Strategic Behavior, Incentives, Heterogeneity and Invasive Species Management: An Update

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Invasive Species Management:

- Individual decisions based on private benefits and costs
- Mitigation or control effectiveness based on collective action
- Incentives may be effectively used to align private and public objectives

Efficient Incentive Mechanisms Require Knowledge of Individual Decisionmakers' Characteristics

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Project Overview

- Emerging Invasive Species
- Agent Actions Prior to Negative Impacts
- Incentives for Efficient Management

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Project Focus:
Develop an Integrated Research Program

- Dynamic game theoretic model with asymmetric information
- Data: Historical, Survey, and Experimental
- Incorporated into numerical models in order to assess effectiveness of institutional frames, management policies, and incentives

Applied to non-dairy cattle operations in New Mexico specifically for Russian knapweed and yellow starthistle

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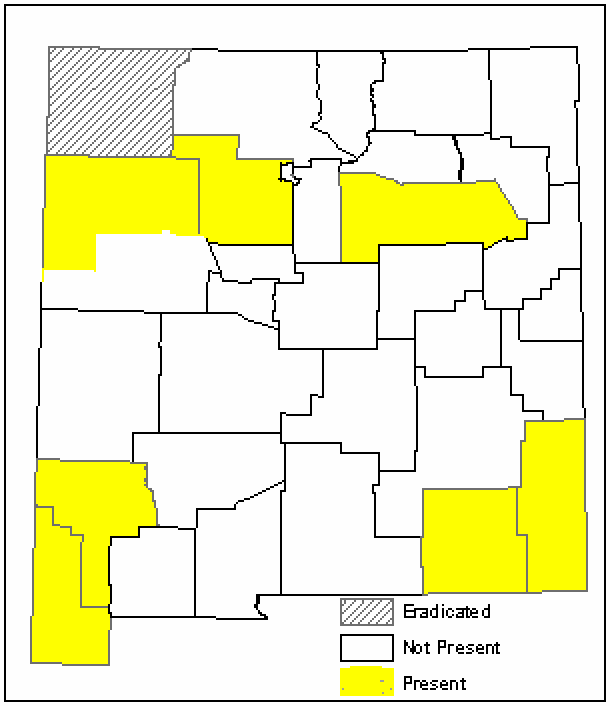
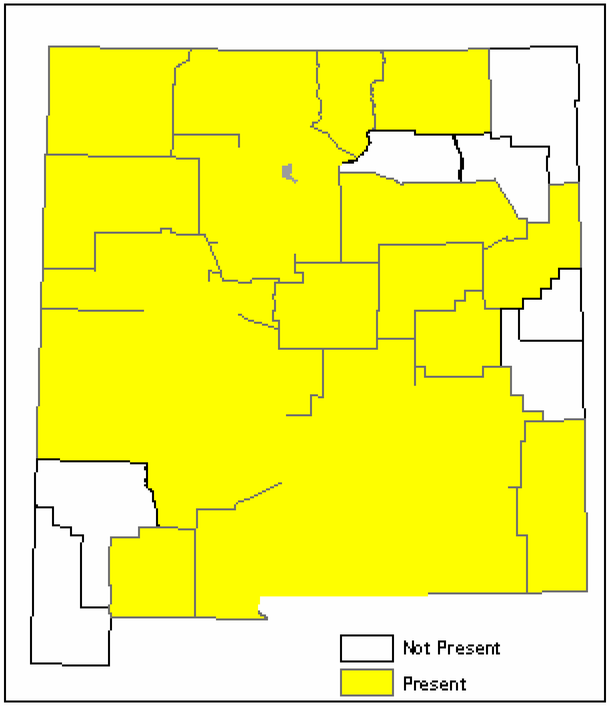
Occurrences

yellow starthistle
(Centaurea solstitialis)



Russian knapweed
(Acroptilon repens)



