LAND TENURE, FARMER’S PERCEPTION AND ADOPTION OF WEED RESISTANCE MANAGEMENT PRACTICES

by

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DEDICATION

When I was a kid, most people including myself thought my capacity would not allow me to do well in formal education system. My mother did not agree with that. She thought I was just not studying enough. Each time I failed, she would hire an additional tutor to the already existing team of home tutors. Even though I did not like it at all, I kept going to school just to make her happy. My father had to stay away from us so that he could afford my education. Ignoring many needs, my parents spent most of their earnings on me. Still, I said I was the one behind my success when asked by a stranger after my tenth-grade exam.

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ABSTRACT

It has frequently been argued that farm operators have less incentive to delay herbicide resistance on leased land than on land they own. This is because resistance management entails short-run costs, while benefits accruing in the future might not be captured if leases are not renewed. Primary data from a survey of 679 U.S. cotton, corn, and soybean producers were analyzed to assess the influence of land tenure on the adoption of 16 weed resistance management practices, controlling for geography, farmer demographic characteristics, and perceptions about weed management. Farmer respondents were divided into three tenure groups: full owners, partial owners, and full tenants to match categories used in the U.S. Department of Agriculture's *Census of Agriculture.* Results from multivariate, ordered probit models run counter to conventional wisdom: full owners are frequently found to have lower adoption rates of adoption of resistance management practices, compared with full tenants and partial owners. After controlling for geography, demographics, and perception variables, land tenure variables show weak or no statistically significant association with adoption. Younger farmers exhibited higher adoption rates, while farmers exhibiting "techno-optimism" (the belief that new herbicides would soon be developed to replace ones facing weed resistance) had lower adoption rates for several practices. Multinomial logit regression to predict tenure status suggest that full owners are, on average, older and more likely to display techno-optimism. Results suggest that age and techno-optimism are greater barriers to resistance management than tenure status.

CHAPTER 1: INTRODUCTION

Introduction of herbicide resistant crops greatly reduced dependence on conventional tillage system. This had a positive effect on environment since soil erosion and fuel usage has been declined. However, indiscriminate usage of herbicides with same mechanism of action has created selection pressure among weed populations. As a result, weed species have become tolerant to herbicides and developed resistance over time (Vencill et al., 2012). Some weed species have even become resistant to multiple herbicides. With this backdrop, no new herbicide has been introduced into the market in last 30 years by chemical companies. Yet, most US farmers are reluctant to adopt weed resistance management practices.

There exists a strong belief in weed science community that owner operators are more likely than renters to adopt weed resistance management practices. See, for example, the following:

> "Many studies have shown that, while herbicide resistance management practices are almost always economically beneficial over the long term, they are often more expensive in the first year or two of implementation. In the same vein, a substantial portion of cropland is rented, and renters often will choose to maximize short-term profits, since there is no guarantee of keeping rented land to be able to realize long-term benefits." (Shaw, 2016)

> "Preventative weed management can be complex and challenging. As a result, farmers are often unwilling to adopt costly preventative practices, especially if the land is rented or leased." (Norsworthy et al., 2012)

> "Another important consideration of farm demographics is the increasing percentage of farm land that is not farmed by the landowner … often the landowner is located more than 40 km from the farm …. Landlords tend to require farmers to use the least expensive weed management tactics because production costs and short- term profitability are often a greater concern than long- term sustainability …" (Owen, 2015)

Over half of the US cropland is leased (Carolan, 2005). The tenant operators might have preferences which may or may not be consistent with owner operators.

Research Objective

A conventional hypothesis in economics is that owner operators are more likely than renter operators to adopt practices that might lower profits in the short run but increase long-term productivity and profits (Soule et al., 1999). This is because a tenant farmer may not recoup the costs of their initial investments if their leases are not renewed. I used both linear and non-linear regression techniques to examine whether tenant farmers are less likely to adopt resistance management practices that conserve the susceptibility of weeds to herbicides. This susceptibility is an exhaustible resource, like soil productivity. Ordinary least squares (OLS) and ordered probit models are used to examine the effect of land tenure status on farmer decisions regarding the adoption of sixteen weed management practices.

While several studies have examined the role of land tenure on adoption of soil conservation practices (see discussion in Chapter 2), very little work has been done to estimate how tenure status affects adoption of resistance management practices. Albright (2016) compared weed management practice adoption on farm plots that were owned versus leased using aggregate national and regional data from the USDA Agricultural Resources Management Survey (ARMS). A limitation of Albright's work, though, was that the data used were only national and regional means and standard errors. Because of this, only univariate tests of differences in means were tested. This leaves open the possibility that not accounting for omitted variables could bias hypothesis tests.

In contrast, the data used in this study has several other sets of control variables capturing differences in geography, farmer demographic characteristics, and farmer perceptions and attitudes about weed management. Farmer respondents were divided into three tenure groups: full owners, partial owners, and full tenants to match categories used in the U.S. Department of Agriculture's Census of Agriculture. Here, multivariate analysis was used to:

- Test whether adoption of weed management practice differed significantly across land tenure status, with land tenure as the only examined difference (similar to Albright).

- Test whether results are robust when control variables for geographical, demographic, and farmer perception variables are included.

CHAPTER 2: LITERATURE REVIEW

A popular hypothesis in agricultural economics is that tenants do not take care of their lands as well owners do. Several studies test this hypothesis with respect to adoption of soil conservation practices like conservation tillage, cover crops etc. (Ervin et al., 1982; Soule et al., 1999; Cole et al., 2002; Nadella et al., 2014). But no studies have focused on the adoption of weed resistance management practices except (Albright, 2016).

In that study, Albright used data from USDA Agricultural Resource Management Survey for corn and soybeans to estimate differences in the adoption of resistance management practices on owned and rented land for a diverse set of weed management practices. That found no strong, systematic relationship between ownership status and practice adoption. In most cases there were no statistically significant differences in mean adoption rates. When there were differences, adoption rates were often higher on leased land than owned land (Albright, 2016). However, the study done by Josh Albright did not have control variables and results were based on tests of differences in sample means. Therefore, studies done on soil conservation practices are still a relevant reference to study the role of land tenure and farmer's perception.

Soil erosion rate used to be popular measure of good stewardship, but modern studies use adoption of conservation practices. Ervin (1982) found lower level of soil erosion control on leased land compared with owned land. However, after controlling for physical erosion potential of land, no significant relationship found between soil loss and tenure type.

By contrast, Sklenicka et al. (2015) found that owners adopted soil erosion practices significantly more than that by renters. This study used four variables to represent farmer's choices in soil erosion control: wide-row crops in crop rotation, soil-improving crops in crop rotation, slope length of production block, and contour farming. Two of these variables are related with crop rotation (i.e. wide-row crops in crop rotation increases soil loss whereas soil-improving crops adds value to the land). The other two variables explain the farmer's decision to intervene the runoff and limit water erosion. In comparison with the owners, renters adopted wide-row crops in crop rotation more often and selected soil-improving crops less often. Owners applied contour farming more frequently than the renters, and chose shorter slope length in production blocks.

In a study conducted on 425 farmers in Canada, Nadella et al. (2014) found evidence that tenure status did not influence the use of conservation tillage, but it was not the same in the adoption of cover crops where owners adopted more compared with renters. Owners found to be more interested in long term benefits from land as predicted from their model. Conventional tillage is the traditional tillage method where soil is completely disturbed. In contrast, conservation tillage limits tillage intensity by retaining crop residue. Cover crops are used on the field following the harvest of a cash crop to limit soil exposure to external wind and water (Creamer and Baldwin, 2000).

Soule et al. (2000) employed a logit adoption model in a study conducted on 941 U.S. corn producers. They found both land tenure type and security to be key factors in farmers' decisions to adopt conservation practices. They separated cash renters from share renters. They found cash-renters are adopting less conservation tillage, while share-renters adopting no differently than owners. Both cash-renters and share-renters were less likely than owners in choosing practices that gives long run benefits which is consistent with the prediction from their theoretical model.

Cole et al. (2002) showed that lease type, length of lease, size of operation, business structure, and tenure security do not explain soil loss on the field rather physical attributes of land found to be most significant. These results denote tenants take care of their land just like owners do. Community norms and social pressure found to play key roles. Also, tenants' own beliefs and values reinforced their decision to manage their land no differently than owners.

Carolan (2005) investigated the effect of tenancy on farming behavior and found that interactive relationship among landlords, tenants, and agricultural agency professionals influences the adoption of practices on rented land. Inspired by the work of Pierre Bourdieu, the author concluded that multiple social fields eventually lead to contestation and reconstruction of field by forming social body.

Shah et al. (2015) used a survey conducted on growers and crop advisors in four Midwestern states (Iowa, Illinois, Ohio and Wisconsin) to study the perceptions of stakeholders engaged in decision making process. Crop growers were found to be older and less educated than advisors. Both parties were engaged in one on one meetings and service was provided primarily in the areas of crop production, pest management and crop nutrients. They found that crop advisors are more likely to advice separate management strategies for rented and owned land, but tenants treated their land similar to owners.

Petrzelka et al. (2014) found that chances are higher for absentee landowners living in urban areas and less likely to get involved in the decision making while adopting management practices. Also, they were found to possess less scientific knowledge and less likely to use extension services. These results suggest that absentee landlords may have lower level of interest in farming practices of their tenants.

Tong et al. (2017) examined the conflict of interest among absentee landowners and on-farm producers while using best-worst scaling method for both parties to rank the advantages of conservation practices. The difference in ranking between the groups found to be significant. While adopting a conservation practice, producers ranked "practice benefits the farm ecosystem" as the most prioritized factor closely followed by, "practice improves profit." Even though absentee landowners prioritized "practice benefits the farm ecosystem" as the most crucial reason, "practice improves profit" was chosen by fewer. These differences between these two groups underscore the role of tenure.

Rogers et al. (1993) studied the role of gender in the decision making process on rented land. Majority of female landlords found to be non-operators. A logistic regression model was run to test the involvement of female owners while using fertilizers and chemicals on the field. Results from this study show that women are less likely than men to engage in the decision making process.

Davey et al. (2008) concluded that making an adoption decision for producers is not that simple. They used a probit demand model to analyze adoption decision by using 1992, 1997, and 2002 Census of Agriculture data. They found that weather and soil conditions play the most crucial role while adopting conservation tillage technology. Also, farm location nearer to a research farm found to have a positive effect on making an adoption decision.

A study of Central Arizona farmers found that level field and basin irrigation technology are more likely to be adopted by younger farmers. Institutional change and resulting long run expected price changes dictate the investments in agricultural technology (Anderson et al., 1999)

Huffman et al. (2008) developed a model to predict best contract choice (share or cash rent) for a farmer from sample contracts data using owners' and tenant's attributes. They concluded that landowners are more likely to choose share contracts with tenants on the land that are highly erodible and not going to be used for other purposes anytime soon except for farming.

Lichtenberg (2006) developed a demand model for seven conservation practices from a study conducted in Maryland, USA and found evidence of negative own price effect for each conservation practices. They also found evidence of cross price effect among different practices.

Results from a bio-economic model illustrates managing glyphosate resistance can influence short- and long-run benefits in corn, soybean, and corn–soybean rotation systems. Even though resistance management decreases the benefits in the first year, it increases returns in the following periods. Long run benefits found to exceed short run costs in all three systems. However, if the neighbor did not manage resistance, long run benefit still surpasses short sun cost except for continuous soybean system (Livingston et. al, 2016)

Due to the evolution of resistance in weeds, diversified weed management strategies are getting more attention recently. Yet, large number of farmers are not adopting diversified management practices. Only focusing on herbicide usage without considering strategies will not help in dealing with herbicide resistance problem. Hence, adoption of diverse management practices needs to be encouraged among farmers. (Owen et al., 2015)

To reduce herbicide resistance in weeds, Frisvold et al. (2010) analyzed the adoption of ten best management practices. They adopted count data models using data from a survey of 1250 U.S. cotton, corn, and soybean users. Also, they used ordered probit model with the frequency of BMP adoption as dependent variable and found yield expectations and variations to be significant. Counties having higher yield coefficient variation have lower BMP adoption rate. In addition, increase in the percentage of owned land was not found to be positively associated with more BMP adoption (Frisvold et al., 2010).

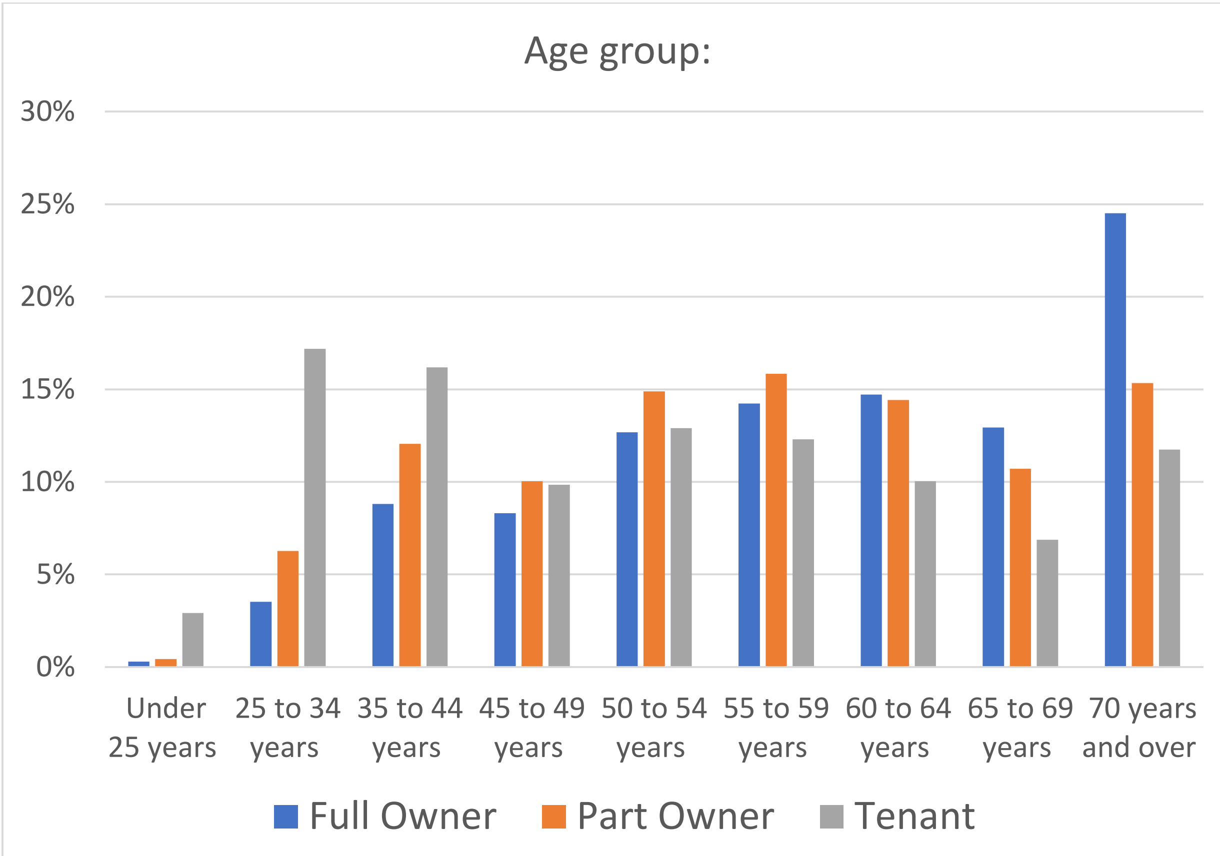
To summarize, the only study conducted on the adoption of weed resistance management practices, focusing specifically on land tenure (Albright, 2016) did not find any significant difference between renters and tenants in most cases. In cases where there were statistically significant differences, adoption rate was often higher on rented land than on owned land. However, studies done on the adoption of soil conservation practices are still relevant. Results in the adoption of soil conservation practices are mixed as land tenure variables i.e. tenure status, tenure security found to be significant in some studies (Soule et al., 1999). They were not found to be significant in other studies (Cole et al., 2002). Tenants' perception regarding environment and community has been found to be important. (Cole et al., 2002). Age, gender, education, farm size, cost and benefit in the short run and long run have been found to be significant in making adoption decision. Non-economic such as social and environmental factors play a key role (Ervin et al., 1982)

CHAPTER 3: DATA & RESEARCH METHODOLOGY

Farm Differences by Land Tenure, USDA 2012 Data

The USDA *Census of Agriculture* reports farm characteristics by tenure status, dividing respondents into three groups: full owners (100% of operated land owned), full tenants (100% of operated land leased in, and partial owners (farms operating both owned and leased in land. From the *Census* data, we see that full owners growing corn, cotton, and / or soybeans have smaller farms, are older, and have lower farm incomes compared to tenant and partial owner operators. Full owners are skewed to higher age cohorts, while full tenants are skewed towards lower age cohorts. As we can see from Figure 1, 25 percent of the full owners are 70 years or older and more than 30 percent of full tenants are less 45 years of age.

