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

Mining Activities

Surface Coal Mine Disturbance

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

(Photos by OSMRE)

Reconstruct Ecosystem Function

Ecologically-based Reclamation

Resource Input

Time

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

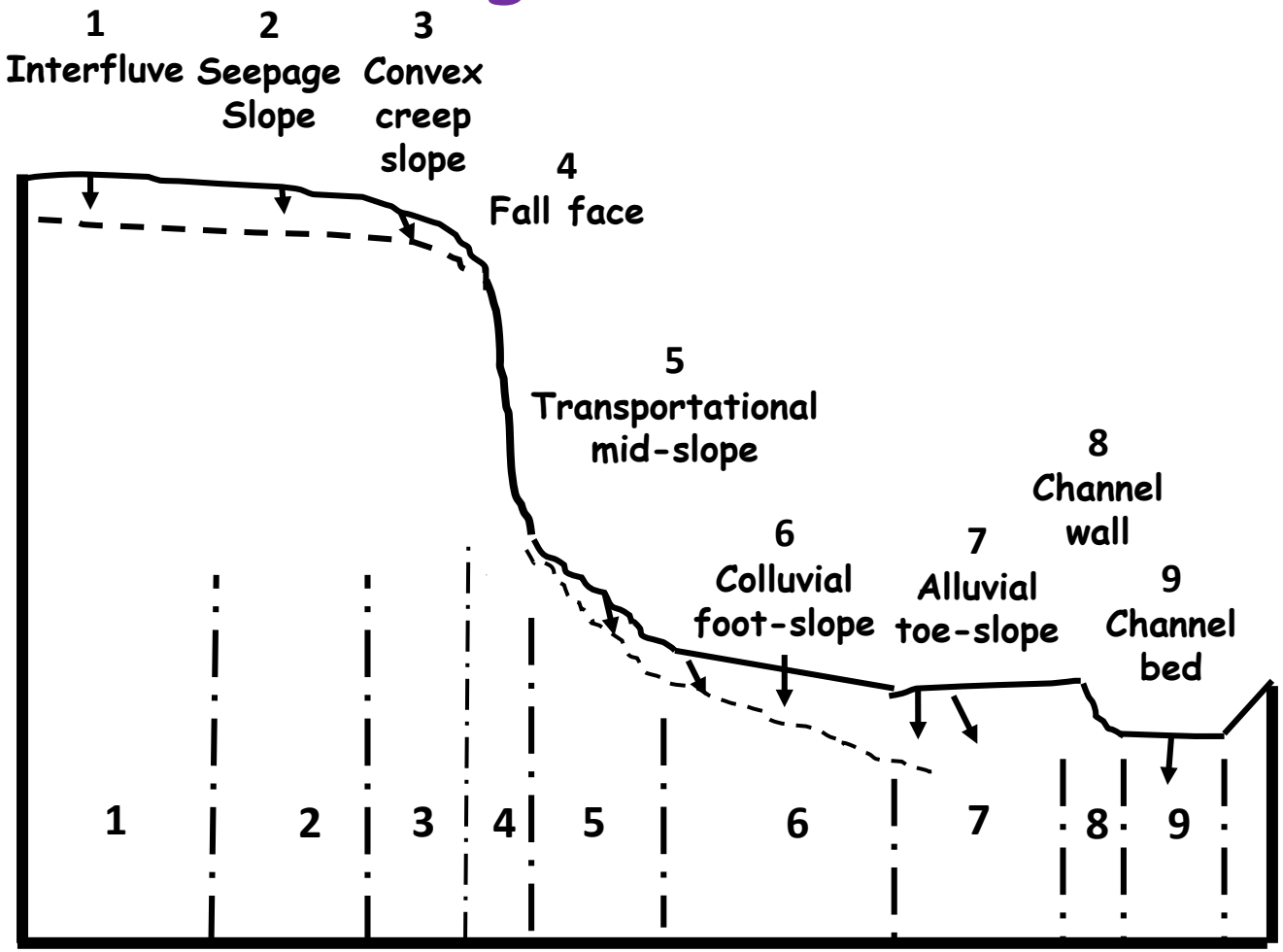
Hydrologic function: The capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.

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.