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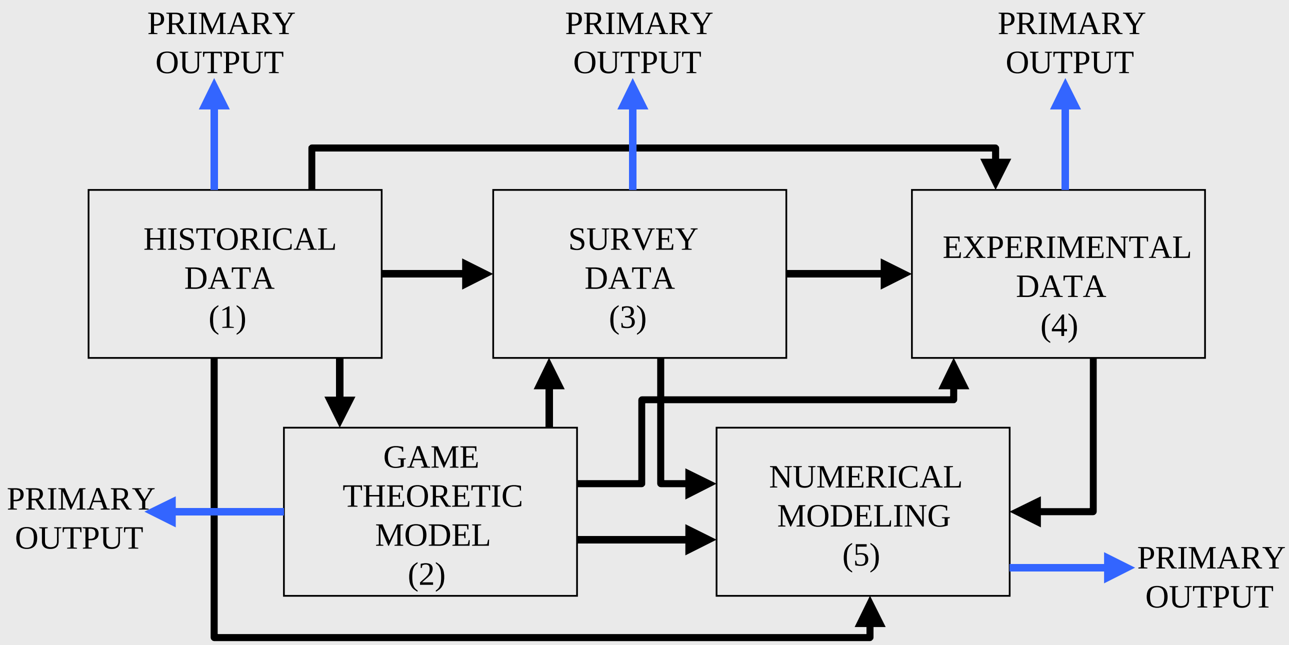
From: http:/weeds.nmsu.edu, last accessed 10/09/06

Project Design



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Historical and Current Data

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Available Historical and Current Data

- NASS Agricultural Census Data
- Species Information (locations, level of infestation,…)
- BLM Allotment Prices (Promised)
- NM Strategic Plan for Invasive Weeds
- Bill Proposed for 2007 Legislative Session
- Community Group Plans

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Modeling

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Inter-temporal, Spatial Game Theoretic Model with a Dynamic Species Stock

The individual agent's problem is to maximize

$$\max_{\mathbf{X}^{\mathbf{F_i}},\mathbf{g^i}(\mathbf{t}),\mathbf{e^i}(\mathbf{t})} \int_0^T e^{-rt}\left(P(t)z(\mathbf{X}^{\mathbf{F_i}}, g^i(t), t; \underline{\alpha}^{\mathbf{i}}) - \mathbf{W}^{\mathbf{F}}\mathbf{X}^{\mathbf{F_i}} - C(G^i(t), g^i, E(e^i(t), e^j(t), t)\right)dt$$

subject to;

$$\dot{G}^i(t) = R(G^i(t), G^j(t), g^i(t), E(e^i(t), e^j(t), t),$$

$$g^i(t) \le G^i(t),$$

and $G^i(0) = G_0^i,\ G^i(T) \ge 0.$

The Individual Agent's Effort Path:

