Rangeland ecology II

- Ecological principles of grazing systems
- Ecological relationships
- Grazing effects
- Herbivore-plant dynamics
- System dynamics
- State-and-transition models
Ecological principles

- Grazing systems consist of herbivores, vegetation, landscape and resources
- Interactions can occur among all system components
- Interactions occur at many levels of ecological organization
- Relationships depend on spatial and temporal scales
- Changes in system components represent states and transitions

- One thing leads to another
- Some things can be changed, others cannot
- Controlability is questionable
Components

- **Livestock**
  - Density, selectivity, foraging behavior and landscape utilization

- **Vegetation**
  - Productivity, structure, composition, palatability and nutritional value

- **Landscape**
  - Heterogeneity of patches and patterns at various scales

- **Resources**
  - Availability and supply of light, water, soil, nutrients, organic matter
Interactions

- Vegetation varies with landscape patchiness and resources
  high and low productivity patches

- Patchiness affects grazing pattern
  depending on grazing density x duration and foraging decisions

- Grazing patterns alter patchiness and vegetation
  due to varying levels of disturbance and consumption; IDH, GOH

- Patchiness and animals determine resource distribution
  due to resource flows and source-sink relations, and distribution of feces/urine/remains
Scales of interactions

• Spatial
  – Sites - Patches - Watersheds
  - Regions - Biomes

• Temporal
  – Seconds - - Years - - Centuries

Runoff generated on crust, Intercepted by shrubs; Leakage from area depends on patchiness (connectivity).

A cow bites off a few blades; After decades of grazing, grassland composition has changed.
Levels of organization

• **Individuals**
  Digestion, behavior, growth, birth, reproduction, death

• **Populations**
  Colonization, growth, extinction

• **Communities**
  Diversification, impoverishment

• **Landscapes**
  Formation, erosion, degradation

• **Ecosystems**
  Resource enrichment, depletion
  Organic matter dynamics
Grazing effects

• **Grazing and diversity** *(similar to the Intermediate Disturbance Hypothesis)*
  – At low GI, dominants are consumed and sparse species benefit
    • From release of competition
    • For sites, light and/or soil moisture
  – At high GI, sparse species are also consumed/trampled

• **Effects of grazing**
  – Include trophic and structural effects
  – Vary with productivity

Baja California

Species richness

- Dominant species are consumed most
- Rare species benefit
- Rare species also negatively affected

Intensity of grazing
Grazing effects

Grazing and productivity (Grazing Optimization Hypothesis)

- At high GI, biomass removal does not permit regrowth
- At low GI, biomass removal encourages growth:
  - Compensatory growth
    - Removal of dead material (self-shading)
    - Removal of old organs (physiological sinks)
    - Increased resource supply (recycling/import by urine, feces)
    - Salivary co-factors (But: why not already maximized?)
      (McNaughton 1976. Amer. Nat. 113: 691-703)

- Changes in allocation patterns (more leaf BM, less RA and storage)
- Changes in composition
  - More fast-growing species

Serengeti

![Graph showing biomass production vs. intensity of grazing]

Removal favors growth
Removal exceeds regrowth

Intensity of grazing
Biomass production

Removal favors growth
Removal exceeds regrowth
Herbivore-plant dynamics

Equilibrium between vegetation growth $G$ and herbivore consumption $C$

- Assuming homogeneous biomass
- Immediate, elastic response

$$\frac{dV}{dt} = G(V) - cH(V)$$

V increases if growth exceeds consumption, Decreases if more consumed than produced

System dynamics

• Transitions
  – Sudden - Gradual; Reversible - Irreversible

• States
  – Stable - Transient

• Positive feedback mechanisms
  – A state strengthens itself and/or inhibits another
  – Enhancing a transition and resisting the opposite direction

• Hysteresis
  – Transition by force greater than feedback strength
  – Reversal of transition requires different force

• S-T models
  – Local and global stability
  – Catastrophe theory
  – vs. successional and range quality models
Rangeland states

Grassland - Shrubland (SW US, AUS)
- Perennial grasses and shrubs exclude each other (pos FB + mutual inhibition)
- Grasses have highly edible biomass, but are not resistant to grazing (reserve depletion)
- Shrubs invade if grass declines, but are not palatable (for cattle)
- Trend is termed desertification, although no decline in productivity.

Shrubland - Bare soil (Old World dryland)
- No perennial grasslands (anymore?)
- Shrub-patch and crust exclude each other (pos FB + inhibition)
- Shrub decline due to browse, trampling and clearing
- Changes in landscape states
- Desertification: loss of resources and productivity.

California

Northern Negev
State-and-transition

- Regions of one stable state and of two alternative states
- Catastrophic behavior: collapse and slow recovery

- At low GI, high-BM state
- At high GI, collapse to low-BM state
- At much lower GI and time+, recovery
- BM between Fc and Fr: depends from where.

- Collapse and recovery occur at different GI values,
- Depending on water availability (rainfall)
- Effect of grazing control depends on rainfall (El Niño years)

State-and-transition

- Do S-T models explain rangeland dynamics?
- Do they predict changes better than climax or range-quality models?

### Explanation
- Explains general behavior
- Many situations with alternative stable states
- No mechanism specified

**Predictive success of S-T model depends on definition of states**
- Vegetation biomass (continuous ecosystem variable) - seems to work
- Composition (by ordination/clustering) - does not fit well: no stable states found with higher probability
  

- Range quality (by productivity/sensitivity) - neither
  - **Landscape states** are most appropriate (in theory and practice).

**Climax and range-quality models**
- applicable, if their own criteria are used
- predict states better (and thus locally useful)
- are equally phenomenological but
- theoretically dubious (reversibility).

Climax models do not predict rangeland degradation and desertification;
They represent the optimistic Balance of Nature view.
Desertification

- Desertification of rangeland results from combinations of
  - Climate change
  - Over-grazing
  - Clearcutting
  - Inappropriate agriculture

- Definitions of desertification vary
  - Cultural and political bias
  - Political or economic goals
  - Include causes (!) (UNESCO, FAO)
  - Ecological, hydrological or agricultural perspectives

The extent of desertification

And time is running...