

The Decision to Manage Invasive Weeds: Which Factors Matter? *†

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Abstract

Invasive weeds increase cattle management costs by crowding out rangeland grasses. Previous research has not empirically examined whether control of an invasive species prior to economic impacts depends on individual actions. In this paper, we model the weed management decisions of 712 New Mexico ranchers for two specific invasive weeds, Yellow Starthistle and Russian Knapweed, using data from a choice-question survey. We estimate the relative importance of participation by other ranchers, the initial level of infestation, the externality impacts of no-management, the impact on carrying capacity, and cost on weed management decisions. We find that community effects are important: ranchers are more likely to manage their weeds when a larger share of other ranchers are managing or if not managing is more likely to impacts others in the community. Although early detection and treatment are the best methods for preventing the spread of invasive weeds, ranchers are more likely to manage their weeds when local infestation rates are high. Management preferences differ both by location in the state and by rancher type.

Key words: invasive species, stated-preference choice question survey, YST, RK, community effects

1 Introduction

An invasive species is defined as an 'alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health' (Executive Order 13112, 1999). In this paper, we focus on a subset of invasive species, Invasive Alien Weeds (IAW). In addition to significant impacts on the natural environment such as water quality and quantity, soil quality, and natural vegetation, IAW pose a costly problem for U.S. agriculture. Pimentel et al. (2005) estimate that IAW costs US agriculture \$27 billion annually, through both crop losses (\$24 billion) and herbicide treatment costs (\$3 billion). Eiswerth and Johnson (2002) cite economic costs from IAW through increased cropping and grazing costs.

While it is estimated that the impact of invasive species on pastureland is on the order of \$6 billion annually (Pimentel et al., 2005), there are not a large number of studies directed at the specific impact of invasive weeds on rangeland and ranching. Yet there is little doubt as to the potential impact. IAW can crowd-out and out-compete native grasses and often have physical features, such as spines, that deter cattle from grazing on them. Thus, by reducing forage quantity and quality, increasing management costs, and forcing possible changes in land use, IAW reduce ranch profits (Eagle et al., 2007). DiTomaso (2000) estimates that rangeland weeds results in losses of approximately two billion dollars per year, more than all other pests combined.

In making any management decision, ranchers would be expected to make their decisions based on private benefits and costs. But an individual rancher does not operate alone. Weeds are mobile and easily spread through wind, water, animals, and human interaction (Levin et al., 2003). The success of any individual rancher's management program depends

on the active participation of other ranchers managing their own weeds and the proximity to spread vectors, such as roads and rivers (Grimsrud et al., 2007; Chermak et al., 2009; Grimsrud et al., 2009). Thus, weed management is essentially a common-pool, renewable-resource problem and individual profit-maximizing behavior may not result in the social optimum. Understanding human interaction and strategic behavior is an important first step in designing effective public management program for invasive weeds.

In order to implement successful public programs that prevent the establishment and spread of invasive weeds, it is critical to understand how ranchers perceive trade-offs on management timing and their willingness to engage in management management when the threat appears relatively low. To our knowledge, this is the first study to examine which factors affect ranchers' decisions to treat an invasive weed.

The focus of this study is on understanding and quantifying the factors affecting the weed management decisions of ranchers. In particular, we are interested in the question of whether ranchers engage in strategic behavior vis-a-vis other ranchers, whether they see light infestations as a management opportunity or a problem to defer, and whether their actions depends on the type of weed. Revealed preference data does not exist that will allow examination of these factors; even if such data did exists, these factors would likely be highly correlated, making it impossible to disentangle the relative importance of each in decision-making. Thus, we address this question by conducting a stated preference survey of ranchers.

To focus this research, we limit our study to New Mexican ranchers. New Mexico has significant geographic differences in vegetation and precipitation that affect the type of ranching conducted in that state. Ranching occurs throughout much of the state, with large numbers

of ranches located in the east and northwestern sections. However, cattle production is concentrated in the eastern portion of the state. Estimated average net profit per cow for 2007 varies significantly by region and ranch size. For example, small ranches and ranches in the southwestern portion of the state generally lose money while northeastern ranches are the most profitable (New Mexico State University Cooperative Extension Service, 2007). With more than 87% of agricultural lands in NM designated as pasture and rangeland (USDA, 2002) cattle ranching will be greatly impacted by the spread of IAW.

We focus on two IAW currently found in New Mexico: RK (*Acroptilon repens* L.) and YST (*Centaurea solstitialis* L.). These two particular IAW have considerable similarities in their potential impact but represent two species at very different stages of invasion. RK has been spotted in all but nine counties in the state and has a number of serious populations in the northwest portion of the state (NRCS, 2006). YST is found in small isolated populations in the state; eradicating existing infestations is the highest priority (New Mexico Department of Agriculture, 1999). Public awareness of each of these weeds, and their perceived threat, may be substantially different.

Each species has been shown to be a substantial threat to agriculture in other states. Hirsch and Leitch (1996) estimate diffuse, spotted, and Russian knapweed have direct, negative impacts on Montana's economy of approximately \$14 million, annually. Direct and secondary impacts were estimated to be about a \$42 million annually. YST has infested between 15 and 20 million acres in California and is continuing to spread. Juliá et al. (2007) perform an input-output analysis for the impact of YST in Idaho and find a direct impact of over \$8 million. Eagle et al. (2007) find via a survey that when forage loss and out of pocket expenses are considered, the costs of YST to California ranchers is over \$17 million

annually.