$$\dot{e}^i = \frac{\left(C^i_{G^i}\frac{\partial E}{\partial e^i} - \mu(t)R_{G^i}\frac{\partial E}{\partial e^i}\right) + \left(rC^i_E\frac{\partial E}{\partial e^i} + \mu(t)R_E\frac{\partial E}{\partial e^i}\right) + \left[\mu(t)R_{EE}\frac{\partial^2 E}{\partial e^i \partial e^j} - C^i_{EE}\frac{\partial^2 E}{\partial e^i \partial e^j}\right]\dot{e}^j}{\left[C^i_{EE}\frac{\partial^2 E}{\partial e^{i2}} - \mu(t)R_{EE}\frac{\partial^2 E}{\partial e^{i2}}\right]}$$

Where the Nash Equilibrium is defined as Agent *i*'s optimal path, such that the value of the objective is as great, or greater than the value associated with any other feasible path given the optimal path choice of Agent *j*.

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From Theory to Practice

- The IS competes with pasture grasses and grasses used in hay production. As a result, infestation by the IS impacts productivity of the range land

- Productivity can be improved by efforts to remove or minimize the IS.

- The IS infests plots of land via natural (wind, water, animals) and human (trucks, machinery, impure seed mixtures) vectors.

- An Agent’s choice of effort level is influenced by; the current level of infestation, adjacent agent’s effort levels, the rate of natural and other human induced weed diffusion, as well as the characteristics of the Agent.

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Grass Production

The growth of grass is modeled using a logistic growth function adjusted for the competition with the IS using a Lotka-Volterra formulation:

$$\dot{G}_i = F_i(G_{it}) = r_G G_{it}\left(1 - \frac{G_{it} - \alpha_{GW} W_{it}}{K_{Gi}}\right) - C(G_{it}) B_{it}$$

$$\text{where: } C(G_{it}) = qG_{it} / (G_{it} + Q)$$

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Weed Diffusion and Beef Production

Diffusion:

$$\dot{W}_k = f\left(W_{kt}, E_{kt}, \bar{W}_t\right) \quad k = i, j.$$

Beef Production:

