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Situation of rangelands in Great Basin (GB)

Invasive weeds (i.e. cheatgrass, medusahead) have changed how GB ecosystem responds to stress from grazing and wildfire

• Rangeland fire historically is natural, restorative, occurring every 50-70 years on healthy rangelands
• Invasive annuals reduce vigor of perennial native plants, increase frequency and severity of wildfire
• If native plant vigor compromised too much, more annual weeds and less perennials return after rangeland fire
• Range scientists predict: if nothing done, all GB rangelands will convert to monoculture annual grasslands burning every 2-10 years
• These weeds cannot practicably be eradicated
• Restoration expensive and less than 20% effective
• Alternative management goal: maintain ecological condition in healthy enough state so that constant, lower cost maintenance is sufficient
Rangeland states

• “Good” states: after fire, same state regenerates, with no more weeds than before
• “Bad” states: after fire, shift to new regime with more weeds and fewer native plants, more frequent and severe subsequent fires
• Series of “bad” states
  – Land productivity for ranching declines, eventually ranching not economically viable
  – Fire suppression costs continue to increase even after sub-economic for ranching
Uncertainty over outcomes

• Even with perfect monitoring of land condition, the best science cannot predict prior to a given fire, whether the condition has crossed a ‘threshold’ where the next fire will result in a worse state, or stay in the current state

• Always some degree of uncertainty in rangeland management for any decision-maker
Management options

• Reduced grazing pressure: reduces stress, improves vigor of native plants
• Treatment effort: generally as condition worsens, treatment costs increase and probability of success decreases
  – Identification of new infestations and “spot-treat” before they establish
  – Apply herbicides to infested areas
  – Mechanical removal of accumulated fuels
  – Reseeding with non-native species that compete with invasives (crested-wheatgrass)
  – Rehab by planting and seeding areas that no longer can regenerate native plants
Both private and public decision-makers engage in rangeland management

- Ranchers lease public rangelands
  - Pay grazing fee per AUM
- BLM responsible for monitoring/controlling range conditions
  - Indirectly through AUMs
    - AUMs determined based on condition of land
    - AUMs reviewed annually
    - Every 10 years leases are renewed
    - In reality not all lands can be monitored
  - Directly through preventative treatments and restoration after wildfire
- Who implements management actions?
Public and private objectives differ

Private rancher
- Rangeland benefits: ranch profits
- Costs of invasive weeds
  - Increased risk to income from increased wildfire frequency and size
  - Reduced productivity of grazing land

Public regulator/society
- Rangeland benefits: ranch profits plus ecosystem benefits
- Costs of invasive weeds
  - Increased costs of wildfire suppression
  - Rangeland treatment: prevention and rehabilitation
  - Lost ecosystem benefits
Problem 1: Externality

- Deviation between private and social optima
- Rationale for analyzing decision problems of both regulator and rancher
- If no other problem, deviation between the two would provide a measure of the incentive necessary for rancher to provide socially efficient level of effort
Problem 2: Asymmetric information (1)

- Unobservable/costly to observe to regulator
  1. State/condition of individual ranchers’ leased rangelands
  2. Rancher effort: grazing pressure reduction and land treatments

(1) Hidden information about land condition
- More costly for regulator to acquire information about land condition and optimal treatments than for rancher
- Regulator could bear costs of monitoring range conditions, or rely on lower cost monitoring and reporting by ranchers, or use a combination
- Rancher may have incentive to inaccurately report the rangeland condition to the regulator
- Uncertainty over where the ecological thresholds lie remains
Problem 2: Asymmetric information (2)

(2) Hidden action of rancher (moral hazard)
• Rancher has little incentive to invest effort above privately optimal levels of treatment and grazing
• Regulator cannot directly observe effort level of rancher

Our approach to designing policy to address problem of information asymmetry: Principal-Agent problem
Purpose of P-A approach

• Current system: fees based on AUMs
  – No explicit reward for improving land conditions
  – No explicit penalty for worsening land condition

• An optimal payment mechanism
  – Based on inferred behavior
  – Based on observables

• We would want to use the model to determine optimal incentive schemes
  – What conditions would compel the principal to maintain ranchers on the land even if ranching is sub-optimal?
  – What is the optimal level of cost sharing between public and private sectors for monitoring land condition and treatment effort?
  – Optimal level of risk sharing?
Signals to infer rancher effort and land condition

• Observables correlated with unobservables:
  – If fire, experts observe and record land state (fuel loads)
  – Cattle sales and weight per unit: indication of grazing pressure and land condition
  – Random monitoring by principal of land condition and rancher effort level
  – Self-reporting by ranchers of land condition (by-product of ranch inputs so lower unit monitoring cost than for principal) and effort level
Our modeling steps

1. Rancher’s problem: private optimum
2. Social planner’s problem: first best
3. Principal-Agent problem
4. Comparison to existing policies
Rancher’s problem: stochastic optimal control

\[
\max_{s,u} E_0 \sum_{t=0}^{\infty} (1 + r)^{-t} \pi_t
\]

subject to

\[
x_{t+1} = (1 + \beta)(1 - \delta)x_t - s_t
\]

\[
x_t \leq A_t = \bar{A} - \sigma_t y_t - u_t
\]

\[
y_t = g(F_t)
\]

\[
F_{t+1} = f(q_t, u_t)
\]

\[
q_{t+1} = q(q_t, u_t, x_t; \varepsilon_t \sigma_t y_t)
\]

