

Optimal Prevented Planting Decisions for Corn and Cotton

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ABSTRACT

Federal crop insurance programs have a prevented planting provision that can protect producers from financial losses and risk associated with delayed planting, but growing concerns about moral hazard in this provision has recently led to prevented planting coverage factor reductions. However, little is known about the likelihood of moral hazard in prevented planting and how this provision change impacts this possibility. The objective of this study was to find the prevented planting option a profit-maximizing and risk-averse corn or cotton producer would prefer. We also determine the likelihood of ex-post moral hazard. If a producer claims prevented planting, they have three planting options to consider, or the producer can take the full prevented planting indemnity payment. History shows that over 99% of the time, producers are choosing the full prevented planting payment. If a producer chooses the full prevented planting indemnity payment over a more profitable planting option, that is considered ex-post moral hazard. Net returns for the prevented planting options were calculated using enterprise budgets, and simulations were conducted to compare the distribution of net returns. We examined how a corn and cotton producer's optimal decision would change according to insurance policy, insurance coverage, and prevented planting coverage factor. A profit-maximizing, risk-neutral corn and cotton producer with revenue protection (RP) or yield protection (YP) would choose a 35% prevented planting indemnity payment for the first crop and plant uninsured soybeans at almost all insurance coverage levels. Only a cotton producer with 80% YP would choose the full prevented planting indemnity payment. A producer with higher insurance coverage was found to have a higher probability of ex-post moral hazard. We found as a producer's risk aversion level increases, abandoning the crop for the full prevented planting indemnity payment was preferred. Also, with the reduced prevented planting coverage factor, a producer would need to be more

risk averse to switch their decision to the full prevented planting indemnity payment option.

Reductions in the prevented planting coverage factors will likely reduce ex-post moral hazard for profit-maximizing and risk-averse producers.

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CHAPTER I: INTRODUCTION AND PROBLEM IDENTIFICATION

Crop yields decline as planting is prolonged beyond the optimal planting period (Lauer et al. 1999; Darby and Lauer 2002; Pettigrew, Molin, and Stetina 2009; Boyer et al. 2015), making planting date one of the least expensive but highest returning decisions for a producer (Egli and Cornelius 2009; Hu and Wiatrak 2012). Several factors such as weather, soil temperature, and machinery capacity and availability can delay planting in a given year (Egli and Cornelius 2009). Federal crop insurance programs have a prevented planting provision that can protect producers from the financial losses and risk associated with delayed planting (United States Congress 1994). Revenue Protection (RP), Revenue Protection with the Harvest Price Exclusion (RP-HPE), Yield Protection (YP), and Area Risk Protection Insurance (ARPI) policies pay indemnities if producers were unable to plant the insured crop by a designated final planting date or within any applicable late planting period due to natural causes (typically drought or excess moisture) (United States Department of Agriculture (USDA) Federal Crop Insurance Corporation (FCIC) 2017). Indemnity payments are determined by the yield or revenue guarantee for a producer's insurance policy. Important producer decisions that determine the revenue or yield guarantee are: unit structure, coverage level, and Actual Production History (APH). The final planting date is the last day a producer can plant the insured crop and obtain the full guarantee specified by their insurance policy. The late planting period is generally a maximum of 25 days after the final planting date depending on the crop.

The prevented planting provision gives producers several options if they were unable to plant the insured crop by the final planting date. The originally insured crop could be planted during the late planting period but the producer's production guarantee would decrease 1% per day after the final planting date until the crop is planted. For example, a policy with 60%

coverage would be reduced to 54% if planting occurs 10 days into the late planting period (60% - (10 days x 1% x 60%). Conversely, the producer could leave the acreage unplanted and receive the full prevented planting indemnity payment, which is equal to the original production guarantee multiplied by the prevented planting coverage factor which varies by crop (50% to 60% for corn, cotton, and soybeans). This option requires leaving the land fallow or planting a summer cover crop after the late planting period that cannot be harvested or grazed before November 1st. This option does not impact the producer's APH, a 4 to 10-year, unit specific, average yield used for crop insurance purchases. The third option is to plant an uninsured later season crop after the late planting period and receive a prevented planting indemnity payment equal to 35% of the full prevented planting indemnity payment. Finally, a producer could switch their crop insurance coverage to a later season crop if they are still in the defined planting window for that crop.

While the prevented planting provision reduces producers' risk, increases in indemnity payments over the last two decades have triggered investigations into producer prevented planting claims and coverage factors by crop (Rejesus et al. 2003; Rejesus, Escalante, and Lovell 2005; USDA Office of Inspector General (OIG) 2013). A 2013 audit by the USDA OIG (2013) found that prevented planting indemnities paid producers \$480 million more than their estimated losses from 2008-2011, and less than one percent of the producers were replanting or planting a second crop. The prevented planting indemnity payment is designed to be equal to a producer's costs-to-date expenses (USDA Risk Management Agency (RMA) 2018d). It is likely that fraud and moral hazard would be more common if the prevented planting indemnity payment exceeds the costs-to-date expenses. Rejesus et al. (2003) and Rejesus, Escalante, and Lovell (2005) stated the prevented planting indemnity payment can exceed the costs-to-date invested in the crop

which could encourage ex-post moral hazard. Insurance fraud is an illegal activity; therefore, this study will only focus on how to prevent moral hazard in prevented planting.

Moral hazard in prevented planting exists when an insured producer chooses to not produce a crop and take the full prevented planting indemnity payment, despite planting during the late planting period or switching crops being more profitable options (i.e., ex-post moral hazard).

In 2017, the USDA RMA decreased the prevented planting payment coverage factor for corn from 60% to 55% and suggested adjustments to other crop coverage factors were coming in the future (USDA RMA 2018d). Research is needed to determine if changes in the coverage factor influences the likelihood of moral hazard in prevented planting. Moreover, this research is particularly vital for the southeastern United States where producers have a diverse crop selection with varying planting windows. The top three spring planted crops in terms of acres, excluding hay, in this region are corn, cotton, and soybeans (USDA National Agricultural Statistics Service (NASS) 2018a), and the majority of these acres are insured with RP and YP coverage (USDA FCIC 2019). The USDA RMA (2018a) defined planting window in this region for corn ranges from March 21st to May 20th, before May 20th for cotton, and April 16th to June 15th for soybeans. Therefore, if a producer was unable to plant corn or cotton, soybeans is a viable second crop since the soybean planting window is after the corn and cotton planting window. The results will provide insight to crop insurance policy makers on further adjustments to prevented planting provisions to limit moral hazard and can educate producers on making optimal decisions if they are unable to plant.

Research Objectives

The objectives of this study are to compare the net returns and variability of net returns for the four prevented planting options available for a corn and cotton producer assuming soybeans as a viable second crop. We determine the optimal prevented planting option using the current prevented planting coverage factor at three RP and YP coverage levels. We also show how reductions in the prevented planting coverage factor would change the optimal selection.