The primary finding of this paper is that community effects are important: ranchers are more likely to manage when a larger share of other ranchers are managing or if not managing is more likely to impacts other ranchers in the community. Although early detection and treatment are the best methods for preventing the spread of invasive weeds, ranchers are more likely to manage weeds on their own land when local infestation rates are high rather than when they are low. We also find heterogeneity in treatment preferences on the basis of geographic location, size of ranch, and the share of income earned from ranching.

2 Previous Work

To our knowledge, there is no previous work examining the treatment preferences of ranchers for invasive weeds using an economic approach. There are, however, several related literatures that have bearing on this study.

There is a small literature examining economic preferences for public management of invasives (e.g., Carlsson and Kataria (2008); Nunes and Van den Bergh (2004)). While the survey methodology used in this paper is similar to those papers, the goal is different. We are interested in understanding the factors that affect decision-making of the producer, rather than on obtaining a value of how much the public is willing to pay to eradicate an invasive.

Another related literature looks at the factors that cause farmers and ranchers to engage in weed/brush management. There are several papers that conclude that certain types of producers are more likely to engage in management: individuals with larger farms/ranches (Hodur et al., 2006) and whose primary income is from agriculture (Hodur et al., 2006;

Rowan and White, 1994). This finding is not uniform, however (Coppock and Birkenfeld, 1999) and this literature is not based on economic-preference models.

Ranchers are not always motivated just by profit. (See Gosnell and Travis (2005) and Sayre (2004) for reviews). Torell et al. (2005) conduct a hedonic model for NM ranches and conclude that factors such as ranch location, scenic view, and the lifestyle had a larger impact on the price of ranches than did ranch income.

Finally, the common property resource problem posed by weed management is common to other environmental and natural resource issues. For example, homeowners in the wild-land urban interface must decide whether and to what degree to treat the area around their home to reduce their own fire risk; in addition, all homeowners in the community are affected by each other's decision (Shafran, 2008; Talberth et al., 2006). In the case of rubber production, management of the undergrowth poses a similar problem to that faced by ranchers in considering weed management (Menz et al., 1998). Property owners faced with nuisance wildlife are affected by the management decisions of their neighbors (Bhat et al., 1996).

3 Data

3.1 The sample and data collection

An individual was considered a rancher for the purpose of this study if the primary purpose of their operation was cow/calf or yearling stocker and if the individual owned any beef calves in the past year. Feedlots and dairies were excluded. Because no list of New Mexico ranchers were available, we obtained our data frame from two sources: inspection data and

the New Mexico Brand Book. The inspection data list included the names and addresses of individuals whose beef had been inspected for sale by the New Mexico Livestock Board between July 2006 and April 2007. Thus, this list captures most active ranchers in the state.¹ The New Mexico Brand Book contains the names and addresses of all individuals with a registered brand in the state of New Mexico. This list includes beef, horse, and sheep; species type cannot be determined. In addition, this list may include inactive brands.

Data-cleaning and excluding undeliverable addresses from the inspection data resulted in a list of 1848 individuals. To this we added an additional 772 unique names from the brand-book list, bringing the total sample size to 2590. The brand-book names were randomly chosen from nine counties identified as large cattle-ranching counties with low inspection rates.²

We administered the survey via both the internet and mail. Following Dillman (2000), participants received multiple contacts asking them to participate in the survey. The first contact in November 2007 was a letter that advised them of the study and provided them with login information if they wished to complete the survey online. In all additional contacts, this login information was also provided. The second contact was a survey packet. The packet included a letter, brochure (with information about each of the weeds and color pictures to assist in identification), letter, and return envelope. Contact 3 was a reminder postcard.

¹It excludes ranchers who took their beef out-of-state to cattle auctions, those who consumed their own beef or engaged in barter with neighbors, and Native American ranchers that sell their cattle on reservations.

²These counties were Chaves, Eddy, Mora, Rio Arriba, San Miguel, Socorro, Taos, Torrance, and Valencia. We defined large cattle-ranching counties as those with more ranches than the state average, as reported by the the agricultural census. A county was defined as having a low inspection rate if the average number of inspections per ranch in a county was less than the state average.

Contact 4 was a replacement survey packet. This was followed by a letter with a postcard asking them whether they were indeed a rancher. Contact 6 was a final survey packet.³

Consistent with recommendations by the American Association for Public Opinion Research (2008) we report a range of response rates. The most conservative estimate, which assumes that all individuals of unknown eligibility were in fact eligible, is 30%. This seems unlikely given that 191 individuals informed us that they were not eligible. The maximum response rate is 73%, and is calculated assuming that all individuals of unknown eligibility were in fact ineligible. We believe that 37% is the most reasonable response rate. This is calculated by assuming that the percent eligible of respondents in the inspection data was the percent eligible in the full sample.⁴ A 37% response rate is likely a conservative estimate.

A number of factors should be considered in assessing this response rate. First, it should be noted that New Mexico ranchers tend to be highly independent and that many are suspicious of government involvement in their business. This may have led some to question the motivations of the survey.⁵ In addition, as noted by McCollum et al. (2008) there is some evidence that mail survey mode response rates are experiencing long-term downward trends in response rates (e.g., Larson (2005)). While it was common to observe response rates over 50% in the early 1970's, response rates in the 30% and 20% range were common

³All survey materials are available at <http://economics.thacher.us/research>.