(Herrick et al. 2006. Journal for Nature Conservation 14:161-171)

Hydrologic Function
Landform Design and Resource Flows



(Adapted from Whisenant, 2005)

Mature Landform (a) and a Mature drainage Channel (b) Following Geomorphic Reclamation

Geomorphic 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

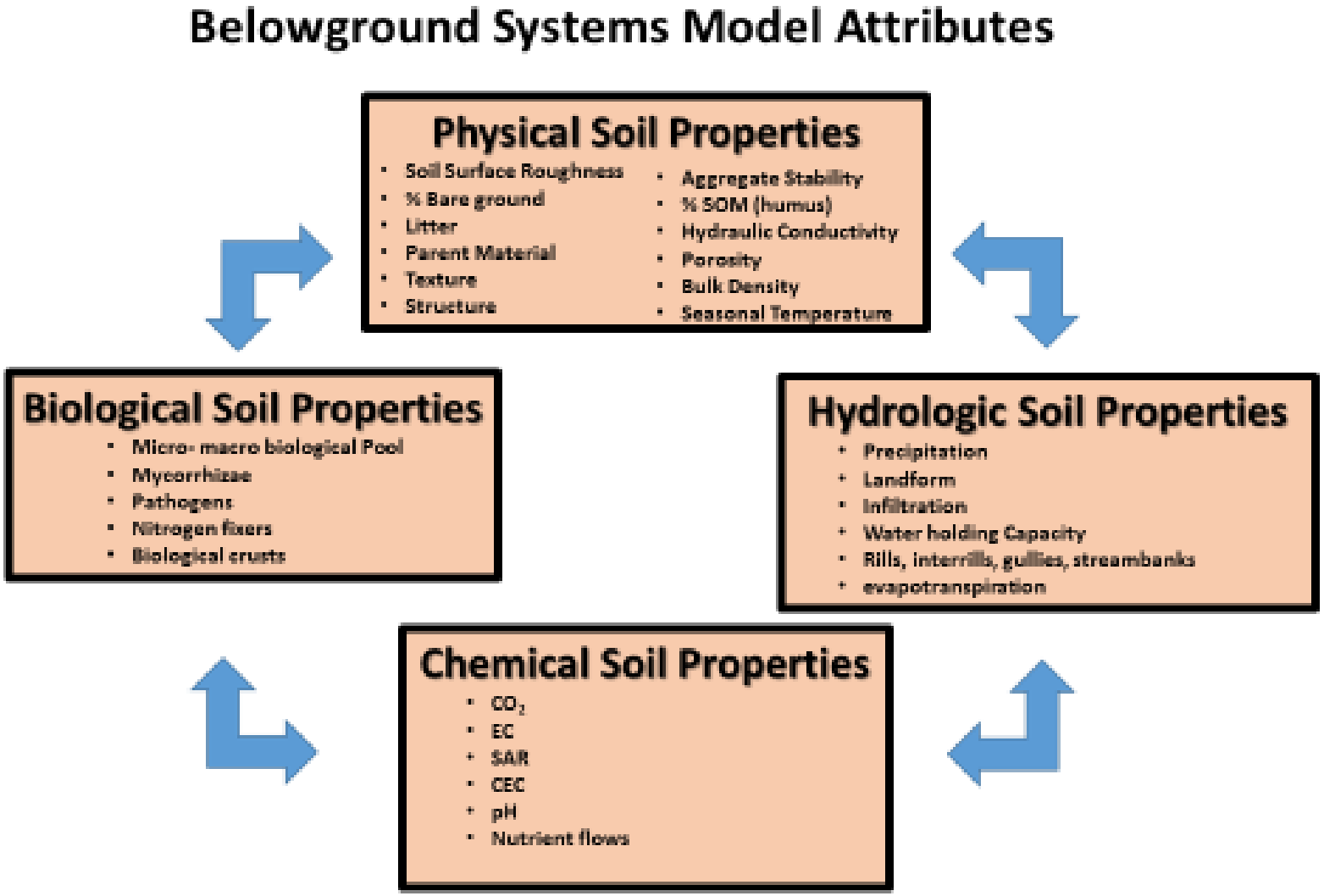
- Rate of **infiltration** relative to the rate of water supply will determine how much water enters the root zone versus how much water will runoff

- 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)