CHAPTER II: LITERATURE REVIEW

Yield Response to Planting Date

Licht and Rees (2017) determined if optimal planting date varies by corn varieties using data from Iowa farms throughout the entire state during 2014 to 2016. Three different corn varieties were planted on April 15th, May 10th, June 5th, and June 30th. The results showed that the yields were maximized at the first planting date and declined at each of the following dates for all varieties. The first two planting date yields were significantly higher than the last two planting dates suggesting that the yield maximizing planting window was from April 15th to May 10th. They also found that switching varieties based on crop maturity time for early or late planting dates did not significantly impact yield.

Lauer et al. (1999) investigated the optimal planting date to maximize corn grain yield in Northern and Southern Wisconsin using data from 1991 to 1994, and Darby and Lauer (2002) researched the optimal planting date to maximize corn forage yield in Northern and Southern Wisconsin using data from 1998 and 1999. The planting dates ranged from mid-April to late-June. Both studies used a quadratic functional form to model yield response to planting date. Lauer et al (1999) found that the optimal planting window for corn harvested for grain in Southern Wisconsin was May 1st to May 7th and May 8th to May 14th for the northern region. Darby and Lauer (2002) found that the optimal planting date for corn forage in the Southern region was May 10th and May 7th for the Northern region. Darby and Lauer (2002) recommend that corn producers in Southern Wisconsin plant corn for grain before corn for forage, and corn producers in the Northern region plant corn for forage before corn for grain.

Abendroth et al. (2017) used data from six Iowa farms to determine the yield maximizing planting windows for corn. The experiment treatments were five planting dates ranging from April 1st to June 1st. A quadratic yield response function was used to estimate the expected yields at planting dates throughout the year. Optimal planting dates for the different locations were then found, and the yield at the optimal planting date was considered 100% of the expected yield. Planting windows were then created for different regions of Iowa where producers should expect yields of 98% - 100% of their expected yields. The yield maximizing planting window for North-central and Northeast Iowa was April 12th to April 30th, Northwest and Central Iowa was April 15th to May 9th, and Southwest and Southeast Iowa was April 17th to May 8th. Therefore, the optimal corn planting window for Iowa was April 12th to May 9th.

Bruns and Abbas (2006) evaluated the effect of planting date on different hybrids of corn in the Mid-South United States. They used field data from Stoneville, Mississippi from 2002 to 2004. A total of 12 different corn hybrids were planted in early-April, late-April, and mid-May. The highest yields occurred at the early-April and late-April planting dates, and yields started to significantly decline at planting dates after April 20th. They also found no significant difference in planting dates and hybrid interactions.

Kucharik (2008) used USDA NASS data from 1979 to 2005 to determine how changes in planting windows impacted yields using climate data. The study found that beginning planting date has been getting earlier over the years, which has increased yields by 19% to 53% in North-central and West-central United States. Also, climate changes were not a significant cause of earlier planting.

Nafziger (1994) tested how corn yields responded to planting date, plant population, and hybrid type. Field experiment data was used from Northern Illinois from 1987 to 1990. Two corn

hybrids were used at four planting dates between mid-April and late-May. The results show that the optimal planting window for Northern Illinois was April 16th to May 11th with April 27th being the optimal planting date. This research also showed no significant interaction between planting date, hybrid, and plant population.

Swanson and Wilhelm (1996) researched if later corn planting could overcome yield loss due to cool soil temperatures and surface residues. They used data from Lincoln, Nebraska in 1986 and 1987. Four surface residue application rates were used at numerous planting dates between late-April and early-June. A quadratic yield response function was estimated. No interaction between planting date and surface residue was found, suggesting that planting date does not matter when it comes to residue effects. The optimal planting date was found to be May 9th with yields declining at a faster rate after the optimal planting date than before the optimal planting date.

For cotton, Pettigrew, Molin, and Stetina (2009) examined how cotton lint yields were impacted by early and normal planting using minimum tillage. They used data from Stoneville, Mississippi during 2004 to 2007. The early planting dates were April 2nd, April 3rd, and April 5th, and the normal planting dates were May 1st, May 3rd, and May 4th. They observed that lint yield was 168 lb/acre and 196 lb/acre higher for early planting in 2004 and 2007, respectively. In 2005 and 2006, there was no significant difference in early and normal planting.

Anapalli et al. (2016) used cotton planting date experiments at Stoneville, Mississippi from 2005 to 2008 and long-term weather data to determine optimal planting windows. They used an agricultural system model that simulated cotton yields during the planting window of March 1st to July 12th. The results showed that early planting had a slightly higher average yield

with a lower average standard deviation. The planting window that maximized lint yield was mid-March to the last week of May.

Wrather et al. (2008) determined the effects of plant population and planting date on cotton yields in the Mississippi Delta region. Data came from an experiment conducted at Portageville, Missouri (southeast Missouri) from 2001 to 2005. Multiple planting dates were tested ranging from April 28th to June 2nd with different plant populations. The results showed that the highest cotton yields came from late-April to early-May planting. Also, there was no significant difference in yields with planting more plants per acre, thus, they conclude a plant population between 13,750 and 27,500 plants per acre is optimal for yield maximization.

Adams et al. (2013) studied how cotton yield loss from the tarnished plant bug could be reduced by planting date and variety choice. To determine this, an experiment was done at Stoneville, Mississippi in 2010 and 2011. They used early and late maturing varieties at planting dates from April 14th to June 2nd. Half of the plots were treated for the tarnished plant bug and half were not. Weekly samples were taken from the plots to estimate the tarnished plant bug population on each plot. The results showed that mid-April had the highest yields for both cotton varieties on all sprayed or unsprayed plots. All sprayed plots had higher yields than unsprayed plots. From the samples, they were able to conclude that early planting had less yield loss from the tarnished plant bug, which results in less insecticide used in production. They also found that the earlier maturing variety yielded more than the late maturing variety. The study suggests that producers should plant an early maturing variety at an early date to avoid yield loss from the tarnished plant bug.

O'Berry et al. (2008) used cotton field experiments from Virginia, North Carolina, and Louisiana in 2005 and 2006 to examine how plant population and planting date impact cotton

yield, growth, and quality. They found that early planting resulted in higher yields for Louisiana, but there was no significance for yield response to planting date for Virginia and North Carolina. Louisiana recorded a greater number of heat units than Virginia and North Carolina, indicating that early planting will maximize yields in areas with higher temperatures. They also found that in areas with higher temperatures such as Louisiana, a lower plant population of 22,662 to 38,445 plants per acre will maximize yields.

Boquet and Clawson (2009) determined the optimal cotton planting window in the Mid-South United States. They use field experiment data from Winnsboro, Louisiana from 2002 to 2005. Eight different cultivars were tested at planting dates from March 25th to June 5th. They found that the planting window from April 15th to May 15th maximized yields, and that planting mid-April will most likely produce greater yields than planting at mid-May. They also found that planting before April 15th can produce high yields but were not consistent year-to-year.

Finally, for soybeans, Steele and Grabau (1997) tested 12 soybean cultivars at four planting windows to evaluate the cultivar performance when planted in a region south of their traditional region. They used field trials conducted in Fayette County, Kentucky in 1993 and 1994. They found that the yield maximizing planting date in this region was mid-June, and the period that produced the worst yields was mid-July. Also, they concluded that early maturing, northern cultivars produce greater yields when planted at early planting dates in southern regions.

