Towards More Efficient Management of the Great Basin Ecosystem: Private Ranchers, Public Rangeland, and Invasive Weed Control

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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

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

Expected rancher profit
s = cattle sales
u = land treatment

subject to

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

Cattle herd dynamics

$$x_t \le A_t = \overline{A} - \sigma_t y_t - u_t$$

$$y_t = g(F_t)$$

$$F_{t+1} = f(q_t, u_t)$$

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

Rangeland availability constraint
A = acreage available for grazing
σ = stochastic factor (0/1)
y = burned area
u = treated area
F = (average) fuel stock
q = cheatgrass prevalence
ε = stochastic transition

Rancher's problem: optimality condition for land constraint

$$E_0\left[\underbrace{-\frac{\partial c_t}{\partial u_t}}_{\text{Financial cost}}\underbrace{-\lambda_t^l}_{\text{Opportunity cost}}+\underbrace{\lambda_{t+1}^q\left(\frac{\partial q_{t+1}}{\partial u_t}+\sigma_t\frac{\partial q_{t+1}}{\partial y_t}\frac{\partial y_t}{\partial F_t}\frac{\partial F_t}{\partial u_t}\right)}_{\text{Future benefit}}\right]\leq 0$$

- 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

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

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

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

Subject to

$$\pi(s_t^*, u_t^*; x_t, q_t) + z(s_t^*, u_t^*; x_t, q_t) + E_t[(1+r)^{-1}V(x_{t+1}, q_{t+1})] \geq V(x_t, q_t)$$

$$\pi(s_t^*, u_t^*; x_t, q_t) + z(s_t^*, u_t^*; x_t, q_t) + E_t[(1+r)^{-1}V(x_{t+1}, q_{t+1})] \geq$$

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

- 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.
- U.S Department of the Interior, Bureau of Land Management, “H-4180—1 -- Rangeland Health Standards” (2001).
- Krueger-Mangold, J.M., Sheley, R.L., and T.J. Svejcar (2006). “Toward ecologically-based invasive plant management on rangeland”. Weed Science 54: 597-605.
- Reever Morghan, K.J., Sheley, R.L., and T.J. Svejcar (2006). “Successful Adaptive Management – The Integration of Research and Management”. Rangeland Ecol Manage 59: 216-219.
- Pellant, M. (1996) “Cheatgrass: The Invader That Won the West”. Interior Columbia Basin Ecosystem Management Project
- Swanson, S. (ed.) (2006). “Nevada Rangeland Monitoring Handbook, Second Edition”.
- Stringham, T.K., Krueger, W.C., and P.L. Shaver (2003). “State and transition modeling: An ecological process approach”. J. Range Manage. 56: 106-113.
- Prendergast, C. (2002). “The Tenuous Trade-off between Risk and Incentives”. Journal of Political Economy 110 (5): 1071-1102.
- Baker, G.P. (1992). “Incentive Contracts and Performance Measurement”. Journal of Political Economy 100 (3): 598-614.
- Zhao, R.R. (2008). “All-of-Nothing Monitoring”. American Economic Review 98 (4): 1619-1629.
- James A. Young and Charlie D. Clements, 2009. *Cheatgrass: Fire and Forage on the Range*, UNR Press.