⁴Assumes 35% ineligible. Calculated as $\frac{\# \text{ ineligible}}{\# \text{ respondents} + \# \text{ Refusals} + \# \text{ ineligible} + \# \text{ eligible others}}$ using inspection data, which was considered to be the most accurate data for identifying ranchers.

⁵As an illustrative example, focus groups in northern New Mexico were suspicious that information collected in the survey about the number of cattle and net pre-tax income would be compared by the government to their reported tax information.

by the late 1990's (Connelly et al., 2003).

3.2 The survey instrument

The survey consisted of 4 sections with a total of 46 questions and took approximately 20 minutes to complete. Section 1 asked respondents about their general experience with invasive weeds, information sources about weeds, and their perceptions of transmission mechanisms. Section 2 focused on awareness and experience with Russian Knapweed and Yellow Starthistle in particular. Section 3 dealt with invasive weeds management: previous control methods, constraints, and issues affecting their level of management. Section 4 consisted of four stated-preferences questions and a series of attitudinal questions. Section 5 included demographic questions and questions about the ranch. The survey instrument underwent extensive testing and revisions, including focus groups, rancher interviews, and debriefings.⁶

In a choice-question survey, individuals are presented with competing alternatives and asked to choose their preferred one. In this survey, respondents were asked to consider alternative invasive weed infestations and identify which, if any, they were more likely to manage. Figure 1 shows an example choice question from the survey. Each weed management alternative is described using five attributes: the reduction in carrying capacity if not managed, the probability the infestation spreads to area ranches if not managed, the percent of area ranches managing the infestation, the degree of infestation in the local area, and the total weed management cost. In addition, both for purposes of understandability and to

⁶Four focus groups were held with ranchers and cooperative extension agents across the state. In addition, interviews were held with ranchers at three cattle auctions across the state and debriefings were held with XX individual ranchers.

allow testing of possible differences between RK and Yellow Starthistle, the two treatment alternatives were presented as management of the two different weeds.

[FIGURE 1 ABOUT HERE]

A significant challenge in this survey was creating choice questions that a heterogeneous set of ranchers would find realistic: as noted earlier, in New Mexico, ranch size and the number of cattle differs dramatically across the state. For this reason, we selected percentage change in carrying capacity as an attribute and did not include a net profit attribute.

3.3 Description of the sample

Eighty-four percent of respondents were male. The average age of respondents was 57 years old. 71% of respondents were white; 25% were Hispanic. The majority of respondents identified as Republican. Ranching is just one source of household income: on average, 37% of household income came from livestock production while 35% came from off-ranch employment and investment. Most labor is supplied by the family. The largest share of respondents have some college; however, there was a wide range with a few ranchers reporting less than a ninth grade education and a few reporting a professional degree. There was significant heterogeneity in the number of cattle, with 10 percent reporting less than 10 and 13 percent reporting more than 500. There was also variability in pre-tax ranching income with the largest share (22%) reporting only 1-\$5000.

Due to space constraints, we do not present summary statistics for all the survey questions. However, we do provide a brief qualitative summary. Ninety-six percent of respondents believe that invasive weeds are a problem in New Mexico. However, other issues, notably

water, energy costs, and public opposition to public lands ranching are seen as more serious problems. Ranchers primarily view the spread of invasive weeds as a ‘natural’ problem (e.g., due to wind, water, wildlife) rather than a human problem. Most (58%) do not have access to an active local program that organizes landowners to cooperatively fight invasive weeds but they tend to think such a program would be effective (63%). Ranchers receive information about invasive weeds from many sources (county extension agents, magazine articles, neighbors, etc).

A significant share of ranchers have heard of and seen RK (68% and 56% respectively). This is larger than the share of ranchers that have heard of and seen YST (54% and 41%). Seventeen percent report a medium or heavy infestation of RK on their ranch while 12% report a medium or heavy infestation of YST on their ranch.

Ranchers report that they are most likely to begin treating a light infestation (47%). A significant share of ranchers report that they have engaged in either physical removal of invasive weeds (57%) or spraying with herbicides (48%). Thirty-three percent report engaging in some type of weed management a couple of times per year, every year. Most (80%) do not have a specific weed management plan and respond as needed.

Generally, ranchers reported that they would neither increase or decrease their efforts if neighbors significantly decreased their efforts, adjacent land changed from public to private ownership (or vice versa), or traffic on adjacent roads increased significantly. However, if neighbors significantly increased their weed control efforts, 54% of respondents said that they would also increase their efforts. In addition, 46% of ranchers reported that if they learned that the spread from truck and machinery tires was more serious than previously thought, they would increase their efforts. Thus, increasing information about how invasive

weeds spread and getting a small cohort of ranchers to increase their effort levels appear to be important means of increasing invasive weed management.

We asked participants to identify the two most important factors in deciding whether to manage invasive weeds from the following list: cost, time constraints, knowledge about how to treat, effectiveness of management, governmental barriers, and other. Cost was by far the most commonly chosen factor, followed by knowledge, and time constraints.