Egli and Cornelius (2009) looked at previous soybean planting date experiments in the Midwest, Upper South, and Deep South regions to determine the planting date when yields started to decline. They also studied if there is an advantage for April planting or early May planting. The results showed that soybean yields in the Upper South were relatively consistent

until June 7th, then yields started to decline about 1.1% per day. Yields in the Midwest declined 0.7% per day starting on May 30th, and yields in the Deep South decreased by 1.2% per day starting on May 27th. Due to consistency in yields in the Upper South and Midwest, they found no significant difference in April and early May planting. However, they found that early planting decreased yields for the Deep South region.

Hu and Waitrak (2012) reviewed the literature to prove that delayed soybean planting has negative effects on the crop. They found that higher temperatures and less precipitation are associated with late planting which should incentivize farmers to early plant. These environmental factors cause significant yield loss in late planting by reducing photosynthesis and growth stages.

Chen and Wiatrak (2010) studied the difference that early and late soybean planting have on the plant development stages and yield. They used data from a 2008 and 2009 experiment in South Carolina. The field experiments were conducted at seven planting dates ranging from late-April to mid-July. They found that earlier planting dates were more likely to lengthen development stages, which leads to greater yields. They suggest a planting window from early-May to mid-May for the Southeastern Coastal Plain to maximize yields.

Salmeron et al. (2014) evaluated how different combinations of planting dates and maturity groups could affect yields of irrigated soybeans in the Mid-South United States. Their data came from eight locations in 2012 and 10 locations in 2013 from different latitudes across the Mid-South. Four planting dates ranging from late-March to early-July and four maturity groups were used for the experiment. They used a general linear mixed model to analyze the data and found that early planting typically leads to greater yields, which suggests that maturity group selection should be given considerable attention when producers have a specific planting

window. They also found that over 20% of soybean yield variability was caused by the genotype and environment interaction.

Boyer et al. (2015) investigated the profit maximizing planting dates of soybeans in Tennessee. A quadratic yield response to planting date function was estimated using field experiment data collected at Milan, Tennessee. The profit-maximizing planting dates ranged from May 13th to May 24th depending on the maturity group. Table 1 summarizes all of the yield response to planting date literature by crop.

Prevented Planting in Southeast

In the Southeastern United States, crop insurance is a highly used tool to manage risk. Based on data from the USDA Farm Service Agency (FSA) (2017), this region frequently has land designated as prevented planting acres (Figure 1) (Newton 2015). Starting in Louisiana and moving north along the Mississippi River, Arkansas, Mississippi, Tennessee, Kentucky, and Missouri have a significant amount of land that is frequently designated as prevented planting acres. Figure 2 shows the average reported prevented planting acres in this region from 2013 to 2017 (USDA FSA 2017). Acres designated as prevented planting for these commodities in this region accounted for 33% of all prevented planting acres in the United States from 2013 to 2017 (USDA FSA 2017). However, no publically available data exists on what happens to these acres after the land is indemnified. Thus, this region is relevant to test the proposed revision to the prevented planting provision.

Moral Hazard in Prevented Planting

Moral hazard occurs when the insured individual becomes less inclined to protect against indemnified outcomes due to the protection provided by the insurance. Typically, moral hazard

in crop insurance occurs before the loss has happened (i.e., *ex ante* moral hazard), such as under-applying chemicals and fertilizer during the production year, knowing they are covered from losses (Horowitz and Lichtenberg 1993; Babcock and Hennessy 1996; Smith and Goodwin 1996; Miranda and Glauber 1997; Coble et al. 1997; Sheriff 2005; Roberts, Key, and O'Donoghue 2006). Moral hazard in prevented planting differs from these studies because a producer's decision to continue with planting during the late planting period or not produce a crop occurs after the loss, which is referred to as ex-post moral hazard (Rees and Wambach 2008; Zweifel and Eisen 2012; Kim and Kim 2018).

Kim and Kim (2018) defined ex-post moral hazard in prevented planting as selecting the full prevented planting indemnity payment over late planting or planting any second crop. This is a problem for the Government and (maybe society overall), because this contradicts several USDA goals (USDA 2018). Clearly, choosing the inefficient option of abandoning cropland and forgoing production is in direct violation to Strategic Goals 1 and 2. Strategic Goal 1 is to ensure USDA programs are delivered efficiently, effectively, and with integrity and a focus on customer service, and Strategic Goal 2 is to maximize the ability of producers to prosper by feeding and clothing the world (USDA 2018). Given the related activities and overall impact of farming on rural communities, it could even be argued that the current preventive planting program violates Strategic Goal 4 to facilitate rural prosperity and economic development.

In our review of literature, Kim and Kim (2018) was the only study that examined ex-post moral hazard in prevented planting. Their objective was to prove that higher insurance coverage results in more prevented planting claims and ex-post moral hazard. They set up indemnity payment equations for both RP and YP and found that they were the same as long as projected price was higher than harvest price and if producers chose 100% price election for YP.

Therefore, they assumed RP and YP indemnity payment to be the same. Then, they used a spatial econometric model to see how the ratio of prevented planting claims to premium policies was effected by insurance coverage level. They found the current prevented planting provision was likely encouraging corn producers to abandon their crop and take the prevented planting indemnity payment, promoting ex-post moral hazard. Furthermore, the study indicated the likelihood of ex-post moral hazard increased when insurance coverage levels increased. Kim and Kim (2018) only examined late planting verses taking the full prevented planting indemnity payment for Midwest corn production, and did not consider switching to a second crop.

While this study is insightful, further analysis is needed to determine how changes in the prevented planting coverage factor, producer insurance coverage, and producer risk preference could affect ex-post moral hazard for corn and cotton producers. Using agronomic data to evaluate ex-post moral hazard in prevented planting would build on these studies as well as provide a base for exploring potential policy changes to the prevented planting provision that would minimize the likelihood ex-post moral hazard.

CHAPTER III: CONCEPTUAL FRAMEWORK

Net Returns

If a corn or cotton producer is confronted with prevented planting due to weather, the producer must choose to plant their original crop late, switch to planting soybeans with or without the prevented planting indemnity payment for the first crop, or accept the full prevented planting indemnity payment. This is a complex decision that depends on several factors. A risk neutral, profit-maximizing producer would select the prevented planting option that maximizes net returns, which is a function of prices and yield expectations given an uncertain planting date. Enterprise budgets were used to calculate net returns for corn and cotton producers that are confronted with these options during late planting.