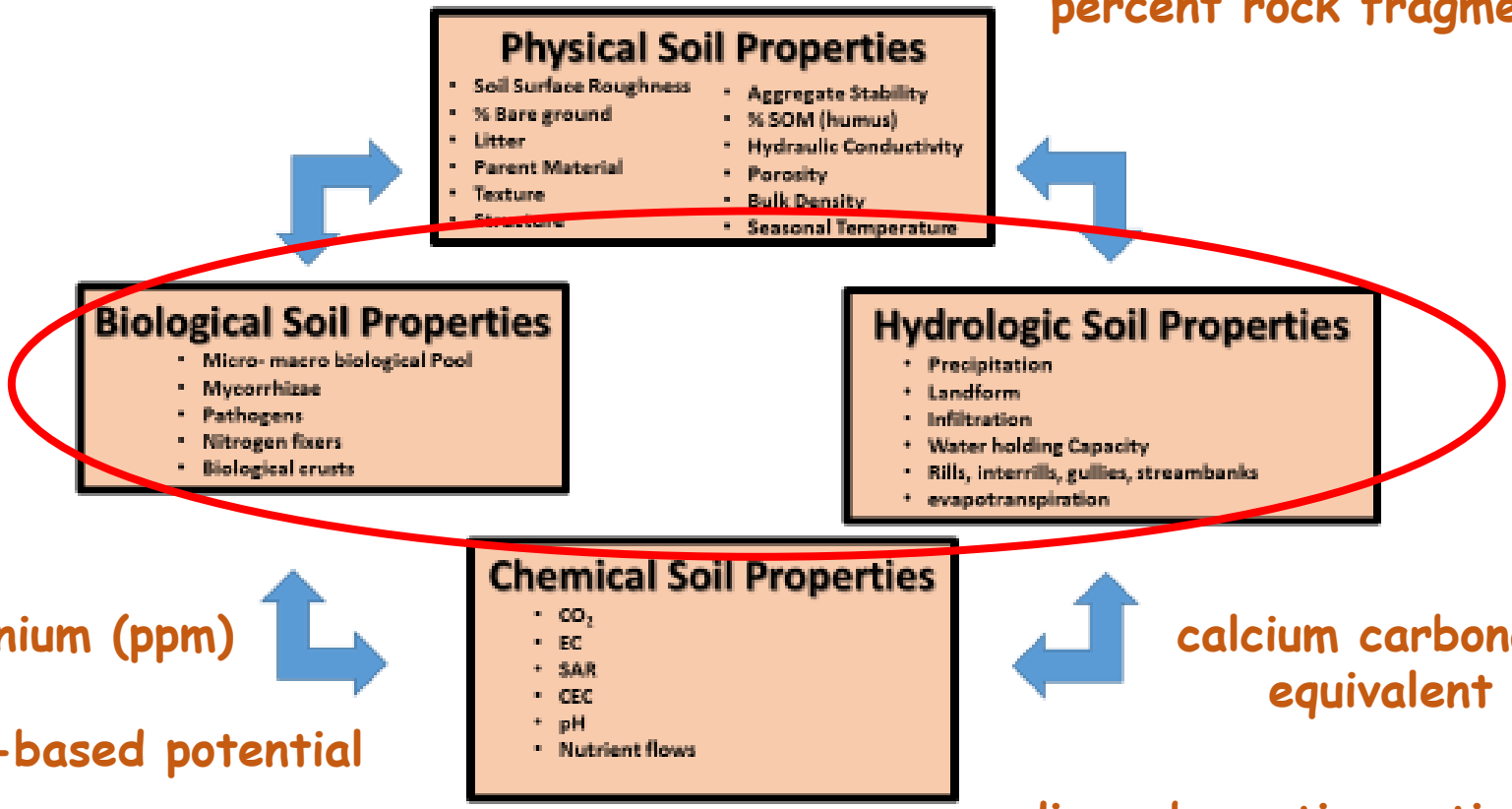
Processes Driving Hydrologic Function, Soil/Site Stability, and Biological Integrity