4 The model

We assume a discrete-choice random-utility model. Thus, we assume that the rancher chooses the alternative that provides them with the highest level of utility; we consider utility because we are allowing ranchers to have social considerations beyond that described by just profit-maximizing behavior.

We consider four possible utility functions in which parameter estimate are allowed to vary by alternative (i.e., branded):

$$\begin{aligned}
 V_k = & ASC + \\
 & \beta_{1k}INFESTHVY_k + \beta_{2k}INFESTMED_k + \\
 & \beta_{3k}OTHR_k + \beta_{4k}OTHR_k^2 + \\
 & \beta_{5k}SPRDHI_k + \beta_{6k}SPRDMED_k + j \in RK, YS \\
 & \beta_{7k}CC_k + \beta_{8k}CC_k^2 + \\
 & \beta_YCOST_k,
 \end{aligned} \tag{1}$$

$$V_{Neither} = \alpha_N \tag{2}$$

$$V_{Both} = \alpha_B + V_{RK} + V_{YS} \quad (3)$$

There are several things to note about these utility specifications. First, only one constant (*ASC*) on V_{RK} and V_{YS} is estimable: α_{RK} will represent the difference between the two weed management options, all else held constant. Second, the given branded specification allows ranchers to act differently with respect to these attributes, depending on whether they are associated with the RK or YST infestation. For example, we can test whether $\beta_{3RK} = \beta_{3YS}$. The one exception to this is cost. We assume that ranchers feel the same about a dollar, regardless of the infestation on which it is spent. Finally, for the simplest model, we assume that the utility associated with the neither alternative is captured through an alternative-specific constant. The utility from choosing to treat both weeds is captured through an alternative-specific constant plus the utility from both of the treatment alternatives.

The variables in the utility function match the attributes in the choice questions and are defined in Table 1. For many of the variables, there is not a clear expected sign. The degree of infestation in the local area is modeled using a set of dummy variables; the omitted case is light infestation. We would expect the area infestation dummies to be positive and significantly different from zero if ranchers thought that a greater degree of infestation meant that the problem was serious and therefore required action. On the other hand, at a high level of infestation, a rancher might feel that action on their part is pointless. In this case, this variable would be negative. *OTHR* is a continuous variable describing the percentage of ranchers in the area managing this weed. It could be that a rancher is more likely to free-ride as a larger share of other ranchers manage the weed; in this case, the sign on *OTHR* would be negative. On the other hand, knowledge that other ranchers are managing these weeds

might convey information about the seriousness of a weed problem or communicate that others are effectively doing their part and thus could make a rancher more likely to manage his own weeds; in this case, the sign would be positive. A quadratic term is included for both *OTHR* and *CC*. We allow for non-linear effects to capture the possibility of a tipping point: perhaps a minimum level of participation is required to induce ranchers to manage their own weeds.⁷

The probability that an infestation spreads to area ranches if not managed is modeled through a set of dummy variables (*SPRDHI* and *SPRDMED*). The omitted case is ‘low’. The question of interest here is whether ranchers care about the probability that their infestation can spread to other area ranches. If significant, we would expect these variables to be positive: with a higher probability of an infestation spreading, a rancher is more likely to choose to manage the infestation. *CC* is a continuous variable describing the percentage reduction in carrying capacity that would be expected if the infestation is not managed. We would expect this variable to be positive: the greater the reduction in carrying capacity from an infestation, the more likely a rancher should manage the infestation. *COST* is a continuous variable measured in thousands of dollars.

[TABLE 1 ABOUT HERE]

We assume that ϵ follows an extreme value distribution. Thus, the probabilities (Pr_{ijk}) have the typical logit form, where i is the individual, j is the choice set, and k is the

⁷The continuous variables are centered around the mean. This allows for a more straightforward interpretation of the intercept and slope and reduces correlation between the linear and quadratic terms. Each observation of *CC* and *OTHR* was recoded as $x - \bar{x}$ for regression purposes.

alternative. The likelihood function is

$$L = \prod_{i=1}^{712} \prod_{j=1}^4 (P_{i,j,RK})^{y_{i,j,RK}} (P_{i,j,YS})^{y_{i,j,YS}} (P_{i,j,N})^{y_{i,j,N}} (P_{i,j,B})^{y_{i,j,B}}. \quad (4)$$

$y_{i,j,YS}$ is an indicator variable that takes a value of one when individual i chooses to manage the YST infestation in choice set j and zero otherwise. The other indicator variables are defined similarly. Parameter estimates are obtained using maximum likelihood estimation methods.

In addition to defining the variables used in the regression, Table 1 also provides descriptive statistics on the independent variables and response variables. First consider the response variables. As can be seen by looking at the complete dataset (labeled 'All Data'), a large share (49%) chose to manage both infestations. While this is informative about rancher decision-making, this is potentially problematic for the RUM, since it is predicated on differences between alternatives. Similarly, while no-choice is an important expression of preference, it does not provide information about the rate at which individuals are willing to trade-off between attributes. Thus, for robustness, we compare a model that includes all the data with a model that uses data where an individual chose to either treat RK or YST (labeled 'RK or YS'). Note that for both datasets, the values for the variables are quite similar. This speaks to both the robustness of the underlying design and the fact that the two datasets are quite similar (e.g., the cases where an individual chose 'both' did not look radically different on average from the case where they chose to treat a particular weed).⁸

Figure 1 is just one example of a choice question seen by ranchers. There were nine different survey versions and each rancher answered four of these types of questions. Thus,

⁸We also compared with the subset of data that included the RK, YST, and Neither options. Results were very similar.

the total design contained 36 different choice sets. We created a linear, branded, main-effects design using the %MktEX macro in SAS. The design had a D-efficiency score (Kuhfeld, 2005) of 100% and the factors were independent. Because it is a main-effects design, interactions between attributes are not estimable.