The first option to consider is planting the original crop during the late planting period with RP or YP. Net returns were calculated as

$$(1) \quad NR_{ijk}^{LP} = \max \left(p_i y_i(PD_i), p_{ij}^{gp} y_i^{APH} (\delta_k - 0.01 \delta_k (PD_i - FPD_i)) \right) - c_i^{bp} - c_i^{ap} - IP_{ij}(\delta_k)$$

where NR_{ijk}^{LP} is expected net returns (\$/acre) from planting the i th crop (i = corn or cotton) during the late planting period with j th insurance protection (j = RP or YP) and k th insurance coverage level (k = 60%, 70%, and 80%); p_i is marketing year average price received by Tennessee producers reported by NASS; $y_i(PD_i)$ is expected yield as a function of Julien planting date (PD_i) where January 1st is equal to day one; p_{ij}^{gp} is the guaranteed price used for insurance payments (RP uses the higher of harvest and projected price, and YP uses projected price (USDA RMA 2018c)); y_i^{APH} is the producer's APH yield; δ_k is the insurance coverage level; FPD_i is the final planting date (Julien day); c_i^{bp} is the expected production cost before planting; c_i^{ap} is the

expected production cost after planting; and $IP_{ij}(\delta_k)$ is the insurance premium for basic units in Gibson county, Tennessee and is a function of insurance coverage level. The max function indicates that the net returns are bounded on the lower end of the distribution by the revenue or yield guarantee. Costs are divided into before and after planting costs because not all options will have an after planting cost. Since corn and cotton have a 15-day late planting period, $(PD_i - FPD_i)$ must be between zero and fifteen.

The second prevented planting strategy is to leave the acreage unplanted and receive the full prevented planting indemnity payment. The net returns for this option are defined as

$$(2) \quad NR_{ijk}^{FP} = p_{ij}^{gp} y_i^{APH} \delta_k \theta_i - c_i^{bp} - IP_{ij}(\delta_k)$$

where NR_{ijk}^{FP} is the expected net returns (\$/acre) from taking the full prevented planting indemnity payment (\$/acre); θ_i is the prevented planting coverage factor. The current coverage factor for corn and cotton is 55% and 50% respectively (USDA RMA 2018a). We also explore how lowering the coverage factor by 10% (45% for corn and 40% for cotton) impacts the optimal decision.

If the first crop cannot be planted by the final planting date, uninsured soybeans can be planted after the original crop's late planting period, and 35% of the original prevented planting indemnity payment can be received by the producer for the first crop. Net returns for this option is shown by

$$(3) \quad NR_{isjk}^{US} = [\lambda p_{ij}^{gp} y_i^{APH} \delta_k \theta_i - c_i^{bp} - \lambda IP_{ij}(\delta_k)] + [p_s y_s(PD_s) - c_s^{bp} - c_s^{ap}]$$

where NR_{isjk}^{US} is the expected combined net returns (\$/acre) for the i th crop and soybeans (s); λ is 35% which is the amount of the original prevented planting indemnity payment received and portion of the producer premium that must be paid; p_s is the market price for soybeans (\$/bu); $y_s(PD_s)$ is the expected yield (bu/acre) at the planting date.

The final strategy is to forgo planting the original crop and plant a second crop, such as soybeans, under insurance. This requires the producer to change their insurance coverage from corn or cotton to soybeans. Net returns for this option is calculated by

$$(4) \quad NR_{isjk}^{IS} = -c_i^{bp} + \max\left(p_s y_s(PD_s), p_{sj}^{gp} y_s^{APH}(\delta_k - 0.01\delta_k(PD_s - FPD_s))\right) - c_s^{bp} - c_s^{ap} - IP_{sj}(\delta_k)$$

where NR_{isjk}^{IS} is the expected combined net returns (\$/acre) from planting insured soybeans. If soybean planting date is before the soybean final planting date, then $(PD_s - FPD_s)$ will be set equal to zero. Soybeans have a 20-day late planting period; therefore, $(PD_s - FPD_s)$ can be no higher than 20.

Figure 3 shows an example of a producer's expected net returns for all four options with RP or YP. The expected net returns of the crops are decreasing as planting is prolonged demonstrating that late planting generally causes decreases in yields. For example, expected net returns for the late planting option are greater at day 141 than at day 155. The net returns for the prevented planting indemnity payment for corn or cotton is constant throughout the late planting period. The other two options of planting uninsured soybeans and insured soybeans are also displayed in Figure 3. The insurance coverage for all crops is also constant until the producer plants during the late planting period of that crop, where the production guarantee will start to decrease 1% per day. Any one of these options could maximize profits depending on the planting date, type of insurance protection, insurance coverage level, and prevented planting coverage factor.

Variability of Net Returns

Another important component to consider when selecting an optimal prevented planting option is how production risk, yield variability, and price uncertainty can impact the variability of net returns (i.e., risk exposure). This study will only estimate yield variability using agronomic data, as it is hard to predict future price movements. Considering this risk and producer's risk preferences in selecting the optimal prevented planting option changes the framework from profit maximization to utility maximization, which is defined as $U(\tilde{NR}, r)$ where $\tilde{NR}$ are uncertain net returns and r is the producer's risk preference level (Hardaker et al. 2004). This study analyzes the optimal prevented planting decision for a profit maximizer at different risk preference levels. We will adjust the full prevented planting indemnity payment coverage factor as well as the insurance coverage to examine how those changes will affect a risk-neutral and risk-averse producer's decision.

CHAPTER IV: MATERIALS AND METHODS

Data

Planting Date

The data used in this study came from a non-irrigated, planting date experiment for corn, cotton, and soybeans in Milan, Tennessee. The corn experiments were conducted from 2010 to 2014. Four replications of planting were done at 29 different planting dates with some planting dates being tested in multiple years. The corn planting dates started March 3rd and ended on June 20th. There were a total of 136 useable observations. Six planting windows between March 3rd and June 20th were created with average yields for each planting window shown in Table 2. Cotton experiments were conducted from 2008 to 2012 with six different planting dates. A total of 960 experiment observations were collected. The planting dates were April 14th, April 21st, May 1st, May 15th, June 1st, and June 15th. The average yield over all the years was 1,124 lb/acre (Table 2). The soybean data were from experiments conducted from 2008 to 2010 with six different planting windows ranging from April 17th to August 10th. There were a total of 641 observations. The average yield of all observations was approximately 44 bu/acre (Table 2).

Budget

Table 3 shows the prices, costs, and crop insurance data used in this study. We collected and used this data from 2011 to 2017, because this was the available time frame of crop insurance data. Market price was determined using the marketing year average prices received by Tennessee producers from 2011 to 2017 for corn, cotton, and soybeans. These prices were

\$4.81/bu for corn, \$0.73/lb for cotton, and \$11.31/bu for soybeans (USDA NASS 2018b).

Production costs were the average costs from 2011 to 2017 from the University of Tennessee field crop budgets for no-till, non-irrigated corn, cotton, and soybeans (University of Tennessee Department of Agricultural and Resource Economics 2018). Production costs before planting include land rent and the chemical and machinery costs for burndown and pre-emerge herbicides. If prevented from planting, fertilizer and seed costs are assumed to have not been incurred. Production costs after planting are all costs not included in before planting costs.

Average RP and YP insurance premiums were estimated for Gibson County, Tennessee from 2011 to 2017 using the USDA RMA cost calculator (2018b) for 60%, 70%, and 80% coverages with basic unit structure. Gibson County was selected because this was the location where the agronomic data were collected. The projected price is the spring crop insurance price, and the harvest price is the harvest crop insurance price. Revenue protection crop insurance uses the greater of projected price and harvest price, and yield protection crop insurance only uses projected price (USDA RMA, 2018c). The average projected price was greater than the average harvest price in Tennessee from 2011 to 2017; therefore, we used the projected price to estimate all insurance indemnity payments. The projected prices for corn, cotton, and soybeans were \$4.85/bu, \$0.82/lb, and \$11.29/bu, respectively. The averages of the crop yields in the data set were used for the APH yields.