Figure 1: Distribution of farmers by different age groups for full owners, part owners and full tenants. (Source: Census Data, USDA 2012)



Full owners are skewed toward smaller farm size. As we can see from figure 2, over 70 percent of full owners operated fewer than 50 acres. Finally, more than 25 percent of full owners have less than $1000 in farm sales (Figure 3).

Figure 2: Distribution of farmers across different farm sizes for full owners, part owners and full tenants. (Source: Census Data, USDA 2012)

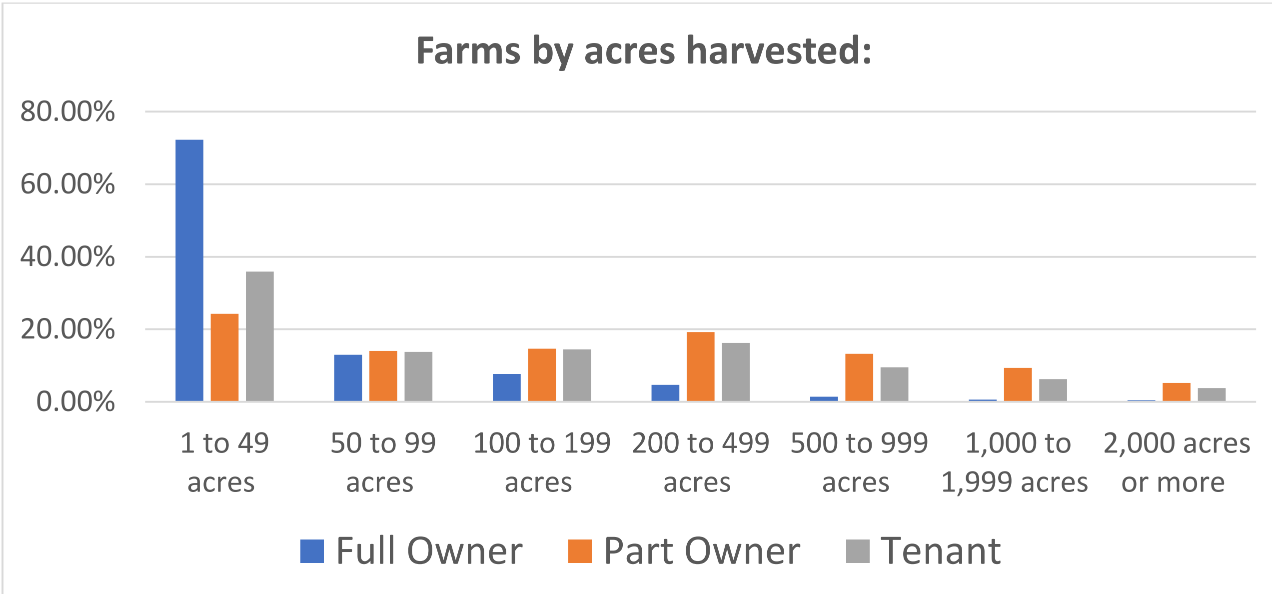


Figure 3: Distribution of farmers across different sales classes for full owners, part owners and full tenants. (Source: Census Data, USDA 2012)

Close to 70 percent of US cotton, corn, and soybean farmers are full owners (Figure 4). Average farm size for full owners is much smaller than for partial owners and full tenants. Average farm size for partial owners is the highest (Figure 5).

Figure 4: Number of farmers for Full owners, Partial owners, Full tenants (Source: Census Data, 2012)

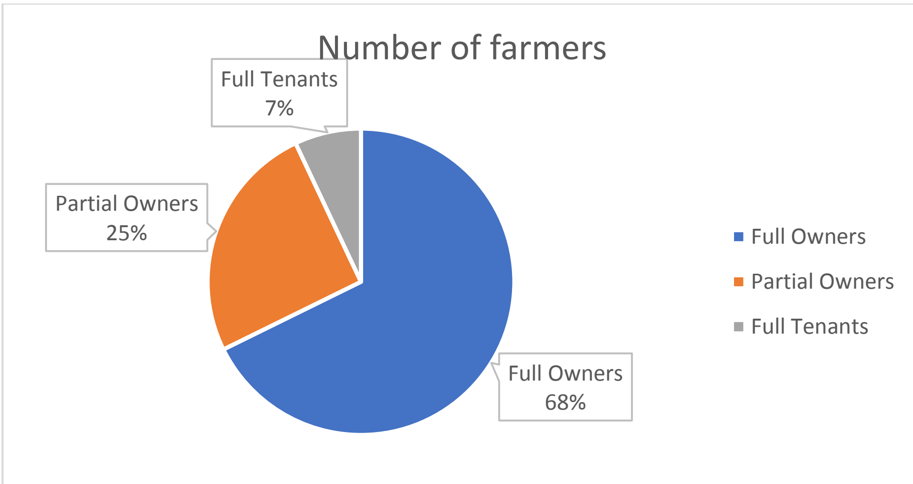
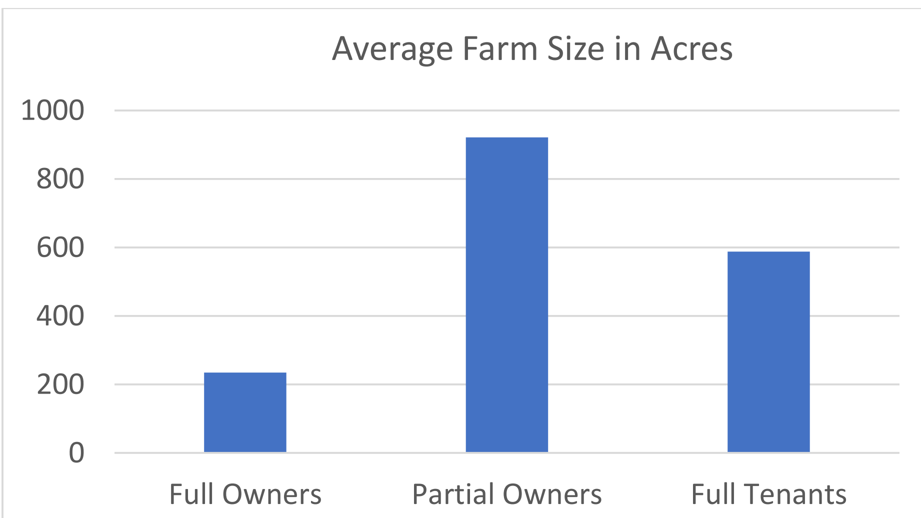


Figure 5: Average farm size for Full owners, Partial owners, Full tenants (Source: Census Data, 2012)



Also, we can see that average age for full owners is higher than for other groups and the average revenue from farms for full owners is much lower than for other two groups as demonstrated from Figure 6 and Figure 7.

Figure 6: Average age for Full owners, Partial owners, Full tenants (Source: Census Data, 2012)

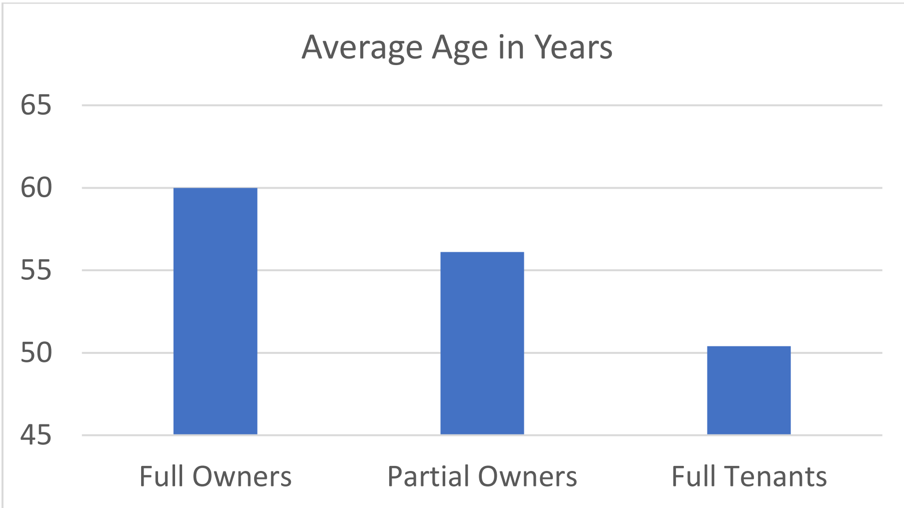
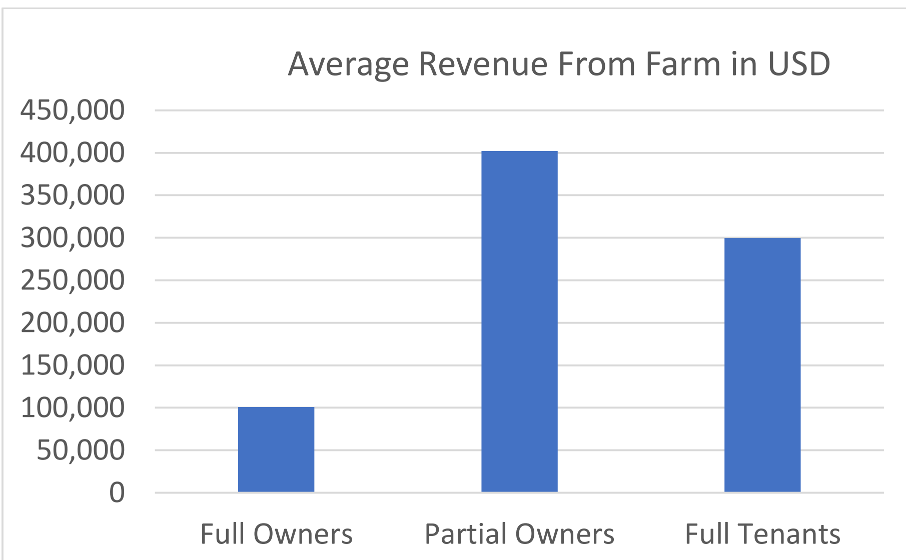


Figure 7: Average revenue from farms for Full owners, Partial owners, Full tenants (Source: Census Data, 2012)



AFRI Survey Data

In 2016, researchers at Michigan State University administered a farmer survey to gain a better understanding of weed management practices among farmers across the United States (Sun et al., 2017). This survey was conducted as part of a USDA Agriculture and Food Research Institute (AFRI) supported project ‘‘Integrating Human Behavioral and Agronomic Practices to Improve Food Security by Reducing the Risk and Consequences of Herbicide Resistant Weeds.” The sample was drawn from a pool that included 8,000 farmers from 28 states comprising five major production regions. The survey was conducted via electronic and regular mail. The response rate was approximately 10 percent. From the overall survey, we have responses from 679 US cotton, corn, and soybean farmers with enough complete information for regression analysis. Among responses, are 16 questions regarding adoption of 16 weed management practices:

1. Inter-Row Cultivation
2. Tillage
3. Crop Rotation
4. Pre-emergent Herbicide Use
5. Post-emergent Herbicide Use
6. Post-Harvest Herbicide Use
7. High Seeding Rates
8. Using Herbicide Mixes
9. Using Multiple Herbicides
10. Hand Weeding
11. Using the Full Label Herbicide Rate
12. Planted Cover Crop or Used Mulches
13. Choosing Planting Dates to Reduce Weed Competition
14. Rotating Herbicides Modes of Action Annually
15. Planting Narrow Rows
16. Using Weed Maps.

Discussion On Weed Resistance Management Practices

Using Multiple Herbicides:

Use of single herbicide across diverse weed species often creates selection pressure. This may result into the evolution of resistance among weed populations. Continuous use of same herbicide with similar mechanism of action has been found to be the most contributing factor in herbicide resistance evolution. Applying multiple herbicides with different mechanism of action can significantly delay the emergence of resistance by reducing selection pressure (Norsworthy et al., 2012).

Herbicide Mixes:

Results from modelling studies indicate that herbicide mixtures can be very useful in delaying resistance. Applying different combination of herbicides can reduce seed movement by limiting pollen movement. (Norsworthy et al., 2012)

Rotating Herbicide Modes of Action Annually:

Rotating herbicide modes of action can be effective as herbicides rotations are not enough. Herbicide rotations with single MOA creates scope for the next generation weed population to survive and gain additional resistance. (Norsworthy et al., 2012)

Crop Rotation:

Crop rotations can be effective strategy for resistance management as different crops have different planting dates and growth pattern. Also, crop rotation naturally demands the application of herbicides having different MOAs (Vencill et al., 2012).

Use Full Label Herbicide Rate:

Usage of herbicide at reduced rate used to be considered environment friendly. However, recent studies proved that repeated use of herbicide at lower rates might allow weed species to survive and create unintended consequences (Norsworthy et al., 2012)

Planting Date:

Crop planting date can affect the growth of weed species. Change in the planting date can give the crop competitive advantage over weeds. (Vencill et al., 2012).

Narrow Rows:

Narrow crop rows increases crop competition by reducing canopy distance. This management strategy naturally limits the growth of weed population (Norsworthy et al., 2012)

High Seeding rate:

High seeding rates has also been used as a strategy to facilitate faster canopy development so that it can give the crop a competitive advantage against weed species (Norsworthy et al., 2012)

Inter-row cultivation:

Inter row cultivation has been found to be valuable in managing herbicide resistance (Norsworthy et al. 2012).