All factors used in the design included three levels, except cost, which included six levels. All factor levels appeared an equal proportion of time (33% for the non-cost variables and 17% for cost). The design allows for estimation of categorical variables in case of the probability of spread and degree of infestation variables. It allows for estimation of non-linear effects for the remaining variable. Because the design was branded, it allows estimation of separate values for the RK and YST attributes as well as an alternative-specific constant, consistent with Equation 1. The design was explicitly created to allow testing of whether ranchers view the RK and YST attributes as distinct.

5 Results

5.1 Homogeneous Model

Table 2 shows the results from the branded-quadratic model (Equations 1 – 3) for the full dataset. Ranchers cared about preventing reductions in carrying-capacity from either weed. As expected, the sign on this parameter is positive. Linear effects appear to be sufficient for RK; the quadratic effect is significant at the six percent level for YST. Ranchers are more likely to choose a treatment when other ranchers are also treating the same weed. Thus ranchers are not free-riding on the behavior of other ranchers. Notable here is that

the quadratic term for *OTHR* is never significant. Thus, we are not seeing a tipping point: under all levels, ranchers will increase their level of management as the share of other ranchers managing increases. This behavior is consistent over both high and low levels of management by other ranchers. This behavior may suggest a signaling effect: action by other ranchers may signal that the problem is serious, causing other ranchers to also manage their weeds.

For RK, ranchers are more likely to manage when local infestation levels are heavy and medium levels of infestation rather than light; for YST, infestation levels do not significantly affect the decision to treat. This suggests that for RK, ranchers are not following a strategy of preventive treatment, as would be recommended. For RK, ranchers are more likely to manage the weed when the probability of spread is medium than when it is low. For YST, both high and medium probabilities of spread are more likely to result in management than low levels of spread. Cost is negative and significant, suggesting that as expected, all else equal, ranchers preferred treatments with lower costs. Allowing attributes to vary by weed type effectively controls for all weed-specific differences when *CCN* and *OTHR* are at their mean levels; the alternative specific constant on RK is not significant. Ranchers are more likely to choose to treat both weeds and less likely to treat neither when *CCN* and *OTHR* are evaluated at their mean levels.

[TABLE 2 ABOUT HERE]

An obvious question of interest is whether individuals view the importance of these attributes as varying by weed. Table 2 also shows results for a model that restricts selected RK and YST parameters to be equal. We tested equality of parameters in several ways. First, we performed t-tests comparing the parameter estimates for each weed. Parameter

estimates are significantly different for medium infestation levels (5%) and heavy infestation levels (10%). Other parameters are not significantly different. We also ran a non-branded specification and calculated a likelihood ratio statistic to assess the differences in fit. In this case, we fail to reject the hypothesis that the attribute parameters were the same for both YST and RK ($\chi_8^2 = 10.06$).⁹ However, if one restricts all parameters to be the same except for the infestation level, there is a significant difference between the branded model and restricted model: $\chi_2^2 = 6.0$. Thus, we can conclude that with the exception of infestation levels, participants view RK as the same as YST. There are a couple of possible reasons why stated infestation levels might affect treatment decisions differently for the two weeds. As noted earlier, RK is currently much more prevalent in New Mexico than YST. A higher share of members of the sample report medium or heavy infestation on their ranch and in their area of RK than YST. In addition, more ranchers had heard of and seen RK than YST.¹⁰

Table 2 also shows that the results are quite similar when this model is applied to the RK/YS choices alone. The only differences is that medium infestation levels become insignificant for RK and the quadratic term for *CCN* and *OTHR* become marginally significant.¹¹ The latter result may be a consequence of the fact that the design was created for the case of the two alternatives (RK and YS), rather than the four.

⁹However, the RK alternative-specific constant becomes highly significant.

¹⁰A nested logit model of treatment/no treatment with branches for treatment (RK or YS) was also explored but was statistically rejected.

¹¹Results were also very similar for the case where both was modeled as only an alternative specific constant: $V_{both} = \alpha_B$.

5.2 Heterogeneity Models

5.2.1 Regional Differences

Given the significant heterogeneity within the state on the basis of location, we first divided the state into four distinct regions (NW, NE, SW, and SE) and ran the model separately on each region.¹² However, preliminary investigation showed that combining the SE and NE into one Eastern region fit the data just as well as a model that treated both as distinct regions; these results are presented in Table 3.¹³ Not surprisingly, given the relatively large share of observations in the East, results from this sample look quite similar to the overall sample results. What is noticeable about the NW and SW regions in comparison to the East, is that neither the share of other ranchers managing the infestation or the probability of spread affect management choices. Also note that the alternative specific constant on RK is negative, implying that all else held constant, ranchers in the East are more likely to choose to manage YST. This is interesting as this is the region in which YST is starting to appear. The results also show that while *COST* and *CCN* are important factors in the NW and SW, community effects (the percent of others treating and the probability of spread) are not significant.