Data in table 3 and Equation (2) were used to calculate the full prevented planting indemnity payment by crop, protection coverage, insurance coverage level, and prevented planting coverage factor, and the expected net returns from this payment are shown in Table 4. Net returns were calculated using the current prevented planting coverage factors of 55% for

corn and 50% for cotton as well as when these coverage factors were decreased by 10% for each crop (USDA RMA 2018a).

Methods

Statistical Analysis

To reflect yield loss due to late planting, a quadratic response function is used to estimate the yield response to planting date, which is a common approach in the literature (Swanson and Wilhelm 1996, Lauer et al. 1999, Epplin, Hossain, and Krenzer Jr. 2000, Darby and Lauer 2002, Hossain, Epplin, and Krenzer Jr. 2003, Boyer et al. 2015, Abendroth et al. 2017). The yield response to planting date was estimated for corn, cotton, and soybeans using

$$(5) \quad y_t = \beta_0 + \beta_1 PD + \beta_2 PD^2 + z_t + e_t$$

where y_t is the yield in year t ; β_0 , β_1 , and β_2 are coefficients to be estimated; PD is the Julian planting date; $z_t \sim N(0, \sigma_z^2)$ is the random year effect; and $e_t \sim N(0, \sigma_e^2)$ is the error term.

Maximum likelihood was used to estimate the model in the MIXED procedure in SAS 9.4 (SAS Institute 2013). A likelihood ratio test was used to test the yields for heteroscedasticity with respect to year. If heteroscedasticity was present, the results for the model that adjusts for the unequal variances by year are reported. Equation (5) is substituted into the net returns equations (1), (3), and (4) to estimate net returns for the three planting options. These estimates are then compared to the expected net returns for the full prevented planting indemnity payment option as specified by equation (2).

Simulation

We conduct Monte Carlo simulations to estimate distributions of net returns for each prevented planting option by crop, insurance coverage level, and prevented planting coverage factor for both RP and YP. Yield variability was considered by randomly assigning parameter estimates for the yield response to planting date function, equation (5). The response parameters were drawn from the multivariate normal (MVN) distribution:

$$(6) \quad \begin{bmatrix} \tilde{\beta}_0 \\ \vdots \\ \tilde{\beta}_2 \end{bmatrix} \sim MVN \left(\begin{bmatrix} \hat{\beta}_0 \\ \vdots \\ \hat{\beta}_2 \end{bmatrix}, \begin{bmatrix} \hat{\sigma}_{\beta_0}^2 & \cdots & \hat{\rho}_{\beta_0, \beta_2} \hat{\sigma}_{\beta_0} \hat{\sigma}_{\beta_2} \\ \vdots & \ddots & \vdots \\ \hat{\rho}_{\beta_2, \beta_0} \hat{\sigma}_{\beta_2} \hat{\sigma}_{\beta_0} & \cdots & \hat{\sigma}_{\beta_2}^2 \end{bmatrix} \right)$$

where “ $\sim$ ” denotes a randomly drawn parameter from the MVN distribution; the mean of the distribution is the vector of the estimated yield response function coefficients $[\hat{\beta}_0, \dots, \hat{\beta}_2]$; $\hat{\sigma}_{\beta_0}^2$ are variance estimates of the parameters; and $\hat{\rho}_{ab} \hat{\sigma}_a \hat{\sigma}_b$ are estimated covariances between the parameters. Rho (ρ) is the correlation coefficient in the four-by-four covariance matrix of parameters. This method of considering production risk has been successfully used for crop yield response functions (Harmon et al. 2017; Boyer et al. 2018).

Simulation and Econometrics to Analyze Risk (SIMETAR©) was used to derive the expected net return distributions and perform the simulations (Richardson et al. 2008). A total of 5,000 net return observations for each prevented planting option were simulated for each scenario. A total of 12 scenarios were simulated (two types of insurance protection x three insurance coverage levels x two prevented planting coverage factors) for each crop. For each scenario, we compare the planting options’ distribution of net returns to the corresponding full prevented planting indemnity payment, which is shown in Table 4, to find the probability of the planting options having greater net returns than the corresponding full prevented planting indemnity payment.

Risk Analysis

For the risk analysis, we compare the cumulative distribution function (CDF) of net returns for all scenarios using stochastic dominance. This allowed us to compare the four prevented planting options within each insurance coverage level at a given prevented planting coverage factor. This comparison shows the optimal prevented planting option at a given insurance coverage level and prevented planting coverage factor. First degree stochastic dominance is when the scenario with CDF F dominates another scenario with CDF G if $F(NR) \leq G(NR) \forall NR$ (Chavas 2004). If a dominant scenario cannot be indicated with first degree stochastic dominance, second degree stochastic dominance is used to compare the scenarios. Second degree stochastic dominance is when the scenario where CDF F dominates another scenario with CDF G if $\int F(NR) dNR \leq \int G(NR) dNR \forall NR$ (Chavas 2004).

If a dominant prevented planting option cannot be found by first and second degree stochastic dominance, we used stochastic efficiency with respect to a function (SERF) to rank the producers' prevented planting options over a range of absolute risk aversions (Hardaker et al. 2004). This requires the specification of a utility function, $U(\widetilde{NR}, r)$, which is a function of the distribution of net returns and absolute risk-preference level r . The certainty equivalent (CE) can be determined from a given utility function, which is the guaranteed net return a producer would rather take than taking a potentially higher uncertain net return. A risk averse producer would be willing to accept a lower expected net return with certainty instead of an uncertain higher expected net return. A rational, risk averse producer would choose the prevented planting option with the highest CE at a given risk aversion level.

In this analysis, a negative exponential utility function was used, which uses constant absolute risk-aversion coefficients (ARAC) to calculate the CE (Pratt 1964). The ARAC is determined by dividing the derivatives of the person's utility function $r_a(r) = -U''(r)/U'(r)$. Following Hardaker et al. (2004), a range of CEs were calculated bounded by a low and high ARAC. Zero was used for the lower bound ARAC, which assumes the producer was a risk neutral, profit-maximizer. To find the upper bound ARAC, we divided four by the average net return for all scenarios, which indicates a high level of risk aversion. Our ARAC values ranged from 0.0 for risk neutral to 0.04 for very risk averse. SIMETAR© was used to conduct stochastic dominance and the SERF analysis (Richardson et al. 2008).

