Erosion on a Loamy Upland State and Transition Model

Jeffry Stone
Ecological Site Definition
- “a distinctive kind of land with specific characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation”.

Important Characteristics
- soil texture, depth of A horizon, and type of B horizon (clay, calcic)
- position on landscape (slope)
Loamy Uplands (12-16 p.z.) STM

HCPC*
- Midgrass
- Annuals
- Short grass

Drought-fire interactions

Soil
- gravely sandy loam
- 1-4 inch A horizon
- clay B horizon

*Historic Climax Plant Community

state
2 way transition
1 way transition
Loamy Uplands (12-16 p.z.) STM

- **HCPC**
  - Midgrass
  - Annuals
  - Short grass

- **Mesquite Natives**
  - Mesquite
  - Lehmans

- **Mesquite Annuals**

- **Dense Mesquite (Eroded)**

- **Natives Mesquite (Eroded)**

- **New Site Potential**
# Erosion on Rangelands

<table>
<thead>
<tr>
<th>Process</th>
<th>Driver</th>
<th>Modifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raindrop detachment</td>
<td>Rainfall energy</td>
<td>Veg/soil characteristics</td>
</tr>
<tr>
<td>Transport/Deposition</td>
<td>Runoff</td>
<td>Slope, roughness, topography</td>
</tr>
<tr>
<td></td>
<td>Sediment Load</td>
<td></td>
</tr>
<tr>
<td>Flow detachment (Sheet, Concentrated flow)</td>
<td>Transport Capacity</td>
<td>Veg/soil, slope, roughness, topography</td>
</tr>
</tbody>
</table>
Problem Statement

- STM: States – semi-quantitative, Transitions - qualitative

- Relationship between STM and erosion is qualitative

- Little or no data on dominant erosion process (deposition, transport, flow detachment)
Rainfall Simulator Experiment

Walnut Gulch Rainfall Simulator
Variable intensity - 25-180 mm/hr
Rainfall Simulator Experiment

4 SMALL PLOTS (0.75 m²)
- rain drop detachment

4 LARGE PLOTS (2 x 6 m)
- infiltration/runoff
- integrated erosion response
- rain and flow detachment, transport, deposition
Loamy Uplands (12-16 p.z.) STM

HCPC
- Midgrass
- Annuals
- Short grass

Mesquite Natives

Mesquite Lehmans

Mesquite Annuals

Dense Mesquite (Eroded)

Natives Mesquite (Eroded)
<table>
<thead>
<tr>
<th>State</th>
<th>Location</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCPC - Mid</td>
<td>San Raphael</td>
<td>8</td>
</tr>
<tr>
<td>HCPC - Short</td>
<td>Empire</td>
<td>12</td>
</tr>
<tr>
<td>Mesquite/Natives High Slope</td>
<td>Empire</td>
<td>14</td>
</tr>
<tr>
<td>Mesquite/Natives Low Slope</td>
<td>Empire</td>
<td>4</td>
</tr>
<tr>
<td>Lehmans</td>
<td>Walnut Gulch</td>
<td>11</td>
</tr>
</tbody>
</table>
## Results – State comparisons

### Hydrology and Erosion Characteristics

<table>
<thead>
<tr>
<th>State</th>
<th>Runoff</th>
<th>Sediment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume</td>
<td>Peak Rate</td>
</tr>
<tr>
<td>HCPC - Mid</td>
<td>0.53</td>
<td>0.83</td>
</tr>
<tr>
<td>HCPC - Short</td>
<td>0.80¹</td>
<td>0.87</td>
</tr>
<tr>
<td>Mes/Nat HS</td>
<td>0.75</td>
<td>0.83</td>
</tr>
<tr>
<td>Mes/Nat LS</td>
<td>0.92</td>
<td>0.93</td>
</tr>
<tr>
<td>Lehmans</td>
<td>0.82</td>
<td>0.86</td>
</tr>
</tbody>
</table>

¹ *blue number* means variable is significantly different than the HCPC - Mid (α = 0.05)
Rainfall Simulator Experiment

4 SMALL PLOTS (0.75 m²)
- rain drop detachment

4 LARGE PLOTS (2 x 6 m)
- infiltration/runoff
- integrated erosion response
- rain and flow detachment, transport, deposition
Results – Erosion Process

Identifying the Erosion Process

- Use rainfall simulator large and small plot sediment, $q_s$, and runoff, $q$, discharge data

- Rain drop detachment is the same on small and large plots

- Any difference between small and large plot sediment discharge, $q_s$, is assumed to be due to dominant erosion process on the large plot
Results – Erosion Process

Sediment Discharge Comparisons

- small plot $q_s >$ large plot $q_s$
  - net deposition on large plot

- small plot $q_s <$ large plot $q_s$
  - net flow detachment on large plot

- small plot $q_s =$ large plot $q_s$
  - threshold of deposition/flow detachment on large plot (i.e. net transport)
Results – Erosion Process