¹²The NW included San Juan, Rio Arriba, Taos, McKinley, Sandoval, Los Alamos, Santa Fe, Cibola, Bernalillo, and Valencia counties. The NE included Colfas, Union, Mora, Harding, San Miguel, Quay, Guadalupe, De Baca, and Curry. The SW counties included Catron, Socorro, Sierra, Gran, Hidalgo, Luna, and Dona Ana. The remaining seven counties are in the SE.

¹³There was not a significant difference between the results in Table 3 and a model that divided the east into Northeast and Southeast ($\chi^2_{14} = 7.78$). The three-region model fit the data significantly better than the homogeneous model shown in Table ?? ($\chi^2_{28} = 87.02$).

[TABLE 3 ABOUT HERE]

5.2.2 Rancher Type Differences

Some previous work suggests that ranch size and source of primary income are important factors in determining whether or not ranchers engage in management (Hodur et al., 2006; Rowan and White, 1994). Thus, we run separate models for both cases.

We first examined the case of ranch size, as defined by the number of cattle. Table 4 shows that small ranches (defined as having less than 50 cattle) differ from larger ranches in their management preferences.¹⁴

[TABLE 4 ABOUT HERE]

There are several issues worth noticing. First is that, perhaps not surprisingly, small ranches put a much smaller weight on the impact of weeds on their carrying capacity than do larger ranches. Small ranches are not more likely to manage when there is a higher probability that the weed will spread. They are also not more likely to manage heavy infestations of RK.

In addition, based on previous findings in the literature, we also examined differences in preferences on the basis of the percent of family income coming from livestock. Initial investigation did not reveal significant differences in models that allowed all parameters to vary between ranches earning more than half of their income from livestock and those

¹⁴There was not a significant difference between this model and one which allowed three categories: small, medium, and large. The definitions of small, medium, and large ranches were chosen based on definitions used by NMSU, although there is variation across the state (New Mexico State University Cooperative Extension Service, 2007). Thirty-six percent of the sample were identified as small ranches.

earning a lower share. Certain parameters did appear different, however. Therefore, we interacted the percent of income earned from ranching with the following key attributes: CC , $SPREADHI_{RK}$, $INFESTHVY_{RK}$, and $OTHR$. Table 4 shows that as expected, ranchers earning a larger share of their income from livestock, put a greater weight on the impact on carrying capacity in their treatment decision. These same individuals were more likely to treat when there is a high probability of the weed spreading than those earning less of their income from livestock production. Income earned from livestock had a marginal positive effect in causing ranchers to react more to RKat heavy infestation levels. Interestingly, although the effect is quite small, ranchers earning more of their income from livestock production are motivated less by the actions of their neighbors.

6 Conclusion

We find that the decision to manage weeds is affected by more than pecuniary concerns. We find that our results are not design-dependent; results are robust when limited to a subset of ranchers who chose management. Several results should be of interest to policy-makers.

First, community effects are important. Ranchers are more likely to manage when a larger share of other ranchers are managing or if not managing is more likely to impacts other ranchers in the community. The first point is important because it suggests that ranchers do not free-ride on the management actions of others. Although at first glance this may seem contrary to our typical economic explanations of how rational economic agents will act in the face of a common property resource, there are several possible reasonable explanations for this behavior. One possibility is that the information that others are managing their weeds acts

as a source of information about a relatively unknown threat. The information that others are treating communicates the seriousness of the threat posed by invasive weeds, without the individual rancher having to do detailed research on their own. Another possibility is that ranchers recognize that effective management of the weed requires a community-wide effort. Given community dispersion effects through grain, vehicles, etc., an infestation cannot be prevented from establishing itself on your land unless others are also managing the weed. Knowing that others are doing their part makes managing your own weeds a worthwhile investment. As noted in the literature review, the problem of managing these types of externalities can be found in other areas such as homeowner actions to reduce wildfire risk; it is worth exploring whether similar results about the importance of community effects carries over to these areas also. This result suggests a clear policy application: focus education and intervention techniques on community leaders. If these individuals can be induced to manage their weeds, other ranchers are likely to follow suit.

The second point about community effects is that ranchers are more likely to manage when they know that not managing their own weed problem will make it more likely that the infestation will spread to others in the community. This result likely reflects the fact that ranching communities are small and highly connected. This can be viewed as the case of a trying to solve a common resource problem with a small number of agents as opposed to a large number. This finding also leads to a clear policy recommendation: provide more education on how infestations spread. This finding tells us that if ranchers know that infestations will spread if not managed, they are more likely to manage. Other results in the survey, however, suggest that ranchers think that spread through wind, water, and wildlife are the primary vectors through which invasive weeds spread, rather than human

vectors. More effective education on the vectors of transmission will induce more active weed management.

A second important issue that is highlighted by this survey is the importance of timing. The results from choice-question portion of the survey show that contrary to the recommendation that invasive weeds be treated early, ranchers are more likely to manage weeds on their own land when local infestation rates are higher. Interestingly, however, they report that they are more likely to begin treating a light infestation. There is a large literature on the importance of treating an invasive early, before it reaches a strong presence (Grimsrud et al., 2007; Chermak et al., 2009; Grimsrud et al., 2009): invasives are difficult to remove once there is a large-scale infestation. This result highlights the importance of providing additional education on the need to manage low-level infestations. This point is made dramatically for the case of YST in California: at this point, the policy recommendation is to maintain current levels rather than try to eradicate.