CHAPTER V: RESULTS AND DISCUSSION

Yield Response

The yield response function, equation (5), results for corn, cotton, and soybeans are shown in Table 5. The linear (β_1) and the quadratic (β_2) parameter estimates were significant for all three crops at the 1% level. The intercept (β_0) was significant at the 5% level for soybeans but insignificant for corn and cotton. Heteroscedasticity was found across years for all crops and results are shown for corrected parameter estimates. The intercept parameter estimate for corn is 61.7003, meaning the average yield at planting date zero is expected to be 61.7003 bu/acre. The linear parameter estimate for corn is 2.6664, meaning corn yield is expected to increase 2.6664 bu/acre per day as planting is prolonged. The corn quadratic parameter estimate of -0.01465 means that yields are expected to decrease by 0.01465 times planting date squared indicating that prolonged planting will eventually lead to decreased in yield. Interpretation for cotton and soybean parameter estimates are the same as corn except cotton estimates are expressed as lb/acre. The parameter estimates show that yields were increasing at a decreasing rate, since the linear parameter estimates were positive and the quadratic parameter estimates were negative. The yield maximizing planting dates for corn, cotton, and soybeans were March 31st, April 7th, and May 18th; respectively. These yield maximizing planting dates are within the planting window for the RP and YP policy (USDA RMA 2018a) and coincide with much of the literature (Lauer et al. 1999; Darby and Lauer 2002; Pettigrew, Molin, and Stetina 2009; Boyer et al. 2015).

Simulated Net Returns

Table 6 show the summary statistics of the simulated distributions of net returns for a corn producer by RP coverage and planting option. Under the current prevented planting provision of 55%, expected net returns were maximized by planting uninsured soybeans after receiving a 35% prevented planting indemnity payment regardless of the RP coverage level. Late planting had the next highest expected net returns and planting insured soybeans had the lowest expected net returns across all the RP coverage levels. As RP coverage increased, the expected net returns for late planting corn and planting insured soybeans decreased. This was due to higher premium prices with increased RP coverage and net returns for these options being greater than the guaranteed net returns from RP coverage. Conversely, the expected net returns for taking the 35% prevented planting indemnity payment and planting uninsured soybeans increased as RP coverage increased. This is because the 35% prevented planting payment increased with higher RP coverage.

Corn showed consistent results when simulated with YP crop insurance (Table 7). Receiving a 35% prevented planting indemnity payment and planting uninsured soybeans maximizes net returns at all YP coverages under the current prevented planting provision. Expected net returns from this option and the insured soybeans option react to changes in YP coverage in the same way they did with RP coverage. However, due to YP having smaller insurance premiums than RP, late planting net returns show a slight increase as YP coverage increases (opposite of RP).

We define ex-post moral hazard as choosing to not produce a crop and take the full prevented planting indemnity payment despite planting during the late planting period or switching crops being a more profitable option. This study, like Kim and Kim's (2018), can only

evaluate the likelihood of ex-post moral hazard existing in the prevented planting provision. Therefore, we compared the expected net returns for the full prevented planting indemnity payment, which is shown in Table 4, to the distribution of the simulated net returns of the three options requiring a crop to be planted (i.e., late planting, 35% prevented planting and uninsured soybeans, and insured soybeans). Then, we look at how the probability of the planting options generating higher net returns than the full prevented planting option changes with insurance coverage level and a prevented planting policy reduction. This tells us whether there is an increase or decrease in the likelihood of ex-post moral hazard.

The likelihood of the expected net returns from the three prevented planting options requiring a crop to be planted being greater than the full prevented planting indemnity payment decreased as RP and YP coverage increased. It appears the likelihood of a corn producer abandoning their crop and accepting the full prevented planting indemnity payment increased with an increase in RP or YP coverage. This would support what Kim and Kim (2018) concluded about higher insurance coverage increasing the likelihood of ex-post moral hazard in prevented planting.

For both RP and YP, when the corn prevented planting coverage factor was decreased to 45%, the net returns to late planting and planting insured soybeans did not change since with these options a producer does not receive a prevented planting indemnity payment. However, the probability of these options having higher net returns than the full prevented planting indemnity payment increased. Reducing the coverage factor decreased the expected net returns for the 35% prevented planting indemnity payment and planting uninsured soybeans because the 35% payment decreased. Despite the reduced expected net returns, the probability of this option producing higher net returns than the full prevented planting indemnity payment increased. Thus,

reducing the coverage factor appears to reduce the likelihood of ex-post moral hazard in prevented planting. This finding supports USDA OIG's (2013) policy recommendation as a way to reduce ex-post moral hazard in prevented planting.

Table 8 shows the same general findings for cotton production as corn production with RP coverage. Planting uninsured soybeans after receiving a 35% prevented planting indemnity payment was also the option that maximized net returns at all RP coverage levels under the current prevented planting policy. Changes in RP coverage levels affect the expected net returns the same as corn producers. The probability of the planting options having higher net returns than net returns from the full prevented indemnity planting option decreased as RP coverage increased. Reducing the coverage factor also reduced the likelihood of ex-post moral hazard.

For cotton with YP coverage at the current prevented planting policy, the option that maximized net returns for 60% and 70% coverage was still 35% prevented planting indemnity payment and uninsured soybeans (Table 9). However, the full prevented planting indemnity payment maximized net returns at 80% coverage. Expected net returns from the 35% indemnity payment and uninsured soybeans increased with increases in YP coverage. Late planting net returns remained constant with increases in YP coverage, and net returns from insured soybeans decreased. Reducing the prevented planting coverage factor reduces the likelihood of ex-post moral hazard, because the probabilities of the planting options generating higher net returns than the full prevented planting indemnity payment option increase.

These results show a risk-neutral, profit-maximizing corn producer would choose to plant uninsured soybeans after receiving a 35% prevented planting indemnity payment regardless of the RP and YP coverage level. A risk neutral, profit-maximizing cotton producer's decision would be the same except for at YP coverage of 80%, the producer would choose the full

prevented planting indemnity payment option. However, the USDA OIG (2013) report states that a very small percentage of producers are actually planting a second crop and the vast majority are not planting their crop and taking the full prevented planting indemnity payment. The estimated net returns found in this study would suggest that ex-post moral hazard is present in prevented planting if producer behavior is to not plant their intended crop and instead receive the full prevented planting indemnity payment. Also, factors such as risk preference might drive a producer to commit ex-post moral hazard.

Risk

The distribution of net returns for corn and cotton production for each RP and YP coverage level and prevented planting coverage factor were compared, and first- and second-degree stochastic dominance did not exist across prevented planting options. The CDFs of the prevented planting options are shown by insurance policy, coverage level, prevented planting coverage factor, and crop in Figures 4-27. The CDFs show the probabilities of producers' expected net returns. For example, in Figure 4, the probability of a net return of \$100/acre is around 85% for uninsured soybeans and partial prevented planting indemnity payment and around 55% for late planting and insured soybeans. The full prevented planting indemnity payment is constant at \$66, because there is no variability with this option.

SERF was used to determine the preferred prevented planting option for corn and cotton production at a given RP coverage level and prevented planting coverage factor across a range of risk aversion levels. We found the preferred prevented planting option for a corn and cotton producer at a given RP coverage level and prevented planting coverage factor was to receive the 35% prevented planting indemnity payment and plant uninsured soybeans, but when risk aversion reached a certain point, the producer would prefer the full prevented planting indemnity

payment. Figure 28 shows the ARAC levels when a producer with RP would switch from preferring the 35% prevented planting indemnity payment and plant uninsured soybeans option to preferring the full prevented planting indemnity payment option.