Tillage:

Tillage can be effective in controlling soil seedbank by increasing seed germination and has found to be better strategy compared to no till system (Norsworthy et al., 2012)

Planted Cover Crop or Used Mulches:

Cover crops are used as soil conservation practice, but it can control weed growth in early planting season. Also, using mulch creates physical barriers between rows to reduce weed growth by limiting light availability (Vencill et al., 2012).

The AFRI survey oversamples larger farms that make of the bulk of U.S. agricultural production. Because of this, it also under samples full owners (who tend to be smaller). In the sample, around 70 percent respondents are partial owners where as close to 70 percent of farmers in population are full owners (Figure 8). Since respondents from different groups were asked to submit their responses through mailbox, self-selection bias is evident in the high response rate of partial owner operators. However, each ownership group in the sample presented attributes similar to those observed in census data. In the sample, full owners were also found to have smaller farm size, were older, and had lower gross farm incomes compared to partial owners and full tenants (Figures 9 – 11).

Figure 8: Number of farmers for Full owners, Partial owners, Full tenants (Source: Survey Data, 2016)

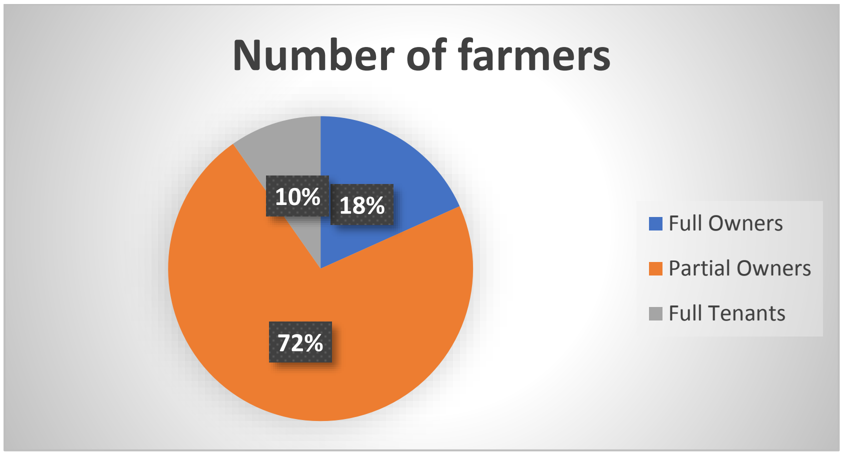


Figure 9: Average age for Full owners, Partial owners, Full tenants (Source: Survey Data, 2016)

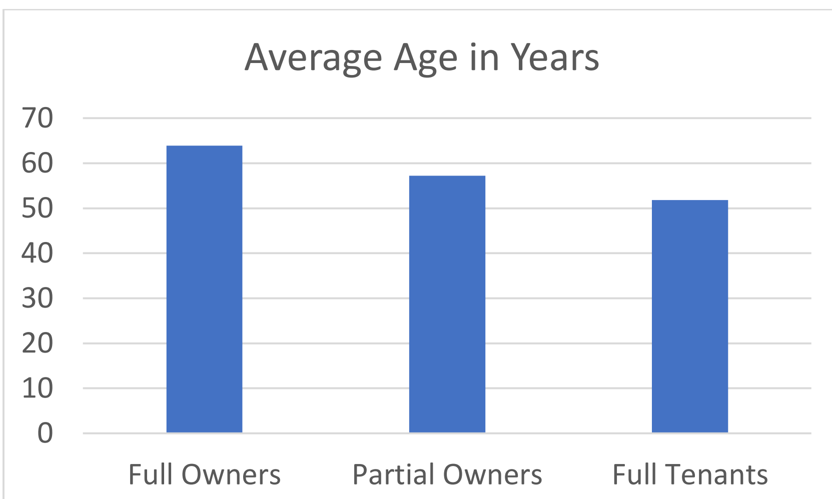


Figure 10: Average farm size for Full owners, Partial owners, Full tenants (Source: Survey Data, 2016)

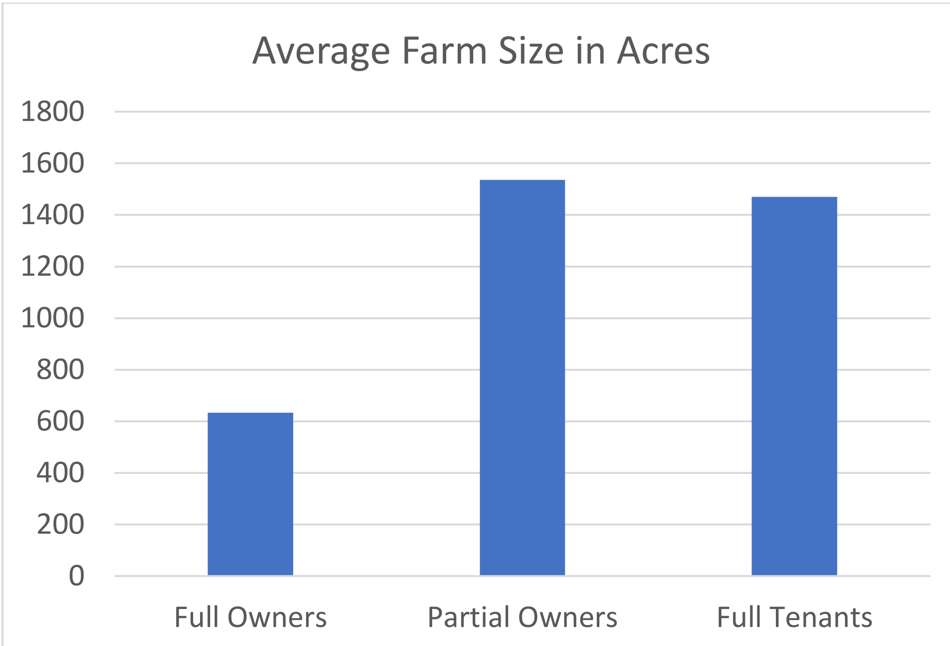
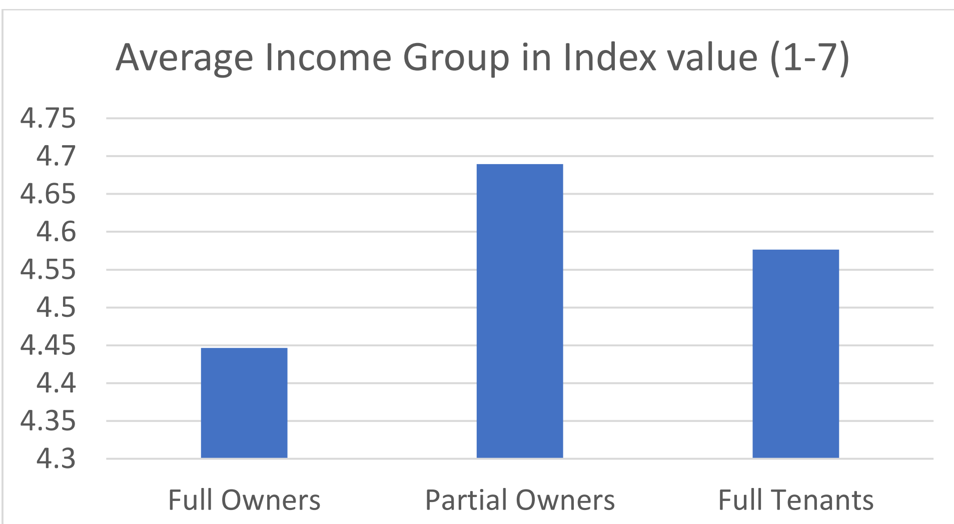


Figure 11: Average income for Full owners, Partial owners, Full tenants (Source: Survey Data, 2012)



Adoption Statistics of Weed Resistance Management Practices:

Survey data were coded to measure the extent to which practices were adopted as follows.

1= No adoption,

2= adoption in less 20 percent of farmland,

3= adoption in 20 to 39 percent farmland,

4= adoption in 40 to 59 percent of farmland,

5= adoption in 60 to 79 percent of farmland,

6= adoption in 80 to 100 percent of farmland.

Mean adoption values for weed resistance management practices associated with herbicide usage are higher than for other practices (Figure 12).

Figure 12: Mean Adoption level for all Weed Resistance Management Practices

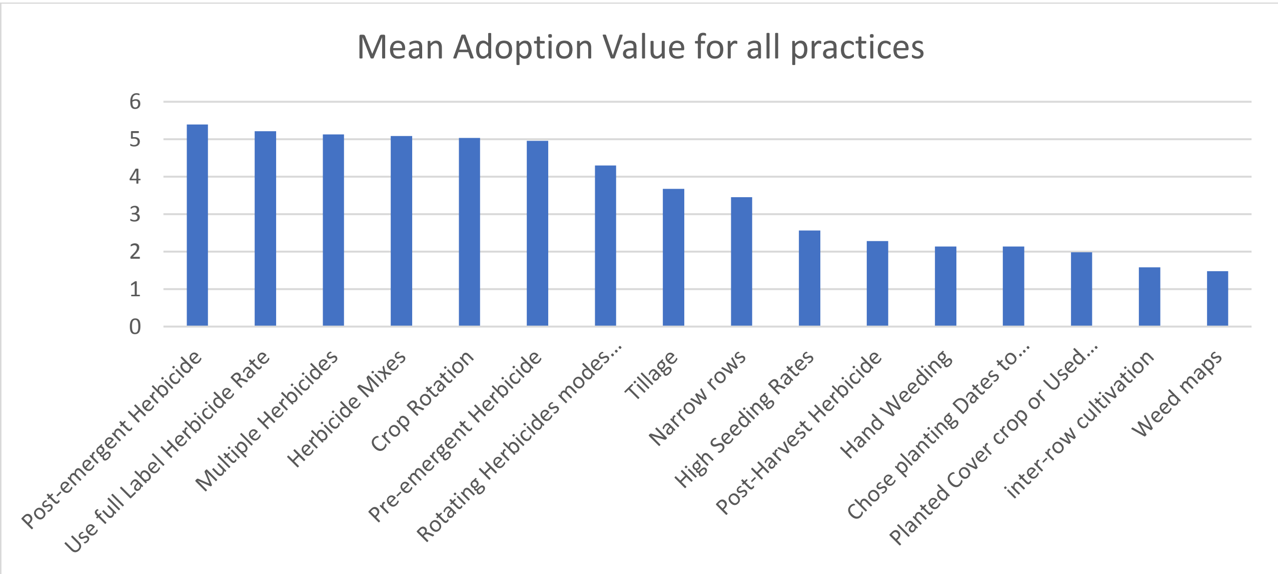


Figure 13 shows, for each weed resistance management practices, the number of farmers who did not adopt a practice on their farmland. All practices associated with herbicide usage except one have a low number of farmers not adopting at all. On the other hand, Figure 14 shows the number of farmers who adopted a practice on most of their land for all practices. As we can see, all practices associated with herbicide use except one were adopted on most farmland by higher number of farmers. However, Crop Rotation, unlike other non-herbicide WR management practices, has a high mean adoption value. Also, this practice has higher number of farmers adopting on most of their farmland and lower number of farmers not adopting at all.

If we look at the Figure 15, all practices associated with herbicide usage except Post-Harvest Herbicide have a higher share of farmers adopting those practices on most of their farmland. On the other hand, all non-herbicide practices except Crop Rotation have higher number of farmers not adopting at all.

Figure 13: number of farmers who did not adopt a practice for all weed resistance management practices

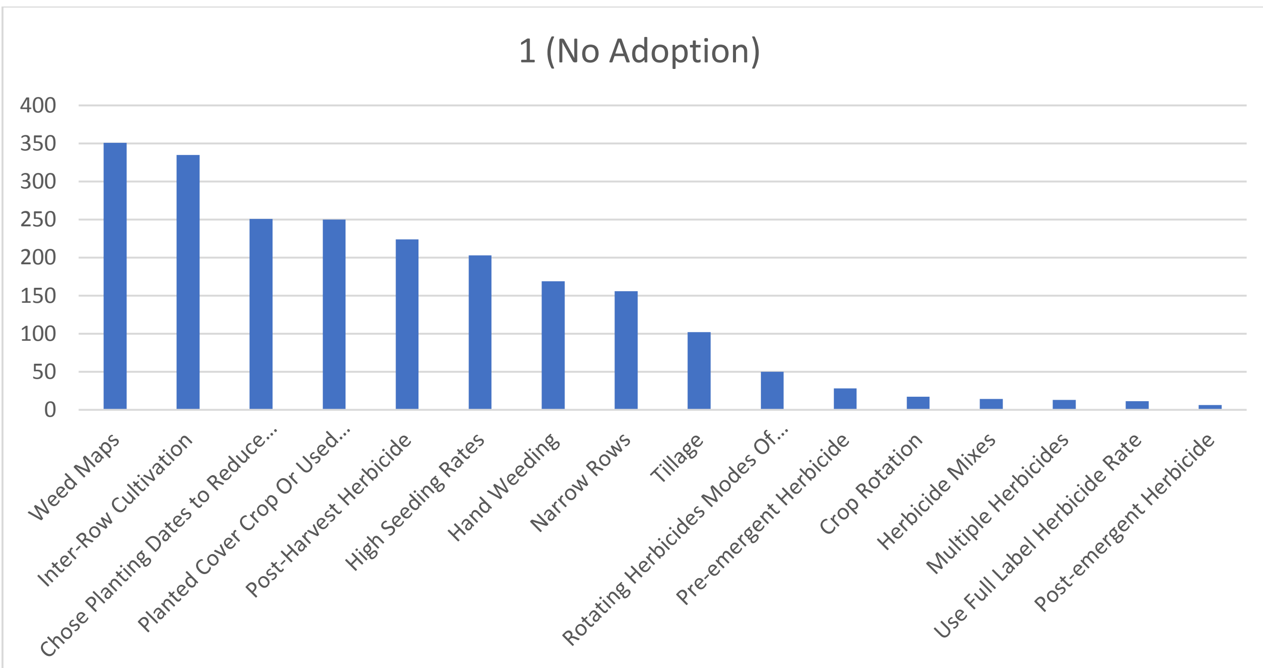


Figure 14: number of farmers who adopted a practice on 80-100 percent of land for all weed resistance management practices