$$Y_{it}(G_{it}, W_{it}) = \eta_{it} \frac{C(G_{it})}{W_{it}}$$

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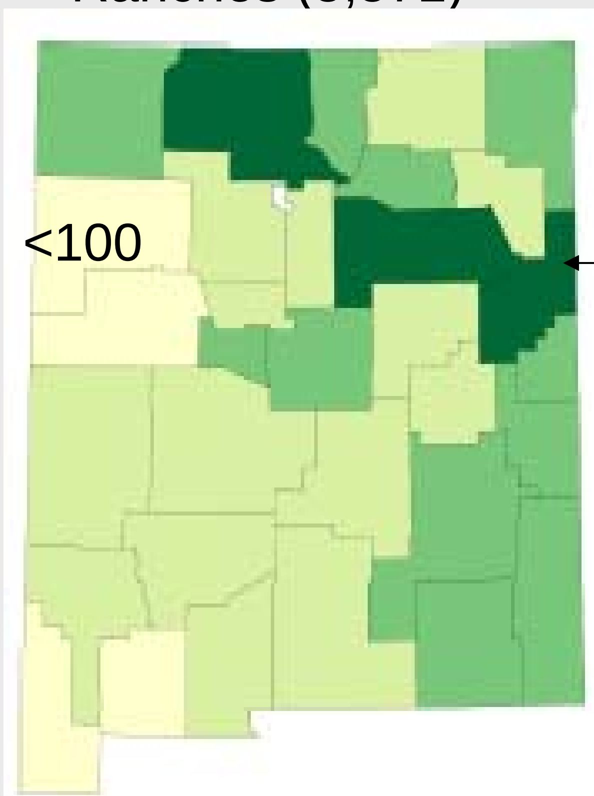
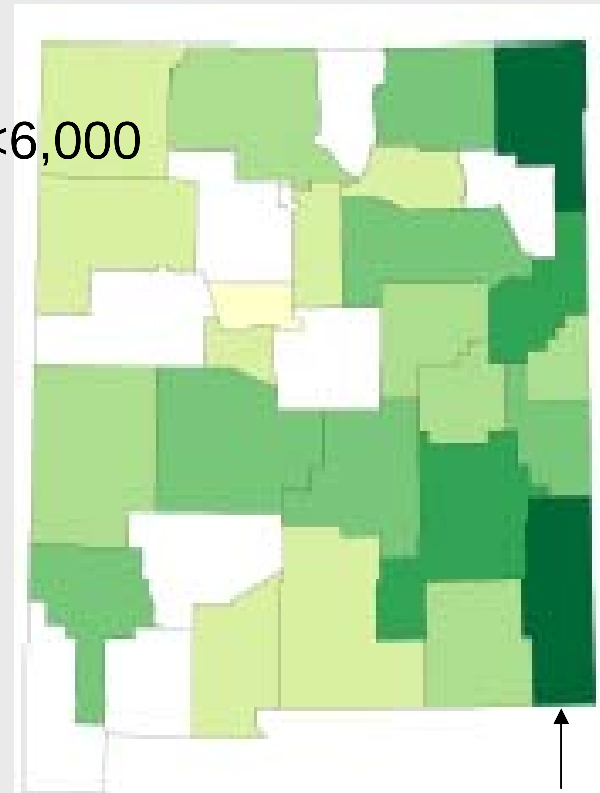
This provides the basics of the model, but we need to know the behavioral aspects also….

The New Mexico Cattle Ranch and Rancher

Ranches (5,571)



Number of Beef Cattle (516,100)



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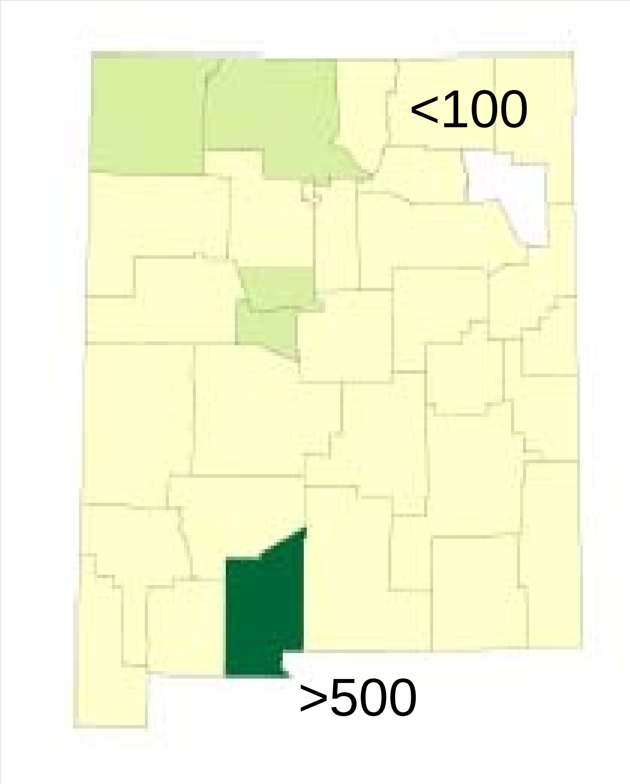
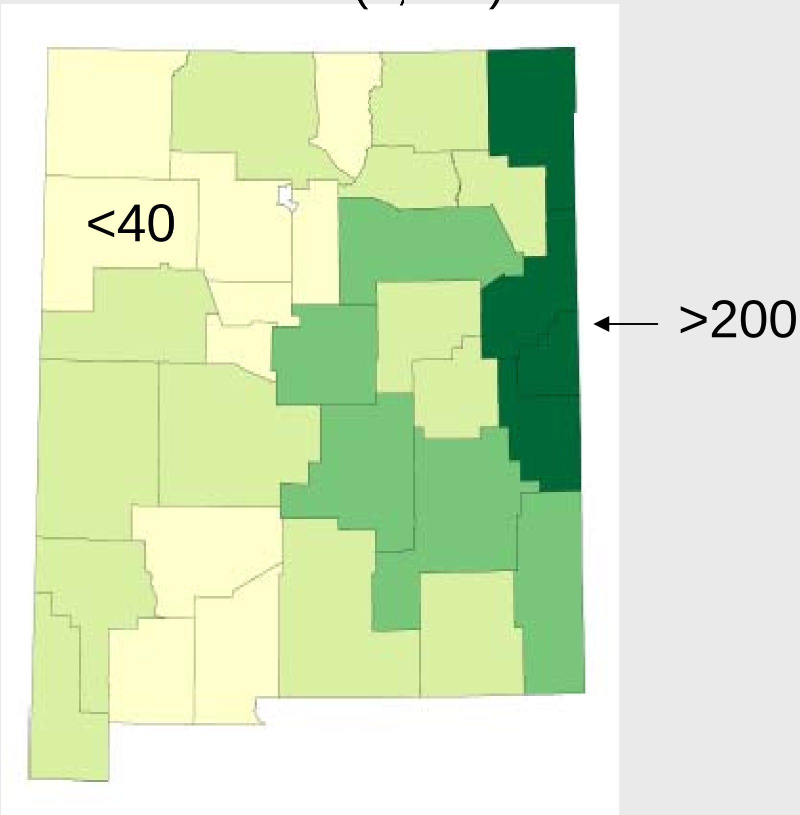
From:nass.usda.gov