As RP coverage increases, the ARAC where a corn and cotton producer switches preferred options decreases, meaning the level of risk aversion decreases where a producer would switch preferred options. That is, at 60% RP coverage, a producer would have to be more risk averse to switch preferred prevented planting options than at 80% RP coverage. This is because the likelihood of the net returns from the profit-maximizing option exceeding the net returns from the full prevented planting option decreases as RP coverage increases. With higher RP coverage, only small changes in risk aversion would need to occur for producers to prefer the full prevented planting indemnity payment option. This indicates that risk aversion has to be more extreme to cause a producer to prefer the full prevented planting indemnity payment when RP coverage is lower, and a producer would have to be less risk averse to switch their preferred option to the full prevented planting indemnity payment with higher RP coverage. Figure 28 also shows that the USDA OIG's (2013) policy recommendation of lower coverage factors increased the ARAC level when a producer would switch to preferring the full prevented planting indemnity payment option. This finding further supports the policy recommendation that ex-post moral hazard would likely decrease as the prevented planting coverage factor decreased.

A SERF analysis was also used to determine the prevented planting option a corn and cotton producer with YP would prefer. Figure 29 shows the level of absolute risk-aversion level when a producer would change their decision from 35% prevented planting indemnity payment and uninsured soybeans to taking the full prevented planting indemnity payment. Notice, with 80% YP for cotton at the current prevented planting coverage factor, a producer would choose

the full prevented planting indemnity payment option at all risk aversion levels, because this was the risk neutral, profit-maximizing decision. At the other coverages, the results are very similar as a producer with RP. As insurance coverage increases, a producer would need to be less risk averse to switch their decision to the full prevented planting indemnity payment. Reducing the prevented planting coverage decreases the likelihood of ex-post moral hazard, because a producer would need to be more risk averse to switch their decision to the full prevented planting indemnity payment.

CHAPTER VI: CONCLUSIONS AND RECOMMENDATIONS

Some crop insurance policies provide financial protection to producers that are unable to plant their crops by the final planting date due to natural occurrences. A producer confronted with this issue has four main options: plant the original crop during the late planting period, take the full prevented planting indemnity payment and not plant a crop, receive a 35% prevented planting indemnity payment and plant an uninsured second crop, and forgo the prevented planting indemnity payment and plant an insured second crop. There has been concern around this provision for several years that it might promote ex-post moral hazard, and USDA RMA (2018d) recently made changes to the prevented planting coverage factors. However, little research has investigated the likelihood of ex-post moral hazard in prevented planting and how these policy changes could impact this possibility.

Therefore, the objective of this study was to determine the optimal prevented planting option a corn and cotton producer would select at various RP and YP coverage levels. We also show how changes in the prevented planting coverage factor would impact the optimal decision. Simulation models were developed to show optimal prevented planting options for risk-neutral, profit-maximizers, and risk averse producers. These results will provide policy makers with insight into revising coverage factors or other prevented planting provisions to reduce the likelihood of ex-post moral hazard.

For a cotton producer with 80% YP coverage, the full prevented planting indemnity payment option maximizes net returns. For all other RP and YP coverage levels for corn and cotton producers, the option that maximized net returns at the current prevented planting coverage factor was planting uninsured soybeans after receiving a 35% prevented planting indemnity payment for the first crop. When risk preferences were considered, a corn and cotton

producer would switch from preferring the 35% prevented planting indemnity payment and planting uninsured soybeans to the full prevented planting indemnity payment when risk aversion reached certain levels. For a cotton producer with 80% YP coverage, risk aversion level does not change a producer's decision, because they are already choosing the full prevented planting indemnity payment. This study suggests that risk averse producers are more likely to commit moral hazard. Overall, we found lowering the prevented planting coverage factors by 10% would reduce the likelihood of ex-post moral hazard for both profit-maximizing and risk averse producers.

It is important that producers consider that estimates in Table 4 and Tables (6-9) are averages; yield variability is a key variable in estimating net returns and can make the planting options riskier than prevented planting payments. Keep in mind that planting later in the season typically comes with decreases in yield. Therefore, a farmer may want to consider how the field(s) left to plant has (have) performed under wet planting conditions. Also, not all producers will be able to switch crops when dealing with a prevented planting situation. The prevented planting coverage factor is set to match a producer's pre-planting costs, therefore, if a farmer already has seed and fertilizer for corn or cotton and it cannot be returned or stored, switching to soybeans may not be a viable option (USDA RMA 2018d). In this case, a farmer should carefully look at their costs to date and consider the amount of insurance coverage when deciding between late planting and the full prevented planting payment option. Our analysis used fixed prices, but an important factor to consider is market price movements after the crop insurance price has been set. Increases or decreases in market price could affect the profit-maximizing prevented planting decision.

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APPENDIX

Tables

Table 1. Summary of Planting Date Literature

Study Name	Crop	Location	Optimal Planting Date or Window
Licht and Rees (2017)	Corn	Iowa	April 15 – May 10
Lauer et al. (1999)	Corn	Northern Wisconsin	May 8 – May 14
Lauer et al. (1999)	Corn	Southern Wisconsin	May 1 – May 7
Darby and Lauer (2002)	Corn	Northern Wisconsin	May 7
Darby and Lauer (2002)	Corn	Southern Wisconsin	May 10
Abendroth et al. (2017)	Corn	Iowa	April 12 – May 9
Bruns and Abbas (2006)	Corn	Stoneville, Mississippi	Early April – April 20
Kucharik (2008)	Corn	Central, USA	Early Planting
Nafziger (1994)	Corn	Northern Illinois	April 16 – May 11
Swanson and Wilhelm (1996)	Corn	Lincoln, Nebraska	May 9
Pettigrew et al. (2009)	Cotton	Stoneville, Mississippi	Early April
Anapalli et al. (2016)	Cotton	Stoneville, Mississippi	Mid March – Late May
Wrather et al. (2008)	Cotton	Southeast Missouri	Late April – Early May
Adams et al. (2013)	Cotton	Stoneville, Mississippi	Mid April – Early May
O’Berry et al. (2008)	Cotton	Suffolk, Virginia	No significant dates
O’Berry et al. (2008)	Cotton	Rocky Mount, N.C.	No significant dates
O’Berry et al. (2008)	Cotton	Clayton, N.C.	No significant dates
O’Berry et al. (2008)	Cotton	Alexandria, Louisiana	May 1
Boquet and Clawson (2009)	Cotton	Winnsboro, Louisiana	April 15 – May 15
Steele and Grabau (1997)	Soybeans	Fayette County, Kentucky	Mid June
Egli and Cornelius (2009)	Soybeans	Midwest, USA	Mid April – May 30
Egli and Cornelius (2009)	Soybeans	Upper South, USA	Mid April – June 7
Egli and Cornelius (2009)	Soybeans	Deep South, USA	Early April – May 27
Hu and Waitrak (2012)	Soybeans	Various Locations in USA	Early Planting
Chen and Wiatrak (2010)	Soybeans	Southeastern, S.C.	Early May – Mid May
Salmeron et al. (2014)	Soybeans	Mid-South, USA	Early Planting
Boyer et al. (2015)	Soybeans	Milan, Tennessee	May 13 – May 24