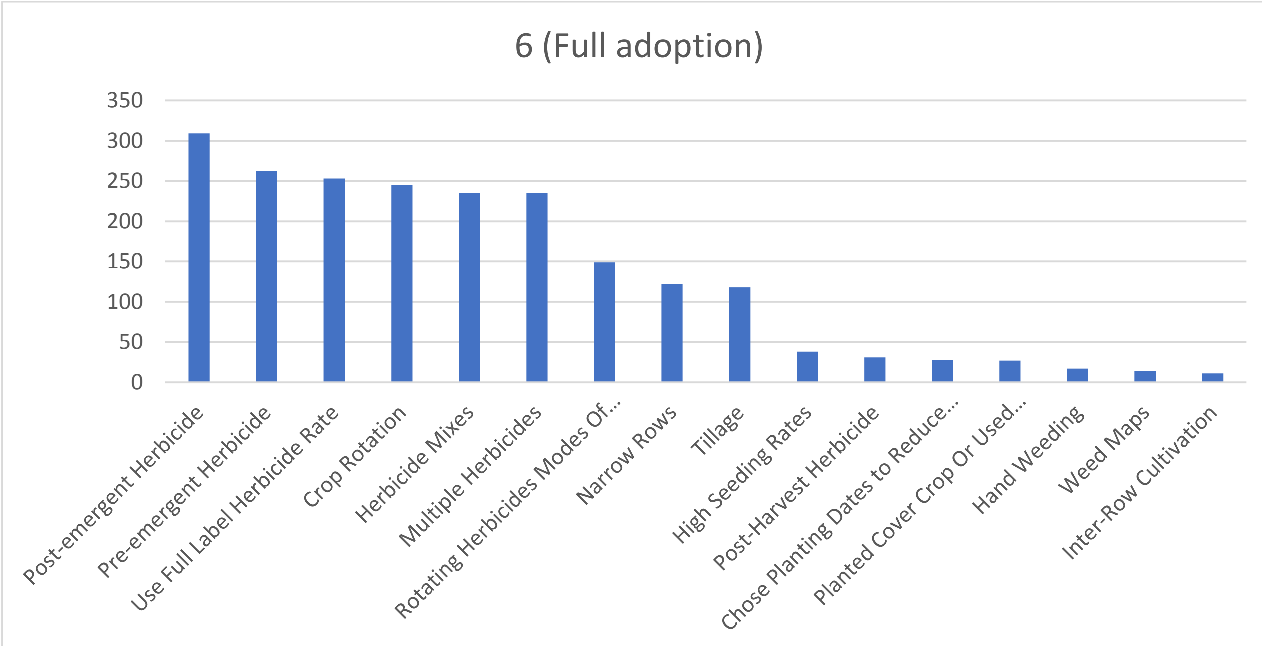
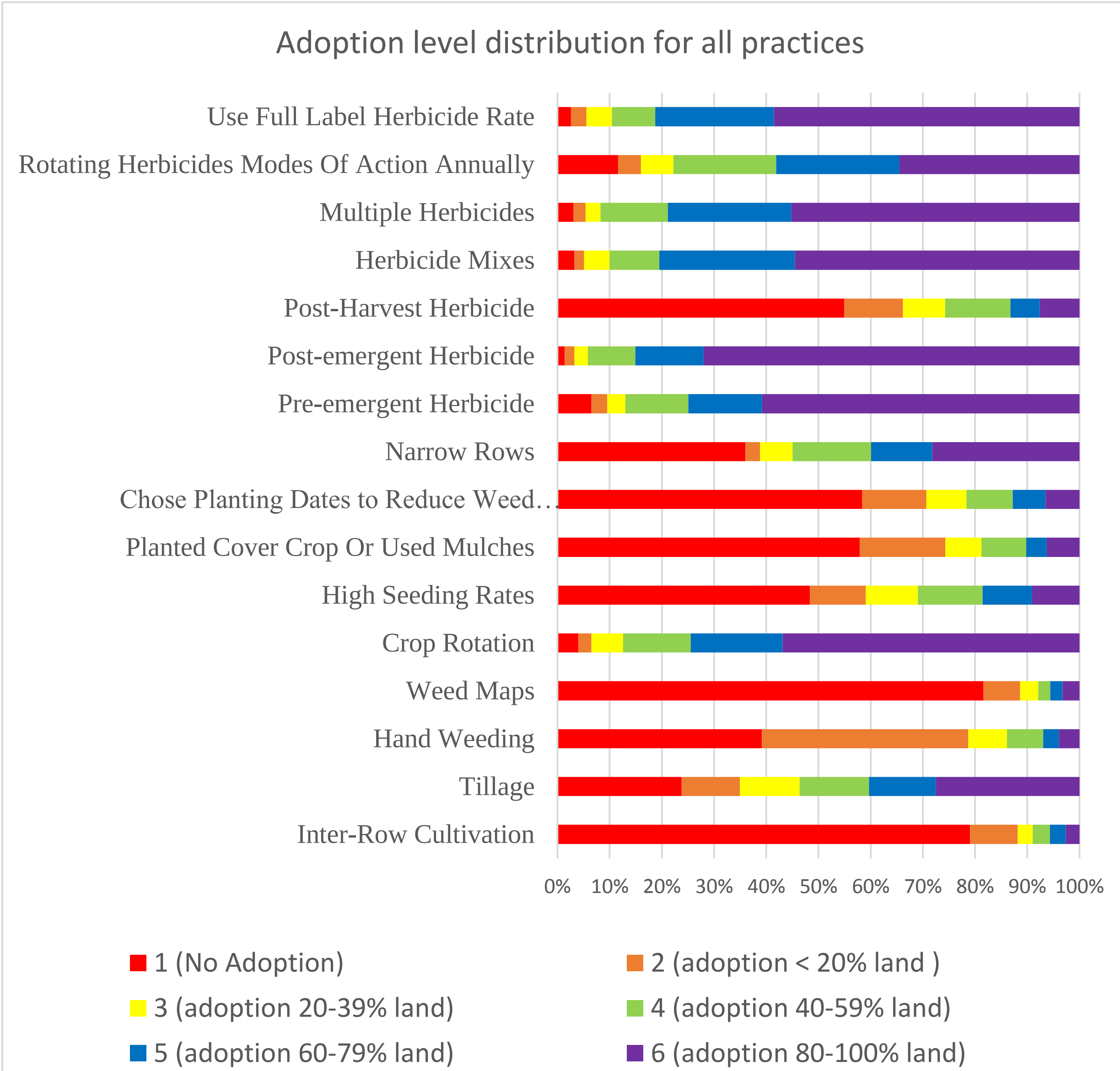


Figure 15: Distribution of farmers adopting a practice at different levels on their farmland for all weed resistance management practices



Variables Used in Regression Analysis

Dependent Variable (Adoption Level of Weed Resistance Management Practices):

The dependent variable is the ordinal measure of adoption, which ranges from a low of 1 to a high of 6 (1= No adoption, 2= adoption in less 20 percent of farmland, 3= adoption in 20 to 39 percent farmland, 4=40 to 59 percent of farmland, 5= 60 to 79 percent of farmland, 6= 80 to 100 percent of farmland).

Explanatory variables

Land Tenure Status:

Respondents were divided into Full Owners, Partial Owners, and Full Tenants using the same classification system as that used in the USDA Census of Agriculture. Two dummy variables were created that equaled one if the respondent was a partial owner and zero otherwise or equaled one if the respondent was a full tenant and zero otherwise. Full owners were the default case.

Regional Dummies:

- Southern plains states (Soplains): Texas, Oklahoma
- Northern Plains states (Noplains): Kansas, North Dakota, Nebraska, South Dakota.
- Mid Southern States (Midsou): Mississippi, Arkansas. Louisiana
- Delmarva Peninsula (Delmarva): Delaware, Maryland, Virginia.
- South Western states (Sowest): Arizona, New Mexico
- Great Lakes Region (Lake): Wisconsin, Minnesota, Michigan
- South- Eastern states (Soeast): North Carolina, South Carolina, Georgia, Alabama
- Corn-Belt states (Cbstates): (Default region) Illinois, Indiana, Iowa, Kentucky, Missouri, Ohio, Tennessee.

Explanatory variables used in this study are measured based on responses to the following questions,

Demographic variables:

Farmer characteristics were measured through answers to the following questions:

- Age: “How old are you?”
- Gender: “Are you male or female?”
- Ethnicity: “Which of the following categories best describes your racial and/or ethnic background? (Please check all that apply)”

Caucasian	American Indian	Spanish, Hispanic, or Latino	Asian or Asian American	Black or African American	Other

- Amount of Acres: “Of the acres of field crops that were planted in 2015, how acres did you?”

Own	Rent

Psychological Variables:

- Risk: “How do you see yourself? Are you generally a person who is fully prepared to take risks or do you avoid taking risks? (Please choose the number that best applies)”

Don’t like to take risks	1	2	3	4	5	6	7	8	9	10	Fully prepared to take risks

- Patience: “How would you describe yourself: are you generally an impatient person, or someone who always shows great patience? (Please choose the number that best applies)”

Very impatient	1	2	3	4	5	6	7	8	9	10	Very patient

- Experience: “How many years have you farmed?”

Perception Variables:

- Concern about Multiple HR Weeds: "How concerned are you about the presence of weeds resistant to multiple herbicides on your farming operation?"

Very concerned	Somewhat concerned	Not very concerned	Not concerned at all

- Concern About HR Weed Mobility from Neighbors: "Please indicate to which extent you agree or disagree with the following statements about herbicide resistant weeds-

I am concerned about herbicide resistant weeds spreading to my farming operations from nearby farming operations"

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
1	2	3	4	5

- Communicate with Neighbor about HR Weeds: "have you ever discussed with the owner/manager of a fields abutting or near one of yours whether herbicide resistant weeds are becoming a problem in your region?"

Yes	No

- Influence of Extension Educators: "Over the past two years, how important were each of the following sources of information for developing weed management approaches for your farming operation? (Please circle the number that best represents your answer)-

Extension educators"

Not important at all	Somewhat unimportant	Neither important nor unimportant	Somewhat important	Very important
1	2	3	4	5

- Influence of Other Growers: "Over the past two years, how important were each of the following sources of information for developing weed management approaches for your farming operation? (Please circle the number that best represents your answer)-

Other growers"

Not important at all	Somewhat unimportant	Neither important nor unimportant	Somewhat important	Very important
1	2	3	4	5

- Techno Optimism: "Please indicate the extent to which you agree or disagree with the following statement about weed resistance-

By the time a weed develops resistance to an herbicide, at least one new herbicide will have been found to replace it."

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
1	2	3	4	5

- Natural Environment: "Please indicate the extent to which you agree or disagree with each of the following statements-

I consider the natural environment on and around my farm to be an important part of my identity"

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
1	2	3	4	5

- Community Ties: “Please indicate the extent to which you agree or disagree with each of the following statements-

I have strong ties to other farmers in my community”

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
1	2	3	4	5

What is “techno-optimism”?

The term ‘Techno-optimism’ captures optimism towards technology to solve human problems. “Alvin M. Weinberg (1966/1981) proposed that remedies to a number of social and environmental problems are available through “Quick Technological Fixes,” in contrast to socially “engineering” (changing) human behavior to address these problems.” (York and Clark, 2010: 481). However, in this study techno-optimism denotes farmer’s expectation of new herbicide discovery before the current ones develop resistance.

Dentzman et al. (2016) conducted focus groups of US farmers about herbicide resistant weeds (HRW) to study techno-optimism. They used focus groups with 64 corn and soybean farmers in Arkansas, Iowa, Minnesota, and North Carolina where they found the expectation in technology to solve current and future herbicide resistant problem to be a common phenomenon in all focus groups.

Economic Model

A simple two period model can be thought of a basis for adoption of decision of weed resistance management practices where short run and long run representing two-time periods. After considering present value of short run and long run profit of adopting a weed resistance management practice, a decision is made by a farmer.

Net Present value without adopting a WR management practice,

Max PV = $\pi_S + \gamma\ \pi_L/(1+r)$;

Net present value after adopting a WR management practice,

Max $PV_i = \pi_{iS} + \gamma\ \pi_{iL}/(1+r)$;

Where, $\pi_{S} = (1-\delta)\ R_S - C_S$ and $\pi_{iL} = (1-\delta)\ R_L - C_L$;

$\pi_{iS} = (1-\delta)\ R_{iS} - C_{iS}$ and $\pi_{iL} = (1-\delta)\ R_{iL} - C_{iL}$;

δ = % yield loss from weed damage= f (N, R, H, M)

N= pre-treatment weed population,

R= Weed resistance to herbicide of interest,

H= vector of herbicide application,

M= Vector of non-chemical practices

π_{iS} = Short run profit of adopting a practice,

π_{iL} = Long run profit of adopting a practice,

γ = Tenure Security and assumed to be exogenous,

r = Discount Rate.

A farmer adopts a practice, if Max PV_i > Max PV.

It is reasonable to assume that $\gamma = 1$ for owner-operators. We can also assume that $0 \leq \gamma_{renter} < \gamma_{owner\text{-}operator}$. For example, we can think of γ_{renter} as being closer to 1 the stronger is the renter's belief that the lease will continue beyond the first period. Thus, γ_{renter} would depend on the expected duration of the lease (Soule et al., 2000).

Both γ and r can remove the long run concern of a farmer and make him decide only based on short run return. If tenure is insecure γ can be as low as 0 and a farmer completely ignores long run profit. Also, a farmer's discount rate can be as high as infinity to make him not consider long run profit. In either case, a farmer would decide mostly on short run profit and accept the decision gives the most return. In that case, a farmer adopts a practice if $\pi_{iS} > \pi_S$. Since, some initial cost associated with adopting a practice, it is reasonable to assume that $C_{iS} > C_S$. Hence, to adopt a practice, Revenue in the short run with adopting a practice should be bigger to such extent that short run profit after adopting a practice becomes greater than the short run profit without adopting that practice. Which is $R_{iS} >> R_S$ such that $\pi_{iS} > \pi_S$ so that Max PV_i > Max PV. To summarize, if a farmer perceives his investment in a weed resistance management practice will not pay off in the short run he will not adopt it.

On the other hand, if an individual has a tenure which is somewhat secured or completely secured and has a discount rate which is not infinity, then long run return comes to play role in the estimation of net present value. However, after considering for discount rate and tenure security in the estimation of long run profit and adding up with short run profit, if an individual find that his pay off from adopting a practice is greater than not adopting a practice which is Max PV_i > Max PV, he will adopt the weed resistance management practice. Otherwise a farmer will not adopt the practice.

Using more of an herbicide accelerates resistance. Using other herbicides slows resistance. Using non-chemical methods delays resistance. Greater use of an herbicide on neighbor's field increases resistance. Using diverse herbicides on a neighbor's field delays resistance. (Frisvold et al., 2017)

Econometric Model

In this study, Ordered Probit model is used to predict whether the farmer is adopting conservation practice or not.

$$y_i = \begin{cases} 6, if\ Adoption\ in\ 80\ to\ 100\ percent\ of\ farmland \\ 5, if\ Adoption\ in\ \ 60\ to\ 79\ percent\ of\ farmland \\ 4, if\ Adoption\ in\ \ 40\ to\ 59\ percent\ of\ farmland \\ 3, if\ Adoption\ in\ 20\ to\ 39\ percent\ farmland \\ 2,\ \ if\ Adoption\ in\ less\ 20\ percent\ of\ farmland \\ 1,\ \ if\ the\ farmer\ decided\ for\ no\ adoption \end{cases}$$

- Ordered Probit model is given by the following equation:

$$y_i^* = \beta_0 + \beta_1 x_{i1} + \cdots \beta_p x_{ip} + u_i$$

$$u_i \sim N\,(0, 1)$$

$$y_i = \begin{cases} 6, & y_i^* > 5 \\ 5, & \mu_5 > y_i^* > 4 \\ 4, & \mu_4 > y_i^* > 3 \\ 3, & \mu_3 > y_i^* > 2 \\ 2, & \mu_2 > y_i^* > 1 \\ 1, & \mu_1 > y_i^* > 0 \\ 0, & y_i^* \leq 0 \end{cases}$$

- Assumptions:

1) Each observation is independent.
2) Adoption of each weed resistance management practice is independent.