CONSTRAINTS OF PLANTS GROWING IN ADVERSE SOIL CONDITIONS (Spoil Suitability)

texture (i.e., % clay or sand)

percent rock fragments



selenium (ppm)

calcium carbonate equivalent

acid-based potential

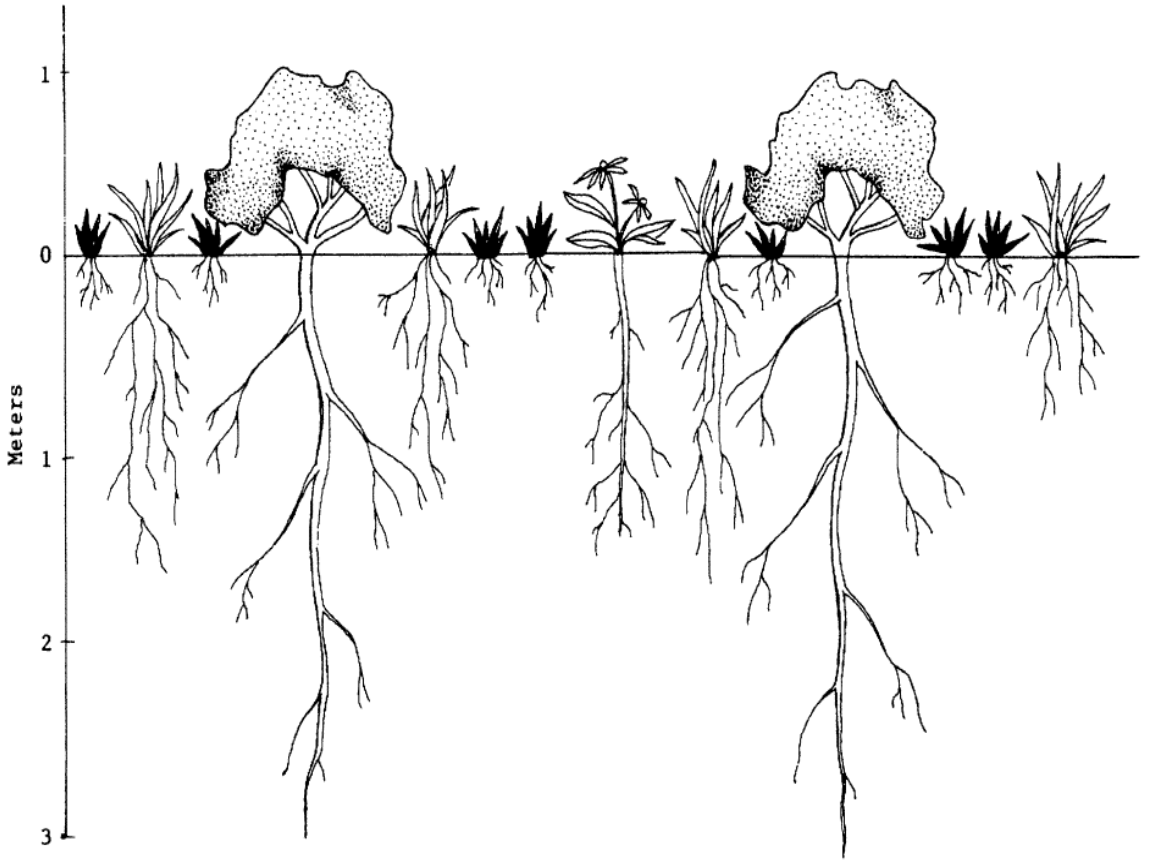
sodium absorption ratio (SAR)

pH

electrical conductivity - EC (mmhos cm^{-1})

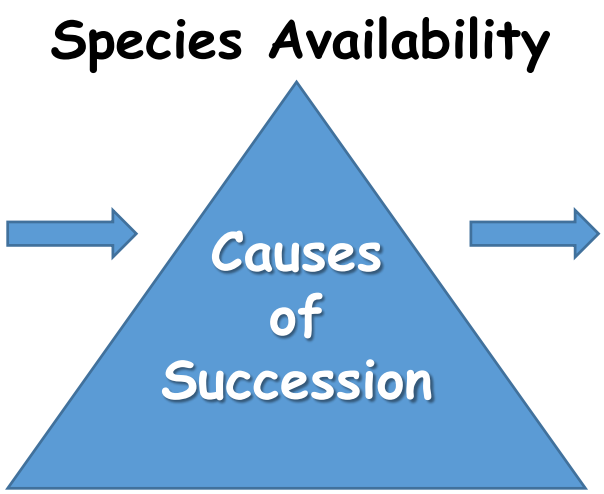
A healthy semi-arid, relatively weed resistant plant community