Results differ by region within the state. While impact on carrying capacity is uniformly important, community effects are only important in the east, where the largest cattle operations are located. Results also differ by ranch size and by the share of family income earned by ranching.

Ranchers in New Mexico are more sensitive to RK infestation levels than they are YST, all else held constant. More remains to be done on exploring why this preference exists. It may reflect the fact that more individuals are aware of RK and that RK is currently more of a problem in the state. Given the significant threat posed by YST (Grimsrud et al., 2007, 2009; Chermak et al., 2009) in New Mexico, more needs to be done on educating ranchers about this weed.

Finally, it is important to emphasize that the question explored in this paper, what factors affect management decisions in the face of a common property resource problem, is broader than IAW. For example, these same problems are seen in homeowners decisions of whether to treat their property to reduce wildfire risk. Future empirical work should examine whether community effects are equally important in other environmental and natural resource applications.

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Table 1: Definition and mean of variables used in regression model by dataset

Variable	Definition	All data		RK or YS ^a	
		RK	YS	RK	YS
Independent Variables					
AreaInfest: Heavy ^b	1 if degree of infestation in local area is heavy; 0 otherwise	0.34	0.35	0.34	0.34
AreaInfest: Medium ^b	1 if degree of infestation in local area is medium; 0 otherwise 0.34	0.33	0.32	0.32	0.32
Othr ^c	Percent of area ranches managing a specific weed	0.49	0.50	0.49	0.49
Sprd: High ^d	1 if the probability that the infestation spreads to area ranches if not managed is high; 0 otherwise 0.34	0.35	0.38	0.37	0.37
Sprd: Medium ^d	1 if the probability that the infestation spreads to area ranches if not managed is medium; 0 otherwise 0.33	0.33	0.31	0.30	0.30
CC ^e	Reduction in carrying capacity if infestation not managed	0.17	0.17	0.16	0.16
Cost ^f	Total weed management cost (measured in thousands of dollars) 1.78	1.73	1.84	1.80	1.80
α_{RK}	RK alternative specific constant				
α_N	No-treatment alternative specific constant				
α_B	Manage-both alternative specific constant				
Response Variables					
y_{YS}	1 if choose to manage YST; 0 otherwise	0.15		0.44	
y_{RK}	1 if choose to manage RK; 0 otherwise	0.19		0.56	
y_N	1 if choose to manage neither; 0 otherwise	0.08		-	
y_B	1 if choose to manage both; 0 otherwise	0.49		-	
Observed choices		961		2848	

^a Individuals choosing to manage either RK (RK) or YST (YST) alone

^b Attribute levels for area infested were: Light, Medium, and Heavy.

^c Attribute levels: 10%, 50%, and 90%.

^d Attribute levels for probability of spread were: Low, Medium, and High.

^e Attribute levels: 5%, 15%, and 30%.

^f Attribute levels: \$100, \$500, \$1000, \$2000, \$2500, \$4500.

Table 2: MLE estimates

Parameter	Branded-Quadratic Model			Restricted Model		
	All data			RK/YS choices only		
	Estimate	Std Error	P-values	Estimate	Std Error	P-values
	Cost and ASCs			Cost and ASCs		
Cost	-0.022	0.0021	<0.01***	-0.021	0.0021	<0.01***
α_N	-1.03	0.15	<0.01***	-0.93	0.14	<0.01***
α_B	1.30	0.14	<0.01***	1.50	0.12	<0.01***
α_{RK}	-0.11	0.190	0.55	0.057	0.11	0.60
	RK only			RK only		
AreaInfest: Heavy	0.33	0.11	<0.01***	0.34	0.11	<0.01***
AreaInfest: Medium	0.30	0.11	0.01***	0.33	0.11	<0.01***
Othr	0.029	0.014	0.04**	-	-	-
Othr ²	0.0015	0.0062	0.81	-	-	-
Sprd: High	0.14	0.11	0.21	-	-	-
Sprd: Medium	0.20	0.11	0.08*	-	-	-
CCN	0.32	0.050	<0.01***	-	-	-
CCN ²	0.0094	0.065	0.88	-	-	-
	YST only			YST only		
AreaInfest: Heavy	0.046	0.11	0.67	0.047	0.107	0.66
AreaInfest: Medium	-0.033	0.11	0.76	-0.035	0.108	0.74
	Shared parameters			Shared parameters		
Othr	0.04	0.014	<0.01***	0.037	0.010	<0.01***
Othr ²	-0.0059	0.0059	0.32	-0.0017	0.0042	0.68
Sprd: High	0.27	0.11	0.01***	0.22	0.077	<0.01***
Sprd: Medium	0.20	0.11	0.07*	0.17	0.072	0.02**
CC	0.34	0.046	<0.01***	0.33	0.034	<0.01***
CC ²	-0.12	0.062	0.05**	-0.054	0.045	0.22
N		2602			2602	
LogL		-2925.43			-2926.61	
					961	
					-543.18	

*, **, and *** denote significant estimates at the 10, 5, and 1 percent levels, respectively. All continuous variables, *Othr* and *CC* are centered.