Expected rancher profit
s = cattle sales
u = land treatment

Cattle herd dynamics

Rangeland availability constraint
A = acreage available for grazing
\(\sigma\) = stochastic factor (0/1)
y = burned area
u = treated area
F = (average) fuel stock
q = cheatgrass prevalence
\(\varepsilon\) = stochastic transition
Rancher’s problem: optimality condition for land constraint

\[ E_0 \left[ -\frac{\partial c_t}{\partial u_t} - \lambda_t' + \lambda_{t+1} \left( \frac{\partial q_{t+1}}{\partial u_t} + \sigma_t \frac{\partial q_{t+1}}{\partial y_t} \frac{\partial y_t}{\partial F_t} \frac{\partial F_t}{\partial u_t} \right) \right] \leq 0 \]

- The opportunity cost of implementing treatment is lower whenever the current-year grazing land constraint is slack or not binding
- *ceteris paribus* treatments are more likely to be taken during a herd-expansion phase, which may occur after certain shocks (e.g. fire, drought, price shock) that cause a reduction in herd size
- The future benefit of treatment is benefit of slower transition or improvement of rangeland state
Social planner’s problem

• In addition to rancher’s, the social planner’s objective includes (among other things)
  – Non-ranch benefit of ecosystem
  – Fire suppression costs

• First best
Solving rancher’s and social planner’s problems

- Parameterize the problems
- Solve using stochastic dynamic programming (SDP)

Rancher’s SDP problem

\[ V(x_t, q_t) = \max_{s,u} \pi(s_t, u_t; x_t, q_t) + z(s_t, u_t; x_t, q_t) + E_t[(1 + r)^{-1} V(x_{t+1}, q_{t+1})] \]

Social planner’s SDP problem

\[ \hat{V}(x_t, q_t) = \max_{s,u} \hat{\pi}(s_t, u_t; x_t, q_t) - z(s_t, u_t; x_t, q_t) + E_t[(1 + r)^{-1} \hat{V}(x_{t+1}, q_{t+1})] \]
Preliminary results of rancher’s problem

• No treatment is optimal with cost at $20/acre
• Break-even treatment cost for ranchers = $0.25/acre
  – But the level of treatment not necessarily socially optimal
  – Problem of asymmetric information
  ➔ How to induce socially optimal levels of treatment and grazing pressure?
Principal-Agent problem

• Principal's problem: full information benchmark

\[
\max_{s^*_t, u^*_t, z(\cdot)} \tilde{\pi}(s^*_t, u^*_t; x_t, q_t) - z(s^*_t, u^*_t; x_t, q_t) + E_t [(1 + r)^{-1} \tilde{V}(x_{t+1}, q_{t+1})]
\]

Subject to

\[
\begin{align*}
\pi(s^*_t, u^*_t; x_t, q_t) + z(s^*_t, u^*_t; x_t, q_t) + E_t [(1 + r)^{-1} V(x_{t+1}, q_{t+1})] & \geq V(x_t, q_t) \\
\pi(s^*_t, u^*_t; x_t, q_t) + z(s^*_t, u^*_t; x_t, q_t) + E_t [(1 + r)^{-1} V(x_{t+1}, q_{t+1})] & \geq \\
\pi(s_t, u_t; x_t, q_t) + z(s_t, u_t; x_t, q_t) + E_t [(1 + r)^{-1} V(x_{t+1}, q_{t+1})]
\end{align*}
\]

• Allow one or more of \( x_t, q_t, s_t, u_t, V(\cdot) \) unobservable to principal to analyze hidden information/action cases
Efficiency of the three most prominent types of regulation

1. Input based - public rangeland; e.g., restrictions on herd size and the length of the grazing season
   - Limit ecological harm
   - Inexpensive
   - But cannot mandate the usage of beneficial benefits above private optimum

2. Cost sharing - private rangeland; e.g., EQIP
   - Subsidize inputs that benefit both the rancher’s private objectives and the regulator’s objectives for ecosystem health
   - Subsidize inputs that are substitutes for inputs that are detrimental for ecosystem health
   - But budget constrained

3. Output based – Reward / Fine based on observable performance measure
   - Ranchers are better informed than regulators about what will work on this rangeland
   - But budget constrained and high monitoring costs
Potential future extension

• Multiple ranchers
  • Optimal number of agents/ranch size?
  • Risk pooling among agents
  • Inter-temporal pooling/transfer of resources
  • Agent types
Sources

• Dr. Sherman Swanson, Dept. of Natural Resources and Environmental Sciences, University of Nevada, Reno. In person interview conducted at the University of Nevada, Reno, on November 17th, 2008.
• Mr. William Dragt, Bureau of Land Management, State Weed Program Coordinator for Nevada. In person interview conducted at the Reno, Nevada, BLM office on October 17th, 2008.