Developing Diverse, Effective, and Permanent Plant Communities on Reclaimed Surface Coal Mines: establishing ecosystem function in reconstructed wildlands

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Pre-mine Land Uses For Surface Coal Mines in the Western United States

Pre-mine Rangelands Used For:

- Livestock grazing
- Wildlife habitat
- Cultural resources
- Pasture
- Forest Products

Surface Coal Mine Disturbance

Damaged hydrologic, nutrient cycling, energy capture, and vegetation processes

(Photos by OSMRE)
Reconstruct Ecosystem Function

Ecologically-based Reclamation

Diverse, Effective, and Permanent Plant Community

Reconstruct ecosystem function or the biological, geochemical and physical processes

“Ecosystem health and sustainability: implies the ability of the ecosystem to maintain its structure (organization) and function (vigor) over time in the face of external stress (resilience)” (Herrick et al. 2006)

(Photos by OSMRE)
Developing Diverse, Effective, and Permanent Plant Communities on Reclaimed Surface Coal Mines: restoring ecosystem function

Objectives

• Attributes of Rangeland Health

• constraints of plants growing in adverse soil conditions;

• assisted plant community succession: reconstructing ecosystem function;

• Ecologically-based Invasive Plant Management (EBIPM) and Weed Prevention

(Photos by OSMRE)
Three Interrelated Attributes of Rangeland Health

**Hydrologic function:** The capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.

**Soil/Site Stability:** The capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water.

**Biotic Integrity:** The capacity of the biotic community to support ecological processes within the normal range of variability expected for the site, to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur.

Hydrologic Function
Landform Design and Resource Flows

(Adapted from Whisenant, 2005)
Geomorphologic reclamation aims to increase diversification of landforms, enhance sustainability, and define ridges and valleys while honoring the major drainage routes.

(Photos by Mychal Yellowman, 2010)
Hydrologic Function: long, straight slopes drive large surface-flow rates

- Constructing landforms that naturally blend into the steep slopes of the surrounding environment may not ensure stability (DePriest et al. 2015. Ecological Engineering 81:19-29)

- Long straight slopes can often foster large surface-flow rates and should be avoided if feasible

(Photo by Ed Vasquez, 2017)
Water Infiltration, Penetration and Runoff

- Rate of **infiltration** relative to the rate of water supply will determine how much water enters the root zone versus how much water will runoff.

- Insufficient water **penetration** is a result of the inability of enough water to infiltrate deep enough into the active root zone to sustain the plant until the next precipitation event.

- **Mitigation**: Prevent soil crust, minimize compaction, increase soil organic matter, incorporate chemical amendments as appropriate, improve topsoil depth and soil structure.

(Photos by Mychal Yellowman, 2010)
Processes Driving Hydrologic Function, Soil/Site Stability, and Biological Integrity

Belowground Systems Model Attributes

**Physical Soil Properties**
- Soil Surface Roughness
- % Bare ground
- Litter
- Parent Material
- Texture
- Structure
- Aggregate Stability
- % SOM (humus)
- Hydraulic Conductivity
- Porosity
- Bulk Density
- Seasonal Temperature

- **Biological Soil Properties**
  - Micro-macro biological Pool
  - Mycorrhizae
  - Pathogens
  - Nitrogen fixers
  - Biological crusts

- **Hydrologic Soil Properties**
  - Precipitation
  - Landform
  - Infiltration
  - Water holding Capacity
  - Rills, interrills, gullies, streambanks
  - evapotranspiration

- **Chemical Soil Properties**
  - CO₂
  - EC
  - SAR
  - CEC
  - pH
  - Nutrient flows
CONSTRAINTS OF PLANTS GROWING IN ADVERSE SOIL CONDITIONS (Spoil Suitability)

- Texture (i.e., % clay or sand)
- Percent rock fragments
- Selenium (ppm)
- Acid-based potential
- pH
- Electrical conductivity - EC (mmhos cm⁻¹)
- Calcium carbonate equivalent
- Sodium absorption ratio (SAR)
A healthy semi-arid, relatively weed resistant plant community

- Functional Group Niche Occupation Helps to Improve:
  - Hydrologic processes
  - Water use efficiency
  - Micro-environmental conditions
  - Resistance and resilience to exotic plant invasion

(Sheley et al. Weed Technol. 7:766-773)
ASSISTED PLANT COMMUNITY SUCCESSION: reconstructing ecosystem function

(Sheley et al. 1996. Weed Technology 10:766-773)
## Assisted Plant Community Succession

<table>
<thead>
<tr>
<th>Causes of Succession</th>
<th>Processes</th>
<th>Management Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site availability</td>
<td>Disturbance</td>
<td>Size, severity, time intervals, patchiness, predisturbance history</td>
</tr>
<tr>
<td>Species availability</td>
<td>Dispersal</td>
<td>Dispersal mechanisms and landscape features</td>
</tr>
<tr>
<td>Species performance</td>
<td>Propagules</td>
<td>Land use, disturbance interval, species life history</td>
</tr>
<tr>
<td></td>
<td>Resources</td>
<td>Soil, topography, climate, site history, microbes, litter retention</td>
</tr>
<tr>
<td></td>
<td>Ecophysiology</td>
<td>Germination requirements, assimilation rates, growth rates, genetic differentiation</td>
</tr>
<tr>
<td></td>
<td>Life history</td>
<td>Allocation, reproduction timing and degree</td>
</tr>
<tr>
<td></td>
<td>Stress</td>
<td>Climate, site-history, prior occupants, herbivory, natural enemies</td>
</tr>
<tr>
<td></td>
<td>Interference</td>
<td>Competition, herbivory, allelopathy, resource availability, predators, other level interactions</td>
</tr>
</tbody>
</table>

(Sheley et al. 1996. Weed Technology 10:766-773)
Assisted Plant Community Succession: reconstructing ecosystem function

Systems Approach to Reconstructing Disturbed Rangelands

(James et al. 2013. J. Applied Ecol. 50: 730-739)
Reconstructing Ecosystem Function

Emergent Properties
- Energy budget
- Carbon balance
- Belowground NPP
- Net Mineralization/Immobilization
- Hydrology

Below-ground Soil Properties

- Physical Soil Properties
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- Chemical Soil Properties
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  - CEC
  - pH
  - Nutrient flows

(Vasquez and Sheley, 2018; James et al., 2013)
EBIPM - Invasive Plant Prevention

Area Occupied

- Eradication Window
  - Implement Early Detection Strategies
- Control Possible
- Containment Possible
- Effective Control Unlikely Without Massive Resource Input

Exotic Seed

Management Costs and Invasion Impacts

Introduction → Establishment → Spread → Impact

(Vasquez et al., 2010. Rangelands 32:3-5)
Remember: reconstruct ecosystem structure and function

(Vasquez and Sheley. In Review. JASMR)
Questions