observations within 10-20 m of the soil pit
Tier 4 (future): incorporating high resolution remote sensed patterns within ESDs and recommended monitoring structures

Within a site, we describe the pattern of highly vegetated and bare areas to help define states expressed at larger scales than a 400m² plot.
### Soil Taxon, Ecological Site and State Determination

#### Soil Taxonomy
- **Site:** 01015
- **Date:** 12/14/2004
- **Map Unit Symbol:**
- **Series:**
- **Particle Size Class:**
- **Mineralogy:**
- **Soil Temp Regime:**
- **Depth Class:**
- **Subgroup:**
- **Greatgroup:**

#### Ecological Site Determination
- **Ecological Site ID:**
- **State within Ecological Site:**
- **Community within State:**

#### Domin-Krajina and Line Point Intercept Summary Data

<table>
<thead>
<tr>
<th>Species</th>
<th>Class</th>
<th>% Cover</th>
<th>LPI Canopy</th>
<th>LPI Basal Cyt</th>
<th>LPI % Prod</th>
<th>Notes</th>
<th>Generate from LPI core</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARIST</td>
<td>1</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARTE3</td>
<td>1</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOER1</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOER2</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>EPTR</td>
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<td>0.05</td>
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<tr>
<td>ERCI</td>
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<td>0.05</td>
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</tr>
<tr>
<td>ERWR</td>
<td>+</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gravel</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GUSL2</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fest2</td>
<td>1</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LITTER</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MACA2</td>
<td>+</td>
<td>0.01</td>
<td></td>
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<tr>
<td>DPM</td>
<td>1</td>
<td>0.05</td>
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</tbody>
</table>

### Additional Options
- Return to Plot and Soil Form
- Return to Plant Composition and Pattern Form
- Enter/Edit Form Data
- View/Enter Photo(s)
Conclusions

• We need more experimentation with regard to various kinds of threshold processes (e.g., productivity loss, soil degradation, invasion) in different sites.

• We need to produce large databases that link point data on vegetation, vegetation and soil surface pattern related to processes, and soil profile properties.

• We need to involve and motivate the research community and support scientific approaches to ESDs.

• We need to maintain focus on management-relevant distinctions and policy issues in conducting research.