However, we relaxed the second assumption to check the differences in results since we found evidence of correlation among regression error terms.

My research interest is to check whether land tenure status has a role to play in decision making. Land tenure status is divided in 3 categories in the USDA data i.e. full owners, partial owners, and full tenant.

$$\boldsymbol{Ordered\ Probit\ Model}\text{: } \boldsymbol{y_i^*} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1}(\boldsymbol{Full\ tenant}) + \boldsymbol{\beta_2}(\ \boldsymbol{Partial\ tenant}) + \boldsymbol{\beta_i}(\boldsymbol{Control\ Variables}) + \boldsymbol{u_i}$$

Conventional hypothesis:

owners are more likely to adopt conservation practices than renters. In that case we are expecting negative sign for $\boldsymbol{\beta_1}$ and $\boldsymbol{\beta_2}$

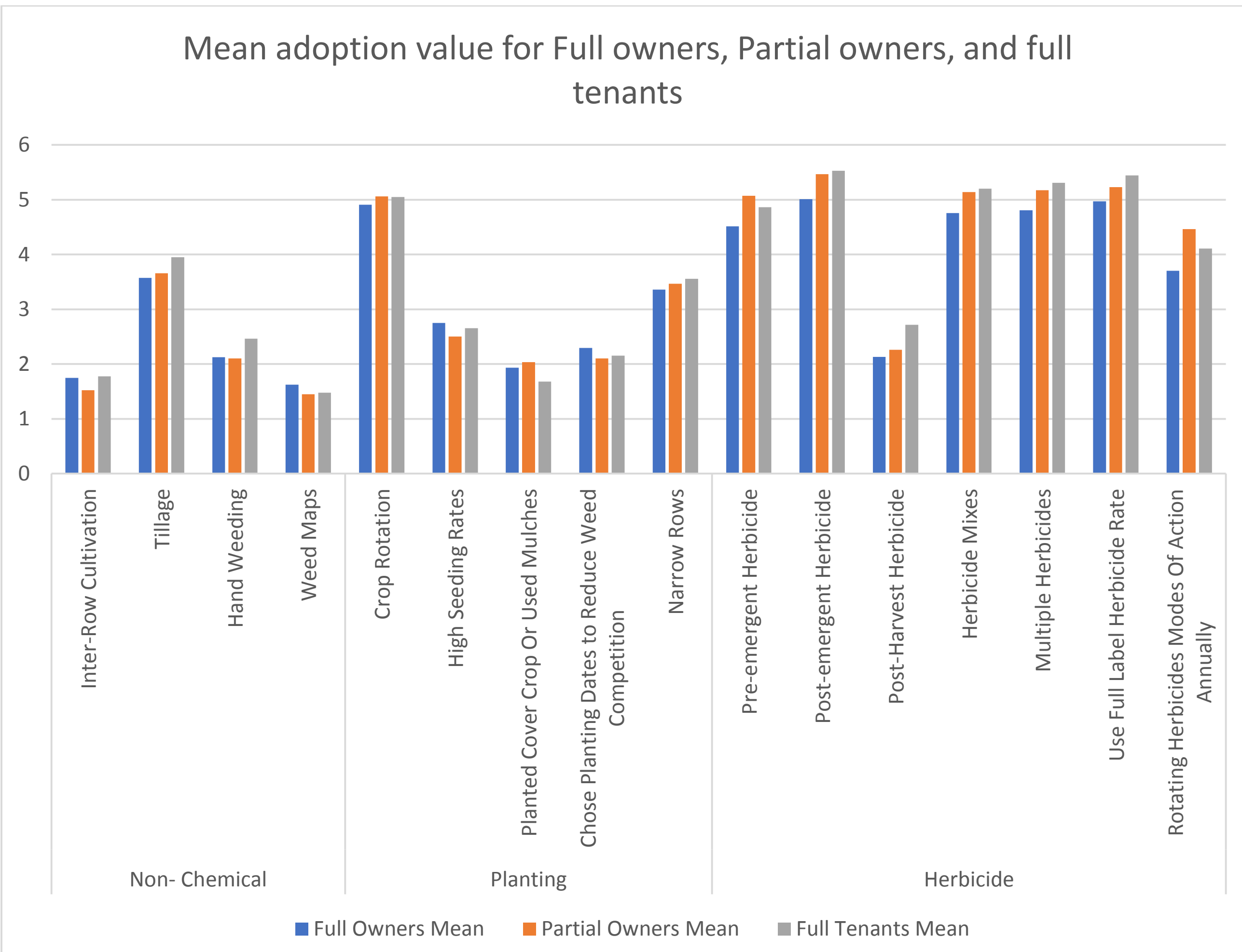
We start with a simple model comprising only tenure variables and keep adding groups of variables in the subsequent models. We will be observing how sign for $\boldsymbol{\beta_1}$ and $\boldsymbol{\beta_2}$ change with the change in control variables.

- $\boldsymbol{Model-1}$: $\boldsymbol{y_i^* = \beta_0 + \beta_1(Full\ tenant) + \beta_2(\ Partial\ tenant) + u_i}$
- $\boldsymbol{Model-2}$: $\boldsymbol{y_i^* = \beta_0 + \beta_1(Full\ tenant) + \beta_2(\ Partial\ tenant) + \beta_i(Geographic\ and\ Demogrpahic) + u_i}$
- $\boldsymbol{Model-3}$: $\boldsymbol{y_i^* = \beta_0 + \beta_1(Full\ tenant) + \beta_2(\ Partial\ tenant) + \beta_i(Geographic, Demogrpahic,\ and\ Psychological) + u_i}$
- $\boldsymbol{Model-4}$: $\boldsymbol{y_i^* = \beta_0 + \beta_1(Full\ tenant) + \beta_2(\ Partial\ tenant) + \beta_i\begin{pmatrix} Geographic, Demogrpahic,\ and\ Psychological, \\ and\ Perception\ Variables \end{pmatrix} + u_i}$

CHAPTER 4: ANALYSIS

From mean adoption value of full owners, partial owners, and full tenants for all weed management practices, we can see the differences in adoption level on average. Contrary to conventional hypothesis, both partial owners and full tenants have higher mean adoption rates for most practices than full owners. Only 3 among 16 practices are found where both the partial owners and full tenants have lower mean adoption value than owners. Three of these practices are not associated with herbicide usage. By contrast, all practices that are associate with herbicide usage have higher mean adoption value for partial owners and full tenants than that of full owner operators. (Figure 16)

Figure 16: Mean adoption value for Full owners, Partial owners, and Full tenants for all weed resistance management practices



The Austin Balance Method is used to test the significance of differences in mean adoption values among the three groups. To simplify the Austin Method, if the selection mechanism for allocating a cross-sectional unit into one group or the other is random, then the distributions of the continuous variables for each group should be quite similar. Alternatively, if we detect statistical differences in the distributions (proportions) of variables across groups, we can infer the selection mechanism is non-random in an important way. The standardized difference is estimated as,

$$d = (\bar{X}_{\text{treatment}} - \bar{X}_{\text{control}}) / \sqrt{((S^2_{\text{treatment}} + S^2_{\text{control}}) / 2)}$$

In Austin method, standardized difference is estimated in mean adoption values in each group and variances of each group for all practices. Austin method says, if the standardized difference is higher than 0.1 then the difference is significant. In table 1, we compared both partial owners and full tenants against full owners against full owners to check the conventional hypothesis. If standardized difference is more than 0.1, then partial owners and full tenants have significantly higher mean adoption value. By contrast, if standardized difference is less than -0.1, full owners have significantly higher mean adoption value than other two groups.

Both partial owners and full tenants have significantly higher adoption rate than full owners for all practices associated with herbicide. Likewise, for Crop Rotation which is a non-herbicide practice. However, all these practices have high adoption rates among all farmers. Two practices, Chose Planting Dates to Reduce Weed Competition and Weed Maps have higher adoption rates for full owners compared to both partial owners and full tenants. However, these two practices have lower adoption rate in general among all farmers. (Table 1)

Table 1: Tests of the significance of differences in means of partial owners and full tenants compared to full owners using the Austin Balance Method

	Conservation Practices	**Standardized difference between Partial Owners and Full Owners**	**Significance based on Austin Method**	**Standardized difference between Full Tenants and Full Owners**	**Significance based on Austin Method**
Non-Chemical	Inter-Row Cultivation	-0.2342	Full Owners	0.0254	Not Significant
	Tillage	0.0600	Not Significant	0.2775	Full Tenants
	Hand Weeding	-0.0213	Not Significant	0.3036	Full Tenants
	Weed Maps	-0.1893	Full Owners	-0.1582	Full Owners
Planting	Crop Rotation	0.1513	Partial	0.1394	Full Tenants
	High Seeding Rates	-0.1882	Full Owners	-0.0746	Not Significant
	Planted Cover Crop Or Used Mulches	0.0912	Not Significant	-0.2504	Full Owners
	Chose Planting Dates to Reduce Weed Competition	-0.1575	Full Owners	-0.1124	Full Owners
	Narrow Rows	0.0697	Not Significant	0.1279	Full Tenants
Herbicide	Use Full Label Herbicide Rate	0.2922	Partial	0.5629	Full Tenants
	Rotating Herbicides Modes Of Action Annually	0.5953	Partial	0.3099	Full Tenants
	Herbicide Mixes	0.3986	Partial	0.4800	Full Tenants
	Multiple Herbicides	0.3874	Partial	0.5257	Full Tenants
	Pre-emergent Herbicide	0.4897	Partial	0.2764	Full Tenants
	Post-emergent Herbicide	0.5273	Partial	0.5603	Full Tenants
	Post-Harvest Herbicide	0.1085	Partial	0.4525	Full Tenants

We also used Austin method to find significant difference in mean adoption value between full tenants and partial owners. Significant differences in mean adoption values have been found to exist between full tenants and partial owners for most of the practices. For most of those practices with significant a difference, full tenants have been found to have higher adoption rate compared with partial owners. (Table 2)

Table 2: Tests of the k significance of differences in means between partial owners and full tenants using the Austin Balance Method

	weed resistance management practices	**Standardized Difference between Full Tenants and Partial Owners**	**Significance based on Austin Method**
Non-Chemical	Inter-Row Cultivation	0.2638	Full Tenants
	Tillage	0.2210	Full Tenants
	Hand Weeding	0.3427	Full Tenants
	Weed Maps	0.0339	Not Significant
Planting	Crop Rotation	-0.0119	Not Significant
	High Seeding Rates	0.1260	Full Tenants
	Planted Cover Crop Or Used Mulches	-0.3505	Partial Owners
	Chose Planting Dates to Reduce Weed Competition	0.0427	Not Significant
Herbicide	Narrow Rows	0.0597	Not Significant
	Pre-emergent Herbicide	-0.1830	Partial Owners
	Post-emergent Herbicide	0.0781	Not Significant
	Post-Harvest Herbicide	0.3544	Full Tenants
	Multiple Herbicides	0.1531	Full Tenants
	Herbicide Mixes	0.0709	Not Significant
	Use Full Label Herbicide Rate	0.2670	Full Tenants
	Rotating Herbicides Modes Of Action Annually	-0.2967	Partial Owners

Figure 17: Mean ethnicity and gender values for full owners, partial owners, and full tenants

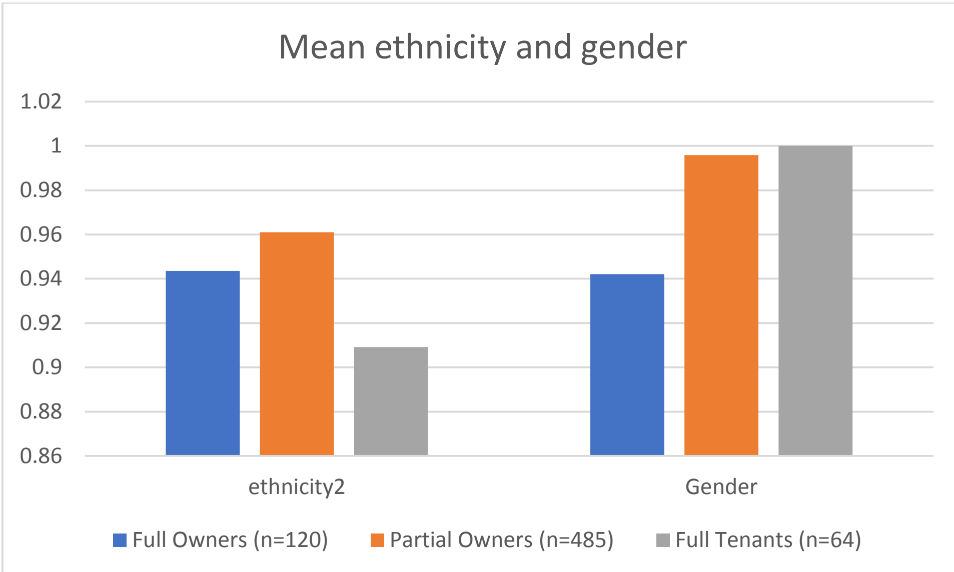


Figure 18: Mean risk and patience values for full owners, partial owners, and full tenants

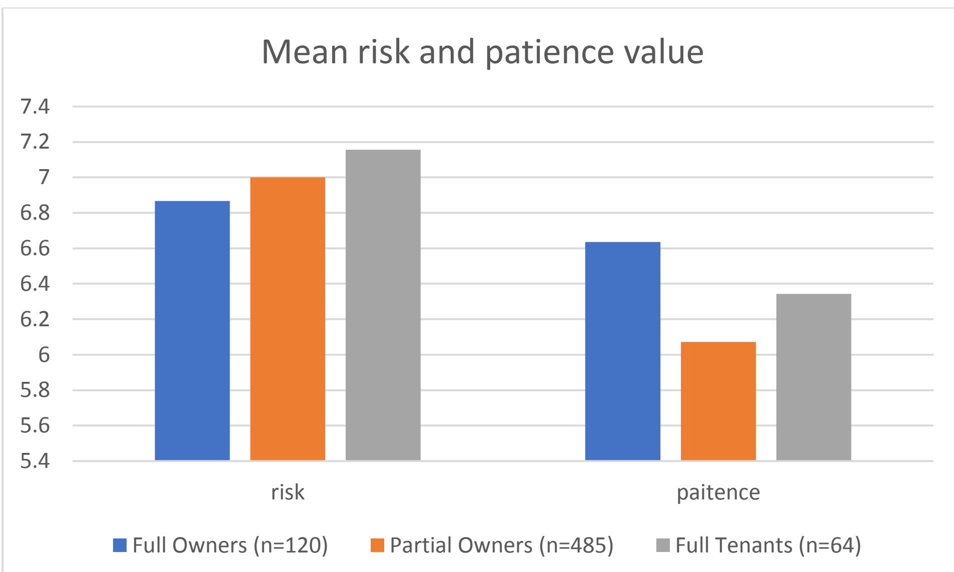


Figure 19: Mean age and experience for full owners, partial owners, and full tenants