Farm Size

1-9 Acres (3,586)



+1000 Acres (3,360)



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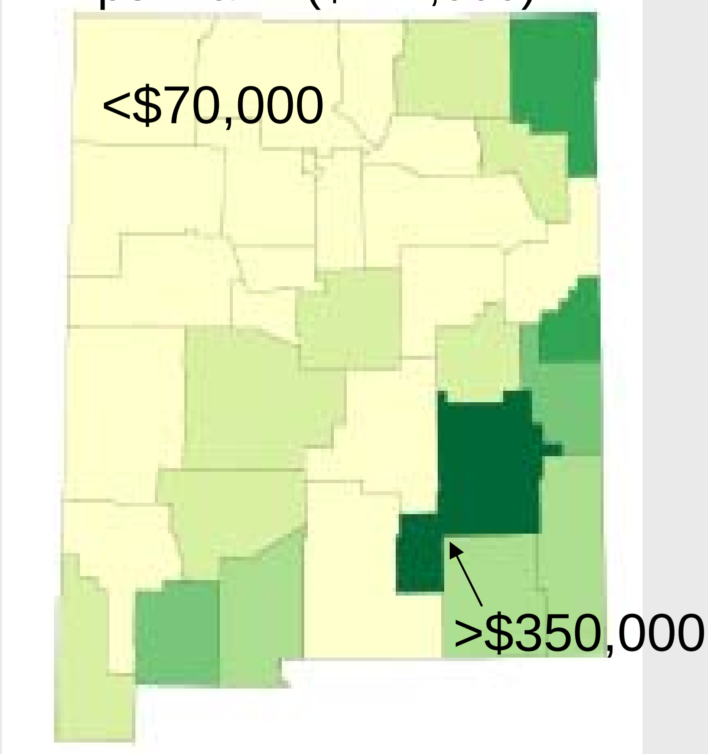
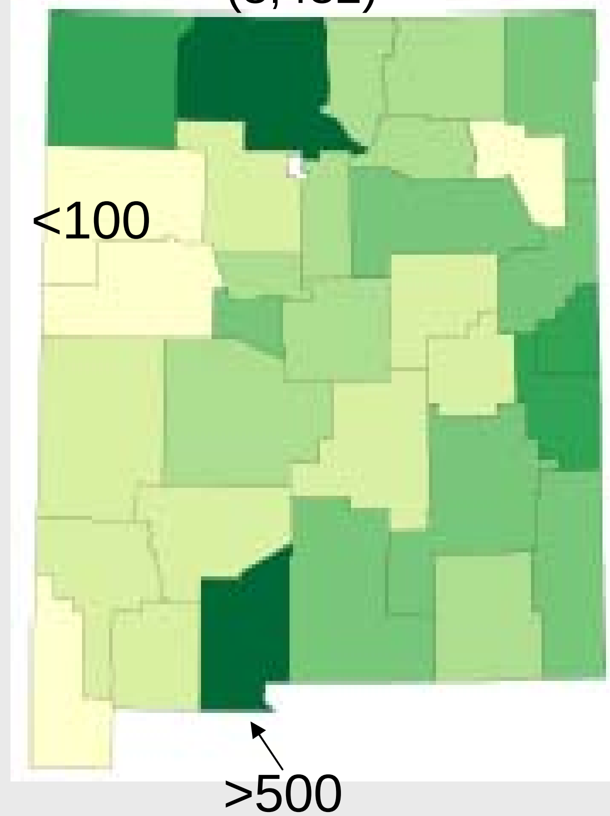
From:nass.usda.gov