- **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)

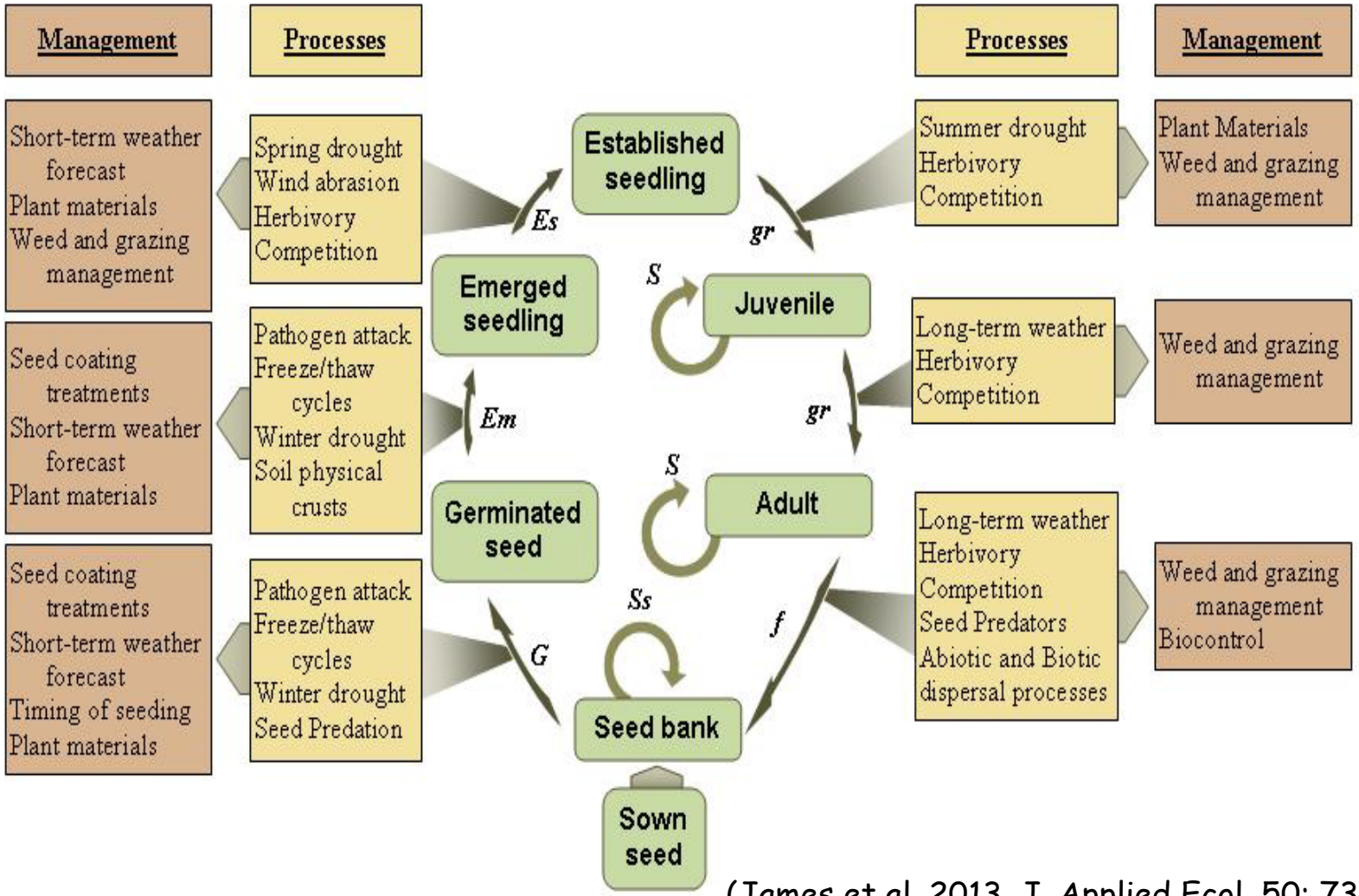
Assisted Plant Community Succession

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

(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

Above-ground

Systems Model Attributes

+/- feedbacks

+/- feedbacks

Below-ground Soil Properties

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
- CO_2
- EC
- SAR
- CEC
- pH
- Nutrient flows