Table 3: MLE estimates by Regions

Parameter	Northwest			Southwest			East		
	Estimate	Std Error	P-values	Estimate	Std Error	P-values	Estimate	Std Error	P-values
RK									
AreaInfest: Heavy	0.21	0.25	0.40	0.19	0.29	0.51	0.45	0.15	<0.01
AreaInfest: Medium	0.50	0.26	0.06 *	0.37	0.30	0.21	0.33	0.14	0.02
α_{RK}	0.59	0.23	0.01 ***	-0.77	0.31	0.01	0.03	0.14	0.84
YST									
AreaInfest: Heavy	0.02	0.21	0.91	-0.09	0.32	0.79	0.09	0.14	0.51
AreaInfest: Medium	-0.064	0.21	0.76	0.22	0.32	0.50	-0.06	0.14	0.71
Other									
Othr	0.01	0.021	0.71	0.039	0.027	0.14	0.048	0.013	<0.01
Othr ²	-0.0010	0.0087	0.91	0.00099	0.012	0.93	-0.0018	0.0054	0.73
Sprd: High	-0.017	0.18	0.93	0.19	0.19	0.32	0.31	0.098	<0.01
Sprd: Medium	0.14	0.15	0.34	0.084	0.20	0.68	0.21	0.092	0.02
CC	0.24	0.069	<0.01 ***	0.44	0.095	<0.01	0.34	0.043	<0.01
CC ²	-0.034	0.095	0.72	-0.16	0.12	0.20	-0.047	0.057	0.41
Cost	-0.012	0.0040	0.01 ***	-0.027	0.0057	<0.01	-0.024	0.0027	<0.01
α_N	-0.88	0.30	<0.01 ***	-1.59	0.36	<0.01	-0.78	0.17	<0.01
α_B	1.46	0.26	<0.01 ***	1.03	0.31	<0.01	1.56	0.14	<0.01
Log L		-675.33			-392.53			-1816.42	
Number of observations		608			341			1653	

*, **, and *** denote significant estimates at the 10, 5, and 1 percent levels, respectively.

All continuous variables, *Othr* and *CCN* are centered.

Table 4: MLE estimates
Less than 50 Cattle **50 or More Cattle** **Income Interactions^a**

Description	Estimate	Std Error	P-values	Estimate	Std Error	P-values	Estimate	Std Error	P-values
RK									
AreaInfest: Heavy	0.195	0.192	0.31	0.406	0.156	0.01***	0.161	0.155	0.30
AreaInfest: Heavy * Income	.	.		.	.		0.00463	0.00288	0.11
AreaInfest: Medium	0.344	0.195	0.08*	0.335	0.154	0.03**	0.340	0.120	<0.01***
α_{RK}	-0.0340	0.183	0.85	0.115	0.147	0.43	0.0554	0.115	0.63
YST									
AreaInfest: Heavy	-0.168	0.185	0.36	0.213	0.148	0.15	0.0692	0.115	0.55
AreaInfest: Medium	-0.214	0.188	0.25	0.0732	0.148	0.62	-0.0295	0.116	0.80
Other									
Othr	0.0373	0.0165	0.02**	0.0460	0.0135	<0.01***	0.0542	0.0120	<0.01***
Othr ²	-0.0105	0.00745	0.16	0.00350	0.00591	0.55	-0.00285	0.00462	0.54
Othr * Income	.	.		.	.		-0.000456	0.000210	0.03**
Sprd: High	0.102	0.134	0.44	0.279	0.105	0.01***	0.141	0.0873	0.11
Sprd: High * Income	.	.		.	.		0.00367	0.00159	0.02**
Sprd: Medium	0.166	0.129	0.20	0.138	0.101	0.17	0.183	0.0809	0.02**
CC	0.128	0.0578	0.03**	0.491	0.0482	<0.01***	0.252	0.0540	<0.01***
CC ²	-0.0846	0.0796	0.29	-0.0561	0.0609	0.36	-0.0751	0.0481	0.12
CC * Income	.	.		.	.		0.00261	0.00106	0.01***
Cost	-0.0181	0.00376	<0.01***	-0.0240	0.00293	<0.01***	-0.0220	0.00230	<0.01***
α_N	-1.15	0.235	<0.01***	-1.07	0.187	<0.01***	-1.08	0.145	<0.01***
α_B	1.43	0.201	<0.01***	1.47	0.150	<0.01***	1.41	0.122	<0.01***
Log L		-978.079			-1571.419			1256.658	
Number of observations		835			1455			2300	

^a Percent of income earned from ranching.

*, **, and *** denote significant estimates at the 10, 5, and 1 percent levels, respectively.

Figure 1

Which of the following two infestations, if either, do you think you would manage, given the following outcomes and costs?

	RK Infestation	YST Infestation
Reduction in carrying capacity if not managed	5%	15%
Probability infestation spreads to area ranches, if not managed	Medium	Low
Percent of area ranches managing this weed	50%	90%
Degree of infestation in local area	Medium	Light
Total weed management cost	\$1000	\$2500

I would be more likely to: *Check one.*

- 1 Manage the YST infestation
- 2 Manage the RK infestation
- 3 Not manage either infestation
- 4 Manage both infestations