More Statistics…

Average Market Value of Product per Farm ($112,000)



Farming Principal Occupation (8,482)



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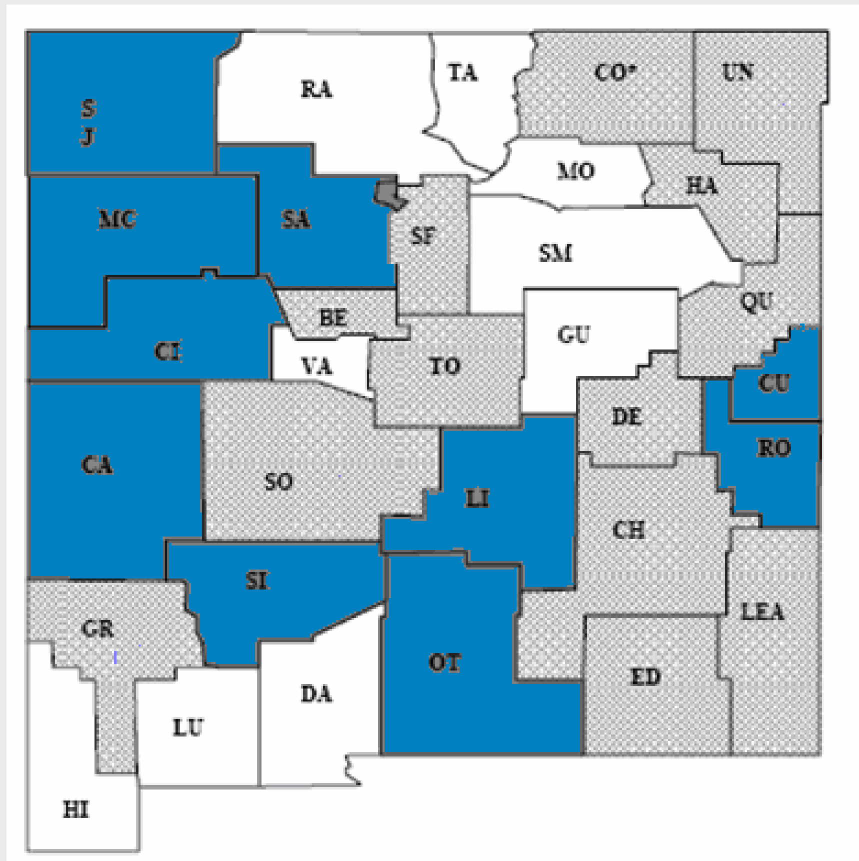
From:nass.usda.gov