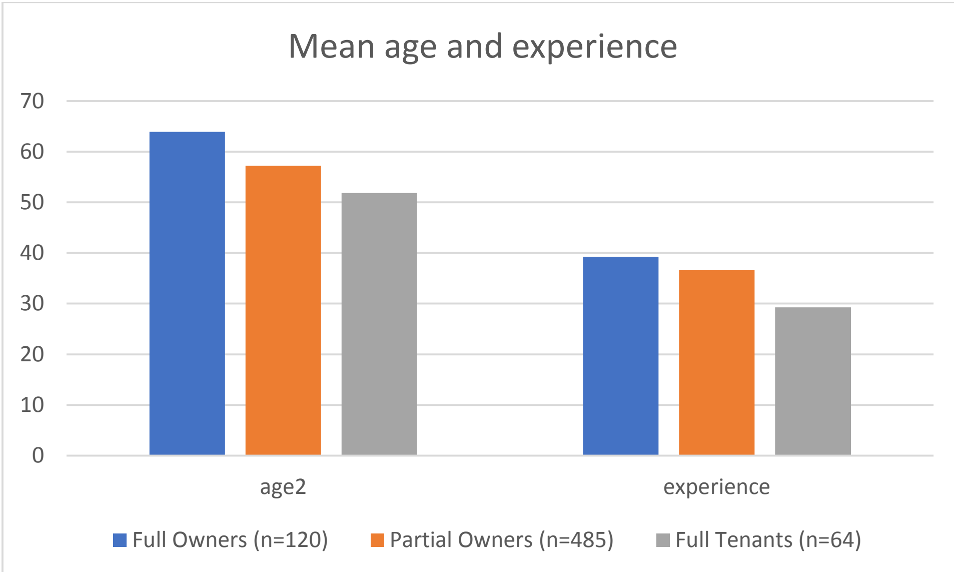
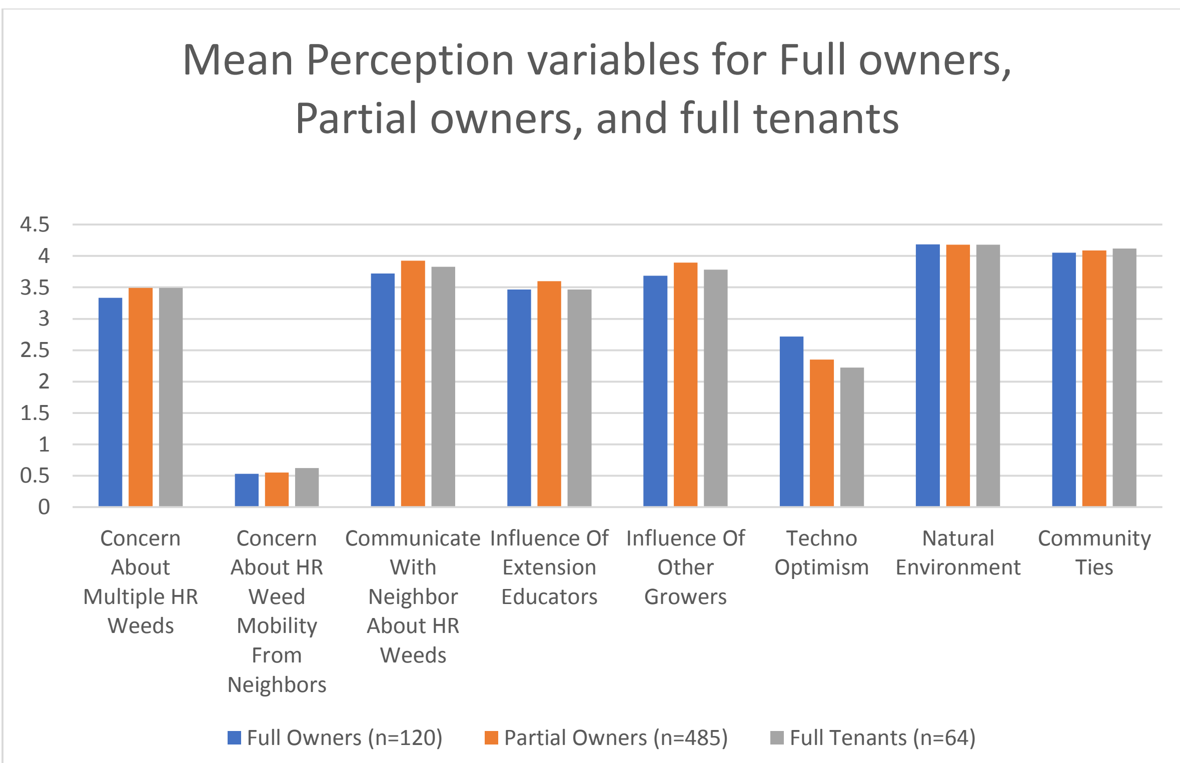


Figure 20: Mean values of perception variables for full owners, partial owners, and full tenants



Results from Ordered Probit Model:

Results from all four models are reported in Table 3. The coefficients for full tenants and partial owners from each model are placed adjacent to each other. The first two columns with numbers showing the coefficients for full tenants and partial owners from first model. Subsequent columns represent pairing of the coefficients from alternative models. The first model is the simplest where only full tenant and partial owner variables are used. Subsequent models are built on previous models by adding new sets of variables to the previous model. If the conventional hypothesis is true we expect a negative sign on the tenure variable coefficients.

Management practices like tillage, crop rotation, planted cover crop or used mulches, and weed maps in any of the ordered probit models employed in this study. Among the practices adoptions that were to be significantly influenced by land tenure status the majority are associated with herbicide use. Here, tenants and part owners are more likely to adopt them. Post emergent herbicide use has produced most robust relationship. It shows a significant relationship consistently in all the models. Both full tenants and partial owners are more likely to adopt post emergent herbicide than owner operators. All practices associated with herbicide except Post Harvest Herbicide are found to be significant consistently, however coefficients from some practices are found to more significant across the models than others. These practices associated with herbicides are more likely adopted by full tenants and partial owners than owners.

By contrast, practices like inter row cultivation, high seeding rates and chose planting dates to reduce weed competition are more likely to be adopted by owners. However, results are not strong compared to the significance of coefficients of practices associated with herbicides. The sign of the coefficients is also found to be consistent all the cases where significant relationships are observed.

We have also run OLS models to check for the consistency. Just like ordered Probit model, results from all four OLS models are produced in one table and results consistent with the results produced from ordered probit model (Table 4).

We have classified all the weed resistance management practices into three groups based on their applications.

Non-Chemical Weed Resistance Management Practices:

Land tenure status plays an unimportant role in adopting these four practices. In adopting inter row cultivation, full owners are found to be significantly more likely to adopt than partial owners in only one model with lesser variables.

Practices Associated with Planting:

Among the five practices associated with planting crops, chose planting dates to reduce weed competition has been found to show significant relationship consistently across the models for both full tenants and partial owners. In the simplest model, the results were not significant. However, as groups of variables were added in the subsequent models, the results became significant. Owners are more likely to adopt this practice than both full tenants and partial owners. In adopting high seeding rates, partial owners were found to be significantly and consistently less likely to adopt than full owners. This result is also consistent with the OLS model.

Practices Associated with Herbicides:

Land tenure variables for practices associated with herbicide usage except post-harvest herbicide use has been found to be highly significant consistently across all models. In none of these practices, were full owners more likely to adopt a practice than full tenants and partial owners. By contrast, both full tenants and partial owners are more likely to adopt these practices than full owners. This result is consistent with the OLS model results.

Table 3: Results from Ordered Probit Model

	Practice (Ordered Probit)	Full-Tenant	Partial	Full-Tenant	Partial	Full-Tenant	Partial	Full-Tenant	Partial
		Model-1 (Full -Tenant Partial)	Model-1 (Full - Tenant Partial)	Model-2 (Geographic, Demographic)	Model-2 (Geographic, Demographic)	Model-3 (Geographic, Demographic, Psychological)	Model-3 (Geographic, Demographic, Psychological)	Model-4 (Geographic, Demographic, Psychological, and Perception)	Model-4 (Geographic, Demographic, Psychological, and Perception)
Non-Chemical	Inter-Row Cultivation	0.2025	0.1402	-0.3023	-0.2773*	-0.1396	-0.2127	-0.1351	-0.2266
	Tillage	0.1992	0.0515	0.0398	0.00819	0.1703	0.0968	0.1433	0.0505
	Hand Weeding	0.3254*	0.065	-0.0291	-0.0628	-0.0335	-0.00961	-0.0608	-0.0796
	Weed Maps	-0.1282	-0.1183	0.0847	-0.00956	0.1447	-0.0199	0.2316	0.0571
Planting	Crop Rotation	0.114	0.1273	0.2282	0.1339	0.1946	0.1517	0.0677	0.0717
	High Seeding Rates	-0.0248	-0.1492	-0.1732	-0.2426*	-0.07	-0.1909~	-0.1473	-0.2695*
	Planted Cover Crop or Used Mulches	-0.1263	0.1526	-0.2166	0.0513	-0.2207	-0.0174	-0.1399	0.00727
	Chose Planting Dates to Reduce Weed Competition	-0.0487	-0.0845	-0.3507*	-0.1918~	-0.367*	-0.2279*	-0.3426~	-0.2171~
	Narrow Rows	0.1069	0.0731	0.388**	0.1762	0.3588*	0.1995~	0.2708	0.0908
Herbicide	Pre-emergent Herbicide	0.3245*	0.3907***	0.2081	0.2957**	0.1335	0.2872**	0.0735	0.237*
	Post-emergent Herbicide	0.6802***	0.4774***	0.5581**	0.3374***	0.4601**	0.3396**	0.4281*	0.317**
	Post-Harvest Herbicide	0.3876**	0.0944	0.1912	-0.063	0.3155~	-0.0156	0.2862	-0.0635
	Herbicide Mixes	0.3392*	0.3476***	0.2362	0.2475**	0.3396*	0.26**	0.272	0.144
	Multiple Herbicides	0.4845***	0.3073***	0.4182**	0.2168*	0.3842*	0.1877~	0.267	0.0768
	Rotating Herbicides Modes of Action Annually	0.213	0.4241***	0.1847	0.3747***	0.1956	0.3755**	0.0725	0.2288*
	Use Full Label Herbicide Rate	0.4915***	0.2446**	0.415**	0.1891~	0.4114**	0.1394	-0.0608	-0.0796

***- significant at 1 % level, **- significant at 5% level, *- significant at 10% level, ~ -significant around 10% level.

Table 4: Results from OLS Model

	Practice (OLS)	Full-Tenant	Partial	Full-Tenant	Partial	Full-Tenant	Partial	Full-Tenant	Partial
		Model-1 (Full -Tenant Partial)	Model-1 (Full - Tenant Partial)	Model-2 (Geographic, Demographic)	Model-2 (Geographic, Demographic)	Model-3 (Geographic, Demographic, Psychological)	Model-3 (Geographic, Demographic, Psychological)	Model-4 (Geographic, Demographic, Psychological, and Perception)	Model-4 (Geographic, Demographic, Psychological, and Perception)
Non-Chemical	Inter-Row Cultivation	0.02662	-0.22489~	-0.28715	-0.22577~	-0.09125	-0.14302	-0.1212	-0.17414
	Tillage	0.38018	0.08462	0.10422	0.00364	0.33572	0.16275	0.29026	0.07572
	Hand Weeding	0.33873~	-0.02154	-0.11474	-0.15797	-0.12731	-0.10471	-0.16558	-0.18469
	Weed Maps	-0.14693	-0.17492	0.03016	-0.078	0.05707	-0.09101	0.14342	-0.01137
Planting	Crop Rotation	0.14021	0.15166	0.24854	0.15268	0.23402	0.18245	0.11966	0.08737
	High Seeding Rates	-0.09613	-0.2491	-0.2914	-0.36506*	-0.1232	-0.27617	-0.24175	-0.34669~
	Planted Cover Crop or Used Mulches	-0.25766	0.09946	-0.34167	0.01215	-0.32937	-0.04387	-0.28034	-0.07118
	Chose Planting Dates to Reduce Weed Competition	-0.13706	-0.18688	-0.55572**	-0.32892*	-0.57541**	-0.35471*	-0.51413*	-0.32216~
	Narrow Rows	0.1942	0.10532	0.65073*	0.26401	0.61747*	0.31145	0.43862	0.10143
	Pre-emergent Herbicide	0.35655	0.60438***	0.03556	0.32754*	-0.09638	0.25338	-0.08745	0.222
	Post-emergent Herbicide	0.52255***	0.45952***	0.37896**	0.33769***	0.30191~	0.32784***	0.30623~	0.34714**
Herbicide	Post-Harvest Herbicide	0.58297**	0.12878	0.33883	-0.08956	0.52094	-0.01317*	0.48585~	-0.06242
	Herbicide Mixes	0.44074**	0.38028**	0.2677	0.25122*	0.42382**	0.26688*	0.33045~	0.12686
	Multiple Herbicides	0.4986**	0.3665***	0.37524*	0.26647*	0.37095*	0.24967*	0.2487	0.11321
	Rotating Herbicides Modes of Action Annually	0.40499~	0.75802***	0.36271	0.65812***	0.39404	0.65553***	0.19133	0.40782**
	Use Full Label Herbicide Rate	0.47393**	0.25969**	0.36079*	0.2014~	0.36576*	0.13889	0.11902	-0.10341

***- significant at 1 % level, **- significant at 5% level, *- significant at 10% level, ~ -significant around 10% level.

Results from Extended Ordered Probit Models:

We found evidence of correlation among the dependent variables in our model. Also adopting one practice does not exclude adopting others. Multiple practices can be adopted together. So, adoption of one practice is not completely an isolated event and based on the correlation table (Appendix B) it is reasonable to believe that these practices are being adopted jointly. The next set of regressions allowed for correlations to exist between the error terms of regression equations. However, because of computational limitation imposed by statistical software, we considered only those practices which were adopted more than 40 percent of farmland on average and ran a joint multivariate probit model. We found a list of ten practices and all practices associated with herbicide made into the list along with Tillage, Crop Rotation, and planting of Narrow Rows.

Two changes in results were observed from the extended model. Narrow Rows, shows more robust and higher level of significance across different models. The conclusion that this is the only non-herbicide practice which has been significantly adopted more by tenants and partial owners has been reinforced from the extended model. Pre-emergent Herbicide, a practice associated with herbicide usage, lost robustness and showed no significant coefficients beyond simple model in extended model results.