Sediment Discharge Comparisons

small plot: \( \ln (q_s) = \beta_{0S} + \beta_{1S} \ln (q S_0) \)
large plot: \( \ln (q_s) = \beta_{0L} + \beta_{1L} \ln (q S_0) \)

If \( \beta_S = \beta_L \) net transport

If \( \beta_S > \beta_L \) net deposition

If \( \beta_S < \beta_L \) net flow detachment
Results – Mesquite Natives LS

- small plot
- large plot
- HCPC - Mid

Deposition

$q_s$ (g/s/m²) vs. $q_{S_0}$ (mm/hr)
Results – Mesquite Natives HS

- small plot
- large plot
- HCPC - Mid

Deposition

$q_s (g/s/m^2)$ vs. $q_S (mm/hr)$
Results – Lehmans

- small plot
- large plot
- HCPC - Mid

Deposition

$q_s$ (g/s m²)

$q S_0$ (mm/hr)
Results – HCPC Short Grass

- small plot
- large plot
- HCPC - Mid

Transport

$q_s (q/s/m^2)$ vs. $q_{S0} (mm/hr)$
Results – Reduced Grazing

Short Grass deposition

Year 2003 after wildfire, drought, and heavy grazing

Short Grass transport

Year 2007 reduced grazing

0.00 0.05 0.10 0.15 0.20
q_t (g/s/m²)

0.00 0.05 0.10 0.15 0.20
q (g/s/m²)

0.00 0.05 0.10 0.15 0.20
q_s (mm/hr)

0.00 0.05 0.10 0.15 0.20
q (mm/hr)

Southwest Watershed Research Center  Tucson - Tombstone, AZ
Results – Wildfire

Mes/Nat HS deposition

Wildfire vs. unburned and burned areas:

- Small plot
- Large plot

Graphs showing q_r (g/s/m^2) vs. q_S0 (mm/hr) for Mes/Nat HS deposition in unburned and burned areas.
Results – Main Driver

Sediment discharge as a function of flow velocity
1. HCPC → Degraded states
   a. increased erosion
   b. net deposition

2. Disturbance/Transition:
   a. Net Deposition ↔ Net Transport
   b. Unknown: Net Detachment ↔ Net Transport

3. Main driver is flow velocity which is a function of slope and ground cover, primarily litter cover
## Results – State comparisons

### Cover Characteristics (%)

<table>
<thead>
<tr>
<th>State</th>
<th>Litter</th>
<th>Basal</th>
<th>GC</th>
<th>Grass</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCPC - Mid</td>
<td>46</td>
<td>16</td>
<td>72</td>
<td>77</td>
<td>79</td>
</tr>
<tr>
<td>HCPC - Short</td>
<td>19&lt;sup&gt;1&lt;/sup&gt;</td>
<td>5</td>
<td>51</td>
<td>35</td>
<td>42</td>
</tr>
<tr>
<td>Mes/Nat HS</td>
<td>14</td>
<td>5</td>
<td>58</td>
<td>22</td>
<td>26</td>
</tr>
<tr>
<td>Mes/Nat LS</td>
<td>21</td>
<td>4</td>
<td>36</td>
<td>24</td>
<td>36</td>
</tr>
<tr>
<td>Lehmans</td>
<td>41</td>
<td>4</td>
<td>68</td>
<td>30</td>
<td>49</td>
</tr>
</tbody>
</table>

<sup>1</sup> blue number means variable is significantly different than the HCPC - Mid (\(\alpha = 0.05\))
Erosion on Rangelands

Accelerated Erosion

- Erosion rate > soil formation rate
- Sheet or concentrated flow erosion
- Impact on Loamy Upland – loss of A horizon → less water holding capacity → competitive advantage to woody species
Erosion on Rangelands

Basic Concept

- Raindrop detachment
  (canopy/ground cover, soil)
- Flow detachment - sheet or concentrated flow
  (ground cover, soil, slope, roughness, microtopography)
- Net transport or Net deposition
  (slope, roughness, microtopography)
## Loamy Uplands Practices

<table>
<thead>
<tr>
<th>State</th>
<th>Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>wildfire</td>
</tr>
<tr>
<td>Mesquite/Natives</td>
<td></td>
</tr>
<tr>
<td>High Slope</td>
<td>wildfire</td>
</tr>
<tr>
<td>Mesquite/Natives</td>
<td>brush treatment</td>
</tr>
<tr>
<td>Low Slope</td>
<td></td>
</tr>
<tr>
<td>Short Grass</td>
<td>Drought/Fire/Grazing recovery</td>
</tr>
<tr>
<td>Lehmans</td>
<td>natives - Lehmans</td>
</tr>
</tbody>
</table>