Demographics:
Concentration of Hispanic Population



<34%   34% to 49%   <49%

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Focus Groups and Survey

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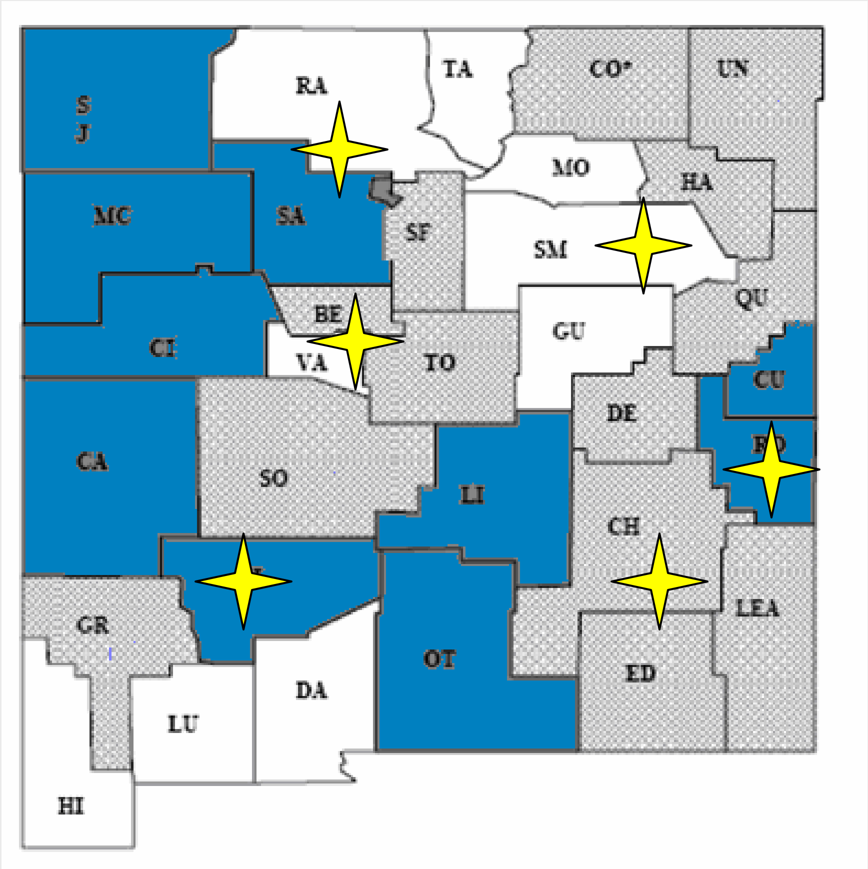
Heterogeneity in Ranches and Ranchers: Interviews and Focus Groups to Gain Knowledge

Talked to ranchers at cattle auctions
- Albuquerque,
- Clovis, and
- Las Vegas

Conducted four focus groups
- Roswell,
- Silver City
- Abiquiu
- Albuquerque
(NM Cattle Grower's Association)



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<34%   34% to 49%   <49%

Goal of Conducting Focus Groups

Knowledge of IS

- Mitigation/prevention practices and costs
- Beliefs about transmission
- What were we missing in our understanding.

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What We Learned

- Size of ranch and type of ranching appear to be important factors determining response to IS

- Humans are important IS transmission mechanism (alfalfa/seed, tires, roads, firefighters).

- Variation in whether IS viewed as a significant problem

- Cost tends to outweigh private benefit of mitigating, particularly for large, non-irrigated ranching.

- Variation in knowledge about IS. Greatest interest is in learning about specific mitigation methods.

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What We Learned (cont)

- Mixed composition ranches (private/leased (federal, state, private))
    - Cultural issues important
    - 'What is in it for me and for you?' Frustration about 'another study' rather than real help for the problem of IS
    - Some demographic questions are considered intrusive

Diverse views, opinions, knowledge. Efficient Management policies will be challenging

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Implications

Conjectured interactions that affect spread of IS are diverse

Ranchers are a diverse group

Survey will have to help capture heterogeneity of ranchers and spatial heterogeneity of ranching industry in NM

Response rate may be low in some locations

- Getting advice from researchers with previous experience in area
- Considering offering monetary incentive for participation in this region
- Considering how contact strategy could be adjusted to combat this

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Survey Design

Survey will provide information on current practices, attitudes, and estimate value ranchers place on invasive species mitigation

Policy	Weed Type A		Weed Type B	
Mitigation Strategy	Ranch Type 1	Ranch Type 2	Ranch Type 1	Ranch Type 2
1				
2				

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Next Up?