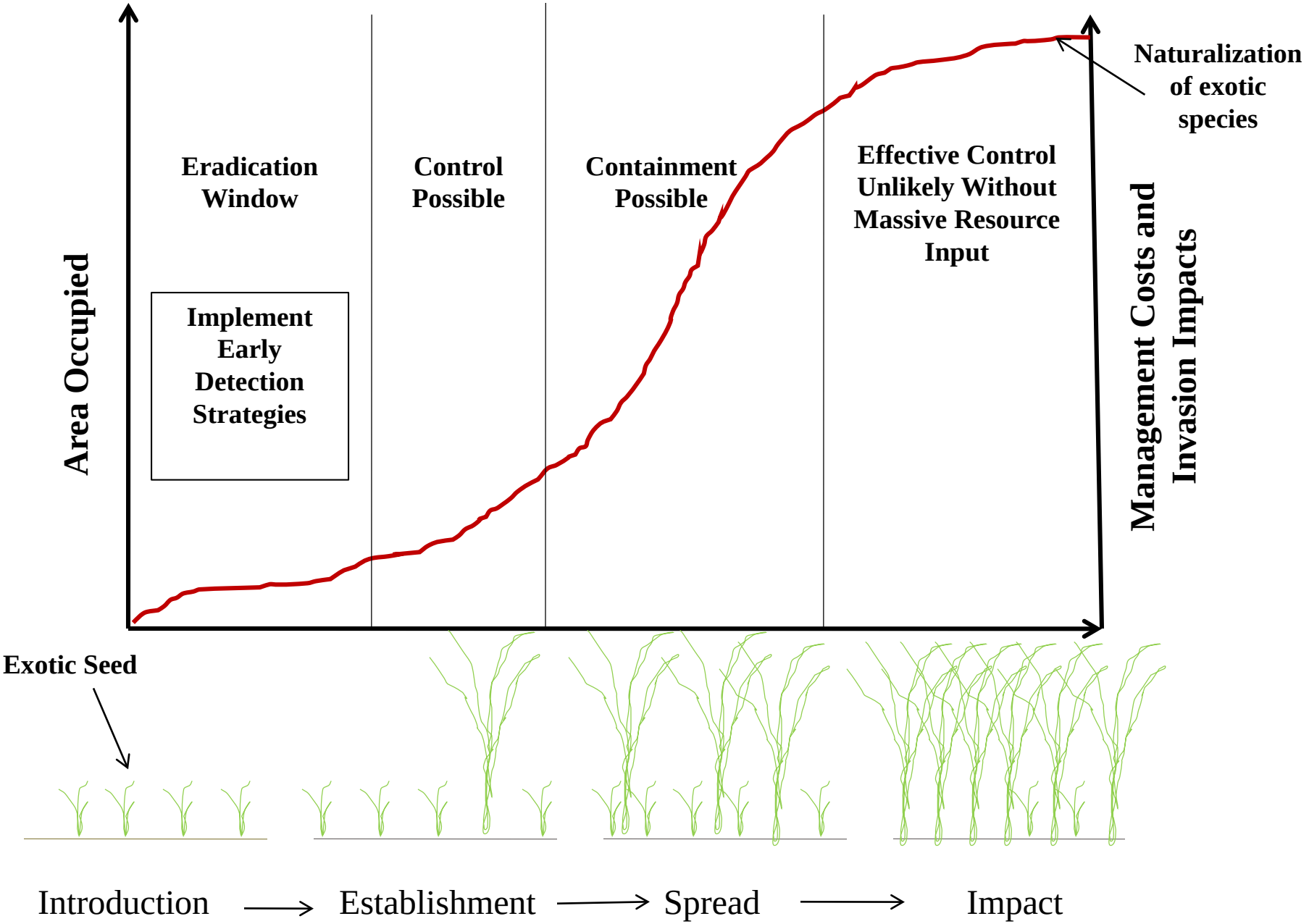
Emergent Properties
- Energy budget
- Carbon balance
- Belowground NPP
- Net Mineralization/Immobilization
- Hydrology