Our original results from previously run separate ordered probit model remained consistent for rest of the practices among top ten adopted practices. However, results from separate and joint multivariate ordered probit model are not exactly comparable. This is because the joint multivariate probit only uses observations where there is complete data common for all practices. So, in the individual ordered probit equations there can be more observations. In the joint regressions, the model only considered the observation which have responses for all ten practices. It did not consider observations which have missing data for any of the practices. Hence, it reduced the number of observations used in the model compared the number of observations used in the separate ordered probit model.

Role of Land Tenure status:

Weed management practices that were adopted on at least forty percent or more of crop acres on average were selected for the joint ordered probit model. General findings remained the same in this model where signs of coefficients are consistent with the previous model. However, coefficients of Narrow Rows became more significant across different models where Pre-Emergent Herbicide lost significance. Here also we can see coefficients of tenure variables for most practices losing significance when perception variables are introduced in model-4. These means perception variables explain most of the differences in the adoption level for most practices. Hence, after introducing perception variables, land tenure variables explain less variation in adoption than previously assumed. So, land tenure status matters (or not at all) after controlling for perception variables. (Table-5)

Table 5: Results from Joint Ordered Probit Model with the Top 10 Adopted Weed Management Practices.

	Practice (Joint Ordered Probit Model)	Full-Tenant	Partial	Full-Tenant	Partial	Full-Tenant	Partial	Full-Tenant	Partial
		Model-1 (Full -Tenant Partial)	Model-1 (Full -Tenant Partial)	**Model-2 (Geographic, Demographic)**	**Model-2 (Geographic, Demographic)**	**Model-3 (Geographic, Demographic, Psychological)**	**Model-3 (Geographic, Demographic, Psychological)**	**Model-4 (Geographic, Demographic, Psychological, and Perception)**	**Model-4 (Geographic, Demographic, Psychological, and Perception)**
Non-Chemical	**Tillage**	0.2063	0.04662	0.11866	0.01157	-0.05194	-0.01841	-0.06433	-0.03958
Planting	**Crop Rotation**	0.12737	0.1629	0.02204	0.09873	0.14831	0.15114	0.05058	0.10328
	Narrow Rows	0.21619	0.12325	**0.5001****	**0.32557****	**0.45814****	**0.27555***	**0.44492***	0.1785
Herbicide	**Pre-emergent Herbicide**	0.32858	**0.32754****	-0.10325	0.02621	0.0334	0.18633	0.01069	0.09643
	Post-emergent Herbicide	**0.71193*****	**0.59542*****	**0.44119***	**0.38595****	**0.49346***	**0.61338*****	**0.4512~**	**0.57742*****
	Post-Harvest Herbicide	**0.47588****	0.18886	0.27273	0.11429	0.27863	0.01962	0.24647	0.01569
	Herbicide Mixes	**0.39016****	**0.3637*****	0.36002	0.25042	0.37894	**0.27651***	0.23926	0.15201
	Multiple Herbicides	**0.58083*****	**0.35457*****	**0.61806*****	**0.30981****	**0.60994****	**0.39996****	**0.47032***	0.2436
	Rotating Herbicides Modes of Action Annually	**0.28919~**	**0.5229*****	0.23774	**0.47718*****	0.22025	**0.31417****	0.12187	0.26201~
	Use Full Label Herbicide Rate	**0.52122****	**0.22815***	**0.54617****	**0.23307~**	**0.6318****	**0.3236****	0.34128	0.11596

***- significant at 1 % level, **- significant at 5% level, *- significant at 10% level, ~ -significant around 10% level.

Table 6: Results from Ordered Probit Model with the Top 10 Adopted Weed Management Practices (Model-4)

		age2	ethnicity2	Gender	income2	risk	patience	experience
Tillage	**Estimate**	-0.0049	-1.3765	-0.7134	-0.0993	-0.0319	0.03669	-0.0072
	Pr > |t|	0.5363	**0.0006**	0.1291	**0.0315**	0.2696	0.1361	0.3111
Crop Rotation	**Estimate**	-0.0039	-0.3407	-0.8515	-0.022	-0.0297	-0.0642	-0.0083
	Pr > |t|	0.6523	0.3966	0.1483	0.6594	0.3436	**0.0132**	0.2762
Pre-emergent Herbicide	**Estimate**	-0.0223	-0.3836	-0.6858	-0.018	0.02402	-0.0364	0.00327
	Pr > |t|	**0.0107**	0.4124	0.2891	0.7281	0.4504	0.1748	0.67
Post-emergent Herbicide	**Estimate**	-0.0244	0.30233	-1.1993	0.20594	-0.0085	-0.0082	-0.01
	Pr > |t|	**0.0094**	0.4927	**0.0831**	**0.0006**	0.8136	0.7838	0.2095
Post-Harvest Herbicide	**Estimate**	-0.0168	-1.2556	0.28937	0.00645	0.03422	-0.0103	0.01438
	Pr > |t|	**0.0517**	**0.0009**	0.5898	0.8949	0.2694	0.6915	**0.061**
Herbicide Mixes	**Estimate**	-0.005	0.10806	-0.8935	0.05998	0.13512	-0.0517	-0.0022
	Pr > |t|	0.5546	0.7931	0.1797	0.2355	**0.0001**	**0.0495**	0.7739
Multiple Herbicides	**Estimate**	-0.0058	0.63377	-0.9701	0.01576	0.12268	-0.06	-0.0017
	Pr > |t|	0.4932	0.106	0.1253	0.7569	**0.0001**	**0.0263**	0.8239
Use Full Label Herbicide Rate	**Estimate**	-0.0087	-0.0517	-0.8128	0.00256	0.01917	-0.0374	-0.0004
	Pr > |t|	0.3072	0.9017	0.1386	0.9599	0.5552	0.1614	0.9583
Rotating Herbicides Modes Of Action Annually	**Estimate**	0.00165	0.45396	0.01948	0.00119	0.07577	-0.0677	0.00013
	Pr > |t|	0.8342	0.2265	0.966	0.9795	**0.0081**	**0.0052**	0.9856
Narrow Rows	**Estimate**	0.01324	0.61857	-0.1948	-0.0922	0.04708	0.00654	0.00685
	Pr > |t|	0.1132	0.1266	0.6882	**0.0607**	0.1202	0.7989	0.3466

Table 7: Results from Joint Ordered Probit Model with the Top 10 Adopted Weed Management Practices (Model-4)

		Concern About Multiple HR Weeds	Communicate With Neighbor About HR Weeds	Concern About HR Weed Mobility From Neighbors	Influence Of Extension Educators	Influence Of Other Growers	Techno Optimism	Natural Environment	Community Ties
Tillage	**Estimate**	-0.0644	0.18701	0.01107	-0.016	0.04613	0.04752	-0.0711	-0.0541
	Pr > |t|	0.4096	**0.0938**	0.8461	0.752	0.4095	0.3835	0.3183	0.4042
Crop Rotation	**Estimate**	0.18303	0.1348	0.04346	-0.0269	0.0743	-0.0793	0.05399	0.04762
	Pr > |t|	**0.0273**	0.2606	0.4776	0.6156	0.1984	0.1727	0.4589	0.4754
Pre-emergent Herbicide	**Estimate**	-0.0278	-0.2065	0.03864	0.00597	0.02038	-0.1744	-0.0476	0.15604
	Pr > |t|	0.7463	**0.0966**	0.5316	0.9149	0.7319	**0.0039**	0.532	**0.0248**
Post-emergent Herbicide	**Estimate**	0.01988	0.25044	-0.0105	-0.0729	0.06461	-0.1144	-4E-05	-0.0544
	Pr > |t|	0.8303	**0.0722**	0.8751	0.2699	0.3267	**0.081**	0.9996	0.476
Post-Harvest Herbicide	**Estimate**	0.13874	-0.1222	0.14607	0.05638	-0.0027	0.00678	-0.0457	0.07911
	Pr > |t|	0.1026	0.3036	**0.0175**	0.2949	0.9631	0.9053	0.5464	0.2513
Herbicide Mixes	**Estimate**	-0.0207	-0.0733	0.20299	-0.155	0.05479	-0.1737	0.05739	0.00987
	Pr > |t|	0.8026	0.5395	**0.0006**	**0.0033**	0.3486	**0.0026**	0.4421	0.8854
Multiple Herbicides	**Estimate**	-0.0575	0.12071	0.19764	-0.1436	-0.0412	-0.3251	-0.0107	0.01036
	Pr > |t|	0.4907	0.3141	**0.001**	**0.0068**	0.4823	**0.0001**	0.8885	0.882
Use Full Label Herbicide Rate	**Estimate**	0.35173	-0.2457	0.04977	-0.0231	-0.158	-0.1309	-0.0623	0.00251
	Pr > |t|	**0.0001**	**0.0441**	0.4121	0.6696	**0.0099**	**0.0266**	0.4227	0.9717
Rotating Herbicides Modes Of Action Annually	**Estimate**	0.10405	0.24687	0.07542	0.02256	0.0178	-0.1384	0.03029	-0.012
	Pr > |t|	0.1845	**0.0259**	0.183	0.6535	0.7459	**0.0102**	0.6628	0.8477
Narrow Rows	**Estimate**	0.33058	0.17126	-0.126	0.06839	0.19644	-0.0227	-0.0139	-0.1774
	Pr > |t|	**0.0001**	0.1456	**0.0356**	0.1918	**0.0009**	0.6912	0.8539	**0.0078**

Role of Other Variables:

We can see that age matters for some practices and is negatively related to adoption. This means younger people are more likely to adopt. Risk and patience matter where tolerance of risk is positively, and patience is negatively associated with adoption. This is surprising since practices are thought to have long run payoffs. (Table-6)

Role of Perception Variables:

Coefficients of full tenants and partial owners for practices are found to be consistently significant until the perception variables are introduced in final model. All but one of the tenure variable coefficients lost significance or became less significant after introducing perception variables. This shed light on the contribution of perception variables into decision making and this also means a sizeable portion of adoption decision making is explained by perception variables. Perception variables used in the final model are found to be significant for conservation practices where tenure variables lose significance in the final model. Concern about multiple herbicide weeds matters as well as concern about HR weed mobility from neighbors. We can see positive relation with adoption which means the more concern a farmer has, the more likely he is to adopt a practice. Techno-optimism has been found to be significant at higher levels for all the practices that were previously identified to have significant coefficient for tenure variables. The result is very robust. Techno-optimistic people are less likely to adopt a practice as they are expecting a new technology soon to be discovered and solve all weed problems. Hence, farmer's perception does matter in the adoption of weed management practices. (Table-7)

Role of Techno-optimism:

To test the strength of techno-optimism we ran a new model with all perception variables in place but techno-optimism in model-4 and compared the results of coefficients with model-3. As we can see, the coefficients have a similar significance level with all other perception variables included in the model. However, after introducing Techno-optimism in model-4, we can see that most coefficients lose significance from the new model to model-4. Hence, we can say that tenure status does not matter much but perception variables especially techno-optimism matters a lot. (Table-8).

Table 8: Results from Multivariate Ordered Probit Model-3, Model-4 (Except Techno-optimism) & Model-4

	Practice (Joint Ordered Probit Model)	Full-Tenant	Partial	Full-Tenant	Partial	Full-Tenant	Partial
		Model-3 (Geographic, Demographic, Psychological)	**Model-3 (Geographic, Demographic, Psychological)**	**(Geographic, Demographic, Psychological, and Perception (Except techno-optimism)**	**(Geographic, Demographic, Psychological, and Perception (Except techno-optimism)**	**Model-4 (Geographic, Demographic, Psychological, and Perception)**	**Model-4 (Geographic, Demographic, Psychological, and Perception)**
Non-Chemical	**Tillage**	-0.05194	-0.01841	-0.117574	-0.076191	-0.06433	-0.03958
Planting	**Crop Rotation**	0.14831	0.15114	0.109719	0.152193	0.05058	0.10328
	Narrow Rows	**0.45814****	**0.27555***	0.065116	0.199986	**0.44492***	0.1785
	Pre-emergent Herbicide	0.0334	0.18633	0.521291	0.631316	0.01069	0.09643
	Post-emergent Herbicide	**0.49346***	**0.61338*****	**0.263552****	**0.015212*****	**0.4512~**	**0.57742*****
Herbicide	**Post-Harvest Herbicide**	0.27863	0.01962	0.300217	0.247382	0.24647	0.01569
	Herbicide Mixes	0.37894	**0.27651***	0.534969	**0.37451~**	0.23926	0.15201
	Multiple Herbicides	**0.60994****	**0.39996****	**0.36316****	**0.18478****	**0.47032***	0.2436
	Rotating Herbicides Modes of Action Annually	0.22025	**0.31417****	0.201515	**0.412574****	0.12187	**0.26201~**
	Use Full Label Herbicide Rate	**0.6318****	**0.3236****	**0.465767~**	0.186339	0.34128	0.11596

CHAPTER 5: CONCLUSION

Contrary to conventional hypothesis, it has been found from this study that tenants and partial owners are adopting more weed practices thought to delay herbicide resistance on average compared to full owners. Age, risk, patience, concern about weeds, techno-optimism are found to have the most statistically significant effects. From descriptive statistics, we saw that tenants and partial owners are younger, have greater risk tolerance, show greater concern about herbicide resistant weeds, are less patient, and less techno-optimistic. To check the robustness of these differences, we ran a multinomial logit model with tenure status as dependent variables including rest of the independent variables (Appendix C). We found age, and techno-optimistic to be significant. Tenants and part owners are found to be younger and less techno-optimistic than owners. Therefore, it may be that tenure status is not driving adoption decisions, but that other exogenous variables are influencing both tenure status and adoption. Full owners are less likely to adopt a weed management practices compared with renters and part owners. Full owners account for 70 percent of the US cotton, corn, and soybean farmers, even though they account for a much smaller share of acres planted to these crops. We have found perception variables especially techno-optimism to play a significant role in adoption decision. Also, the influence of extension educators was not found to play a significant role in decision making. In fact, it was even negatively associated with adoption of some practices. Age is found to be important but there is not much that can be done regarding this issue. If we want to see higher adoption level of weed resistance management practices, a useful area of future research would be to better understand which factors cause farmers to possess techno-optimism.

APPENDICES

Appendix A: Simple descriptive statistics of adoption variables for all weed resistance management practices.

Variable	N	Mean	Std Dev	Median	Minimum	Maximum
Post-emergent Herbicide	651	5.39324	1.14309	6	1	6
Use full Label Herbicide Rate	643	5.20995	1.21302	6	1	6
Multiple Herbicides	642	5.12617	1.26687	6	1	6
Herbicide Mixes	646	5.08204	1.28597	6	1	6
Crop Rotation	645	5.03256	1.37317	6	1	6
Pre-emergent Herbicide	655	4.9542	1.56541	6	1	6
Rotating Herbicides modes of action annually	647	4.29521	1.72247	5	1	6
Tillage	638	3.67085	1.95189	4	1	6
Narrow rows	650	3.45538	2.10846	4	1	6
High Seeding Rates	626	2.5607	1.79341	2	1	6
Post-Harvest Herbicide	608	2.28618	1.70579	1	1	6
Hand Weeding	653	2.14089	1.39732	2	1	6
Chose planting Dates to reduce weed competition	646	2.14087	1.63592	1	1	6
Planted Cover crop or Used Mulches	642	1.98131	1.51733	1	1	6
inter-row cultivation	628	1.58439	1.28823	1	1	6
Weed maps	644	1.48137	1.21216	1	1	6

Appendix B: Correlation among adoption variables of all practices.