Survey

which will provide input into

Experiments

which will provide input into

Dynamic Simulations

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Experiments

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General Experimental Protocol

Participants assigned to high risk or low risk environment (e.g., weed has or has not been seen)

Participants determine "investment" or tokens to pay to mitigate weed (reduces payoff)

Joint investment of participants in group determines aggregate mitigation

Random determination of actual weed invasion

- For example, high risk face 75% probability; low-risk 10%
- Actual outcome determined by draw from bingo cage or other mechanism

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Information in Experiments

- Participants know community size and how aggregate investment affects outcome
- Participants know probabilities of infestation when making investment
- Actual infestation event and others' investment known only at end

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General Game Schematic

Initial Allocation of Probability

Low Risk

		Own Effort		
Sum Of Other's effort		1	2	3
	2	worst		
	3			
	4			
	5	Nash		Max

High Risk

		Own Effort		
Sum Of Other's effort		1	2	3
	2	worst		
	3			
	4			
	5	Nash		Max

Treatments

Payoffs in the cells will differ with treatment.

- Coordination treatment: highest payoffs on diagonals
- "Weakest link" treatment: outcome strongly dependent on lowest investment in community.
- Threshold: mitigation only if aggregate exceeds minimum level

Other treatments

Informational

Distribution of effort level in community

Educational

Ask: What do you think the other decisions were?

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Sample Game:

Your payoff shown, Weakest Link treatment; endow=5

		Own Effort				
Minimum effort of others		**1**	**2**	**3**	**4**	**5**
	1	*4*	*3*	*2*	*1*	*0*
	2		*5*	*4*	*3*	*2*
	3			*6*	*5*	*4*
	4				*7*	*6*
	5					*8*

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Here, takeover by weeds yields benefit of 0; effort is per-token invested.
Complete eradication of weeds yields benefit of 13, minus 5 invested.

What Do We Gain?

Behavioral Data with which to

- Estimate demand
- Test for heterogeneity
- Test different incentives
- Input into the Simulation Model

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Dynamic Simulations

Conceptual Model:

Species Considerations

Transition of species through time, considering management options and the change in the carrying capacity based on the biologic specifics of the species, the management program, the effort of agents and previous conditions.

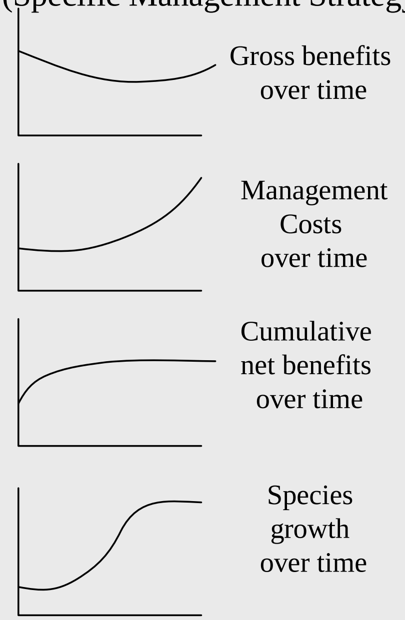
Economic Considerations

Net benefits to agents, response of agents under different incentive provisions and exogenous factors.

Numerical Simulation Model

Dynamic game theoretic frame with bioeconomic growth

Output (Specific Management Strategy)



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Goals:

- Develop a general modeling approach that is applicable to a wide range of invasive species

- Develop assessment tool to answer questions such as:

  - What, if any, incentives can bring private response in line with the social optimum?

  - How do the species spread under alternative management mechanisms?

  - Are spatial patterns (land ownership) important?

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Thank you

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