Ecological Processes and Management Options

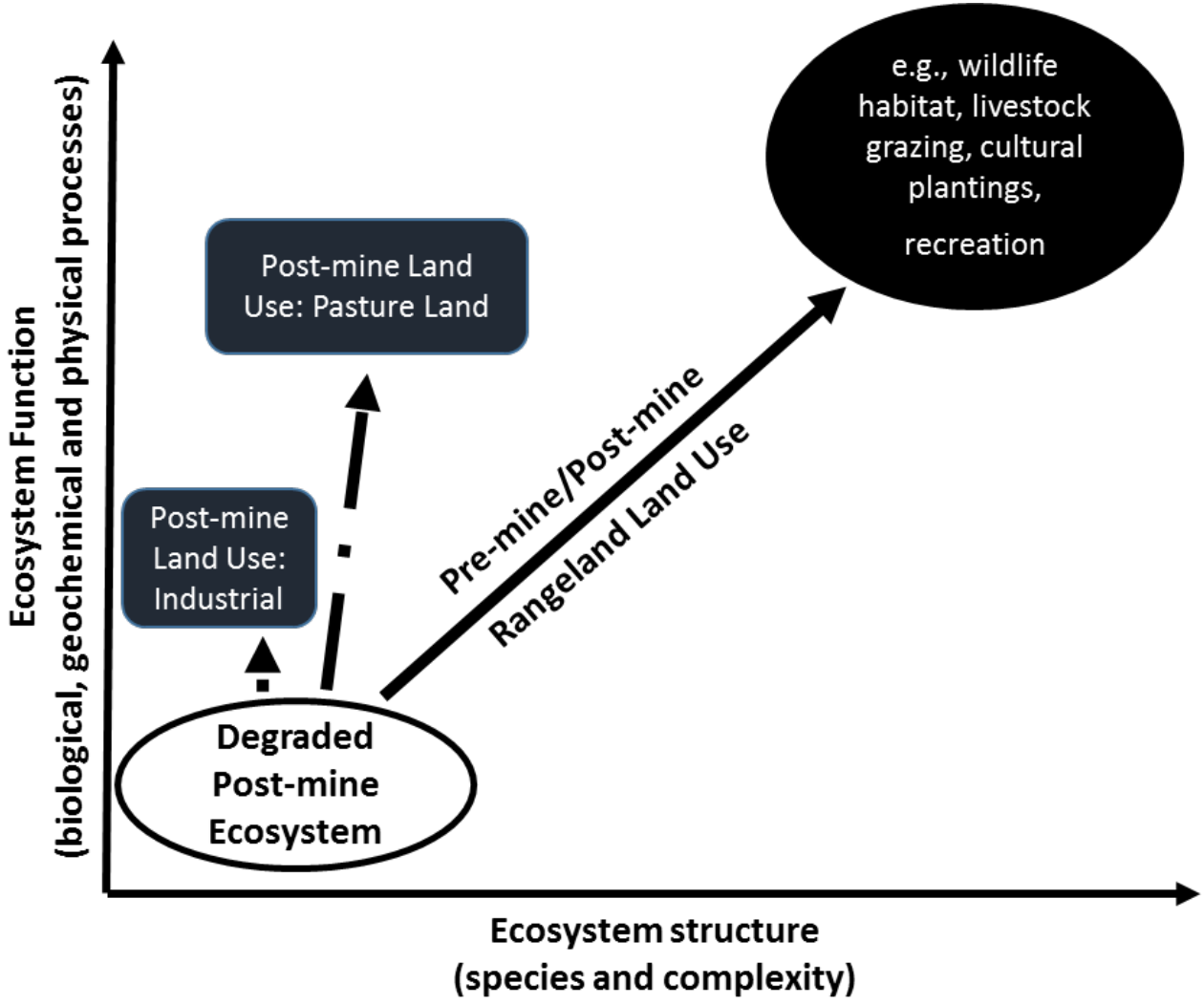
(Vasquez and Sheley, 2018; James et al., 2013)

(Vasquez et al., 2010. Rangelands 32:3-5)

EBIPM - Invasive Plant Prevention



Remember: reconstruct ecosystem structure and function



(Vasquez and Sheley. In Review. JASMR)

Questions