Pearson Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	inter-row cultivation	**Tillage**	**Crop Rotation**	**Pre-emergent Herbicide**	**Post-emergent Herbicide**	**Post-Harvest Herbicide**	**High Seeding Rates**	**Herbicide Mixes**	**Multiple Herbicides**	**Hand Weeding**	**Use full Label Herbicide Rate**	**Planted Cover crop or Used Mulches**	**Chose planting Dates to reduce weed competition**	**Rotating Herbicides modes of action annually**	**Narrow rows**	**Weed maps**
inter-row cultivation	1	0.2874	-0.01785	0.04118	-0.1245	0.07274	0.08273	-0.03028	-0.02447	0.19699	0.0194	-0.01307	0.08792	-0.04347	-0.09355	0.05072
inter-row cultivation		***0.0001***	0.6582	0.3056	***0.002***	0.0788	0.0426	0.4527	0.5461	***0.0001***	0.6308	0.7458	0.0289	0.2798	0.0196	0.2076
Tillage	0.2874	1	0.09482	-0.09441	0.02736	-0.09422	0.03807	-0.10591	-0.0675	0.04922	0.05488	-0.25309	0.01108	-0.04238	-0.05033	-0.01641
Tillage	***0.0001***		0.0174	0.0179	0.4948	0.0217	0.3483	***0.0082***	0.0936	0.2173	0.1716	***0.0001***	0.7822	0.289	0.2075	0.6823
Crop Rotation	-0.01785	0.09482	1	0.13068	0.04069	0.09685	0.02812	0.09383	0.14511	0.05542	0.11694	0.04893	-0.00302	0.26468	0.10948	0.0609
Crop Rotation	0.6582	0.0174		***0.001***	0.3075	0.0184	0.4879	0.0187	***0.0003***	0.1637	***0.0034***	0.2207	0.9398	***0.0001***	***0.0058***	0.1271

Pearson Correlation Coefficients

Prob > |r| under H0: Rho=0

Number of Observations

	inter-row cultivation	**Tillage**	**Crop Rotation**	**Pre-emergent Herbicide**	**Post-emergent Herbicide**	**Post-Harvest Herbicide**	**High Seeding Rates**	**Herbicide Mixes**	**Multiple Herbicides**	**Hand Weeding**	**Use full Label Herbicide Rate**	**Planted Cover crop or Used Mulches**	**Chose planting Dates to reduce weed competition**	**Rotating Herbicides modes of action annually**	**Narrow rows**	**Weed maps**
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Pre-emergent Herbicide	0.04118	-0.09441	0.13068	1	0.14713	0.06138	-0.00418	0.24282	0.28873	0.23919	0.20763	0.11921	0.03239	0.25351	0.07035	-0.00145
Pre-emergent Herbicide	0.3056	0.0179	***0.001***		***0.0002***	0.1328	0.9174	***0.0001***	***0.0001***	***0.0001***	***0.0001***	***0.0027***	0.4149	***0.0001***	0.0751	0.971
Post-emergent Herbicide	-0.1245	0.02736	0.04069	0.14713	1	0.02315	-0.03433	0.22564	0.26997	0.07547	0.21511	-0.07528	-0.03852	0.1962	0.10078	-0.0077
Post-emergent Herbicide	***0.002***	0.4948	0.3075	***0.0002***		0.5723	0.3958	***0.0001***	***0.0001***	0.0568	***0.0001***	0.0592	0.3329	***0.0001***	0.0109	0.847
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Post-Harvest Herbicide	0.07274	-0.09422	0.09685	0.06138	0.02315	1	0.13189	0.11292	0.04662	0.10234	0.08942	0.11238	0.16779	0.1317	0.03979	0.05512
Post-Harvest Herbicide	0.0788	0.0217	0.0184	0.1328	0.5723		***0.0014***	***0.0057***	0.2566	0.012	0.0292	***0.0059***	***0.0001***	***0.0012***	0.3305	0.1787

Pearson Correlation Coefficients

Prob > |r| under H0: Rho=0

Number of Observations

	inter-row cultivation	**Tillage**	**Crop Rotation**	**Pre-emergent Herbicide**	**Post-emergent Herbicide**	**Post-Harvest Herbicide**	**High Seeding Rates**	**Herbicide Mixes**	**Multiple Herbicides**	**Hand Weeding**	**Use full Label Herbicide Rate**	**Planted Cover crop or Used Mulches**	**Chose planting Dates to reduce weed competition**	**Rotating Herbicides modes of action annually**	**Narrow rows**	**Weed maps**
High Seeding Rates	0.08273	0.03807	0.02812	-0.00418	-0.03433	0.13189	1	0.1033	0.01212	0.0514	0.0119	0.10743	0.26562	0.06608	0.21403	0.18395
High Seeding Rates	0.0426	0.3483	0.4879	0.9174	0.3958	***0.0014***		0.0102	0.7648	0.2016	0.7685	***0.0077***	***0.0001***	0.1005	***0.0001***	***0.0001***
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Herbicide Mixes	-0.03028	-0.10591	0.09383	0.24282	0.22564	0.11292	0.1033	1	0.65587	0.07603	0.24985	0.09705	-0.00549	0.28113	0.10372	0.0185
Herbicide Mixes	0.4527	***0.0082***	0.0187	***0.0001***	***0.0001***	***0.0057***	0.0102		***0.0001***	0.0551	***0.0001***	0.0149	0.8901	***0.0001***	***0.0089***	0.6428
Multiple Herbicides	-0.02447	-0.0675	0.14511	0.28873	0.26997	0.04662	0.01212	0.65587	1	0.10783	0.29081	0.03661	-0.02713	0.32132	0.12494	0.02312
Multiple Herbicides	0.5461	0.0936	***0.0003***	***0.0001***	***0.0001***	0.2566	0.7648	***0.0001***		***0.0066***	***0.0001***	0.3617	0.4966	***0.0001***	***0.0016***	0.5634
Hand Weeding	0.19699	0.04922	0.05542	0.23919	0.07547	0.10234	0.0514	0.07603	0.10783	1	0.10182	0.082	0.12377	0.12206	0.05795	0.09827
Hand Weeding	***0.0001***	0.2173	0.1637	***0.0001***	0.0568	0.012	0.2016	0.0551	***0.0066***		0.0101	0.0387	***0.0017***	***0.002***	0.1425	0.013

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations																
	inter-row cultivation	**Tillage**	**Crop Rotation**	**Pre-emergent Herbicide**	**Post-emergent Herbicide**	**Post-Harvest Herbicide**	**High Seeding Rates**	**Herbicide Mixes**	**Multiple Herbicides**	**Hand Weeding**	**Use full Label Herbicide Rate**	**Planted Cover crop or Used Mulches**	**Chose planting Dates to reduce weed competition**	**Rotating Herbicides modes of action annually**	**Narrow rows**	**Weed maps**
Use full Label Herbicide Rate	0.0194	0.05488	0.11694	0.20763	0.21511	0.08942	0.0119	0.24985	0.29081	0.10182	1	-0.00116	0.04556	0.18539	0.04799	***0.00905***
Use full Label Herbicide Rate	0.6308	0.1716	***0.0034***	***0.0001***	***0.0001***	0.0292	0.7685	***0.0001***	***0.0001***	0.0101		0.9768	0.2523	***0.0001***	0.2272	0.8203
Planted Cover crop or Used Mulches	-0.01307	-0.25309	0.04893	0.11921	-0.07528	0.11238	0.10743	0.09705	0.03661	0.082	-0.00116	1	0.11344	0.03494	0.08226	0.09257
Planted Cover crop or Used Mulches	0.7458	***0.0001***	0.2207	***0.0027***	0.0592	***0.0059***	***0.0077***	0.0149	0.3617	0.0387	0.9768		***0.0043***	0.3798	0.0382	0.0198
Chose planting Dates to	0.08792	0.01108	-0.00302	0.03239	-0.03852	0.16779	0.26562	-0.00549	-0.02713	0.12377	0.04556	0.11344	1	0.14538	0.07524	0.08901

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations																
	inter-row cultivation	**Tillage**	**Crop Rotation**	**Pre-emergent Herbicide**	**Post-emergent Herbicide**	**Post-Harvest Herbicide**	**High Seeding Rates**	**Herbicide Mixes**	**Multiple Herbicides**	**Hand Weeding**	**Use full Label Herbicide Rate**	**Planted Cover crop or Used Mulches**	**Chose planting Dates to reduce weed competition**	**Rotating Herbicides modes of action annually**	**Narrow rows**	**Weed maps**
reduce weed competition																
Chose planting Dates to reduce weed competition	0.0289	0.7822	0.9398	0.4149	0.3329	***0.0001***	***0.0001***	0.8901	0.4966	***0.0017***	0.2523	***0.0043***		***0.0002***	0.0573	0.0247
Rotating Herbicides modes of action annually	-0.04347	-0.04238	0.26468	0.25351	0.1962	0.1317	0.06608	0.28113	0.32132	0.12206	0.18539	0.03494	0.14538	1	0.18786	0.08245
Rotating Herbicides modes of action annually	0.2798	0.289	***0.0001***	***0.0001***	***0.0001***	***0.0012***	0.1005	***0.0001***	***0.0001***	***0.002***	***0.0001***	0.3798	***0.0002***		***0.0001***	0.0378

Pearson Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	inter-row cultivation	**Tillage**	**Crop Rotation**	**Pre-emergent Herbicide**	**Post-emergent Herbicide**	**Post-Harvest Herbicide**	**High Seeding Rates**	**Herbicide Mixes**	**Multiple Herbicides**	**Hand Weeding**	**Use full Label Herbicide Rate**	**Planted Cover crop or Used Mulches**	**Chose planting Dates to reduce weed competition**	**Rotating Herbicides modes of action annually**	**Narrow rows**	**Weed maps**
Narrow rows	-0.09355	-0.05033	0.10948	0.07035	0.10078	0.03979	0.21403	0.10372	0.12494	0.05795	0.04799	0.08226	0.07524	0.18786	1	0.14081
Narrow rows	0.0196	0.2075	***0.0058***	0.0751	0.0109	0.3305	***0.0001***	***0.0089***	***0.0016***	0.1425	0.2272	0.0382	0.0573	***0.0001***		***0.0003***
Weed maps	0.05072	-0.01641	0.0609	-0.00145	-0.0077	0.05512	0.18395	0.0185	0.02312	0.09827	***0.00905***	0.09257	0.08901	0.08245	0.14081	1
Weed maps	0.2076	0.6823	0.1271	0.971	0.847	0.1787	***0.0001***	0.6428	0.5634	0.013	0.8203	0.0198	0.0247	0.0378	***0.0003***	

Appendix C: Results from Multinomial Logit Model using Tenure variables as dependent variables with Geographic dummies, Demographic, Psychological, Perception as explanatory variables

Analysis of Maximum Likelihood Estimates							
					Standard	Wald	
Parameter		Tenure	DF	Estimate	Error	Chi-Square	Pr > ChiSq
Intercept		2	1	0.989	1.9217	0.2649	0.6068
Intercept		3	1	-5.4486	75.4478	0.0052	0.9424
SoPlains		2	1	-0.8266	0.522	2.5071	0.1133
SoPlains		3	1	0.52	0.69	0.5679	0.4511
NoPlains		2	1	-0.5309	0.3721	2.0352	0.1537
NoPlains		3	1	-0.4131	0.6035	0.4685	0.4937
MidSou		2	1	-0.4991	0.4423	1.2735	0.2591
MidSou		3	1	0.9299	0.5942	2.4494	0.1176
Delmarva		2	1	0.9377	0.7402	1.6047	0.2052
Delmarva		3	1	1.332	1.0714	1.5457	0.2138
SoWest		2	1	11.348	815.9	0.0002	0.9889
SoWest		3	1	14.4841	815.9	0.0003	0.9858
Lake		2	1	-0.04	0.4004	0.01	0.9204
Lake		3	1	-0.7358	0.8746	0.7078	0.4002
SoEast		2	1	0.7369	0.5641	1.7065	0.1914
SoEast		3	1	1.2725	0.7837	2.6363	0.1044
age2		2	1	-0.0563	0.0128	19.3693	***0.0001***
age2		3	1	-0.098	0.0168	33.9429	***0.0001***
ethnicity2	1	2	1	0.2927	0.691	0.1795	0.6718
ethnicity2	1	3	1	-0.1307	0.888	0.0217	0.883
Gender	1	2	1	2.661	0.9719	7.4956	***0.0062***
Gender	1	3	1	9.9326	75.4138	0.0173	0.8952
risk		2	1	-0.0387	0.0669	0.3336	0.5635
risk		3	1	0.0234	0.0984	0.0567	0.8118
paitence		2	1	-0.1185	0.0601	3.8794	***0.0489***
paitence		3	1	-0.0798	0.0866	0.8506	0.3564
amount_of_acres2		2	1	0.00176	0.000288	37.5864	***0.0001***
amount_of_acres2		3	1	0.00156	0.000305	26.0994	***0.0001***
Concern_about_multip		2	1	0.2602	0.1712	2.3107	0.1285
Concern_about_multip		3	1	0.3216	0.2608	1.521	0.2175
Communicate_with_nei		2	1	-0.2287	0.2779	0.677	0.4106
Communicate_with_nei		3	1	-0.0648	0.4046	0.0257	0.8727
Concern_Neigh		2	1	-0.0737	0.1301	0.3215	0.5707

Analysis of Maximum Likelihood Estimates							
					Standard	Wald	
Parameter		Tenure	DF	Estimate	Error	Chi-Square	Pr > ChiSq
Concern_Neigh		3	1	-0.2681	0.1864	2.0679	0.1504
Influence_of_extensi		2	1	0.1455	0.1149	1.6034	0.2054
Influence_of_extensi		3	1	-0.0288	0.161	0.032	0.8581
Influence_of_other_g		2	1	0.0733	0.1211	0.366	0.5452
Influence_of_other_g		3	1	-0.0798	0.1748	0.2085	0.648
techno_optimism2		2	1	-0.3598	0.1263	8.1114	***0.0044***
techno_optimism2		3	1	-0.45	0.1867	5.8117	***0.0159***
Natural_Environment2		2	1	0.0294	0.1623	0.0327	0.8564
Natural_Environment2		3	1	0.2719	0.2423	1.259	0.2618
Commmunitiy_ties2		2	1	0.0684	0.1578	0.1878	0.6647
Commmunitiy_ties2		3	1	-0.017	0.2285	0.0056	0.9406

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