Table 2. Summary of Crop Yields at Each Planting Date or Planting Window

Planting Date or Planting Window	Average Yield	Minimum Yield	Maximum Yield	Standard Deviation
Corn (bu/acre)				
March 3 – March 21	176	175	178	1.48
March 22 – April 9	169	55	239	64.82
April 10 – April 28	176	26	254	74.39
April 29 – May 16	163	18	238	69.64
May 17 – June 3	150	89	197	37.14
June 4 – June 20	117	21	193	49.92
Cotton (lb/acre)				
April 14	1,397	663	2,306	370.48
April 21	1,266	755	1,912	286.92
May 1	1,368	791	2,212	313.36
May 15	1,159	318	1,903	293.41
June 1	944	230	1,575	300.54
June 15	611	176	1,571	280.01
Soybeans (bu/acre)				
April 17 – May 6	48	17	74	10.94
May 7 – May 25	52	21	75	11.52
May 26 – June 13	51	12	68	8.89
June 14 – July 1	45	17	71	9.72
July 2 – July 21	38	18	83	10.16
July 22 – August 10	25	11	65	11.95

Table 3. Data Used to Calculate Net Returns for Corn, Cotton, and Soybeans

Variable Definition	Symbol	Corn	Cotton	Soybeans
Market Price (\$/bu or \$/lb)	p	\$4.81	\$0.73	\$11.31
Projected Price (\$/bu or \$/lb)	p^{gp}	\$4.85	\$0.82	\$11.29
Actual Production History Yield (bu or lb)	y^{APH}	152	1124	44
Production Cost before Planting (\$/acre)	c^{bp}	\$126	\$133	\$55
Production Cost after Planting (\$/acre)	c^{ap}	\$386	\$509	\$246
RP Premium with 60% Coverage (\$/acre)	$IP(\delta)$	\$7	\$11	\$9
RP Premium with 70% Coverage (\$/acre)	$IP(\delta)$	\$15	\$20	\$15
RP Premium with 80% Coverage (\$/acre)	$IP(\delta)$	\$31	\$41	\$32
YP Premium with 60% Coverage (\$/acre)	$IP(\delta)$	\$5	\$7	\$7
YP Premium with 70% Coverage (\$/acre)	$IP(\delta)$	\$10	\$12	\$12
YP Premium with 80% Coverage (\$/acre)	$IP(\delta)$	\$20	\$26	\$25
Final Planting Date (Julien day)	FPD	140	140	166

Note: Land rent included in corn and cotton production cost before planting

Table 4. Corn and Cotton Net Returns (\$/acre) from the Full Prevented Planting Payment at 60%, 70%, and 80% RP and YP Coverage with Current and 10% Less Prevented Planting Coverage

Crop	60% Coverage		70% Coverage		80% Coverage	
	RP	YP	RP	YP	RP	YP
Corn with Current 55% Prevented Planting Coverage	\$110	\$112	\$143	\$148	\$167	\$178
Corn with Reduced 45% Prevented Planting Coverage	\$66	\$68	\$91	\$97	\$109	\$119
Cotton with Current 50% Prevented Planting Coverage	\$133	\$137	\$170	\$178	\$195	\$210
Cotton with Reduced 40% Prevented Planting Coverage	\$78	\$82	\$105	\$113	\$121	\$136

Table 5. Parameter Estimates for Corn, Cotton, and Soybean Yield Response Function to Planting Date

Parameter	Corn	Cotton	Soybeans
Intercept (β_0)	61.7003	-252.52	-49.9654**
Day (β_1)	2.6664***	32.8457***	1.4556***
Day*Day (β_2)	-0.01465***	-0.1663***	-0.00522***
Number of Observations	136	960	641

Note: Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1% level. Units are reported in bu/acre for corn and soybeans and lb/acre for cotton.

Table 6. Summary Statistics from the Simulated Net Returns (\$/acre) for Corn Producer by Prevented Planting Option, Revenue Protection Coverage Level, and Prevented Planting Coverage Factor

Option	60% Revenue Protection		70% Revenue Protection		80% Revenue Protection	
	Net Returns (\$/acre)	Probability Net Returns $\geq$ Full Prevented Planting Payment ^a	Net Returns (\$/acre)	Probability Net Returns $\geq$ Full Prevented Planting Payment	Net Returns (\$/acre)	Probability Net Returns $\geq$ Full Prevented Planting Payment
<i>With a 55% Prevented Planting Coverage Factor</i>						
Late Planting	\$135 (\$157)	54%	\$135 (\$147)	45%	\$129 (\$131)	35%
35% Prevented Planting + Uninsured Soybeans	\$174 (\$66)	84%	\$187 (\$65)	75%	\$195 (\$67)	66%
Insured Soybeans	\$102 (\$62)	44%	\$96 (\$62)	23%	\$80 (\$63)	8%
<i>With a 45% Prevented Planting Coverage Factor</i>						
Late Planting	- ^b	65%	- ^b	56%	- ^b	49%
35% Prevented Planting + Uninsured Soybeans	\$160 (\$65)	93%	\$169 (\$66)	88%	\$173 (\$64)	84%
Insured Soybeans	- ^b	73%	- ^b	53%	- ^b	33%

Note: Standard deviation is in parenthesis.

^a Probabilities were calculated using the expected net returns for each crop, revenue production coverage level, and prevented planting coverage factor shown in Table 4.

^b Simulated net returns for were the same as when the prevented planting coverage factor was 55%.

Table 7. Summary Statistics from the Simulated Net Returns (\$/acre) for Corn Producer by Prevented Planting Option, Yield Protection Coverage Level, and Prevented Planting Coverage Factor

Option	60% Yield Protection		70% Yield Protection		80% Yield Protection	
	Net Returns (\$/acre)	Probability Net Returns $\geq$ Full Prevented Planting Payment ^a	Net Returns (\$/acre)	Probability Net Returns $\geq$ Full Prevented Planting Payment	Net Returns (\$/acre)	Probability Net Returns $\geq$ Full Prevented Planting Payment
<i>With a 55% Prevented Planting Coverage Factor</i>						
Late Planting	\$140 (\$159)	56%	\$142 (\$150)	45%	\$145 (\$132)	37%
35% Prevented Planting + Uninsured Soybeans	\$175 (\$65)	83%	\$189 (\$65)	73%	\$199 (\$66)	62%
Insured Soybeans	\$104 (\$62)	45%	\$100 (\$61)	22%	\$86 (\$62)	7%
<i>With a 45% Prevented Planting Coverage Factor</i>						
Late Planting	- ^b	64%	- ^b	58%	- ^b	49%
35% Prevented Planting + Uninsured Soybeans	\$160 (\$65)	92%	\$172 (\$65)	88%	\$180 (\$64)	83%
Insured Soybeans	- ^b	73%	- ^b	53%	- ^b	30%

Note: Standard deviation is in parenthesis.

^a Probabilities were calculated using the expected net returns for each crop, yield production coverage level, and prevented planting coverage factor shown in Table 4.

^b Simulated net returns for were the same as when the prevented planting coverage factor was 55%.

Table 8. Summary Statistics from the Simulated Net Returns (\$/acre) for Cotton Producer by Prevented Planting Option, Revenue Protection Coverage Level, and Prevented Planting Coverage Factor

Option	60% Revenue Protection		70% Revenue Protection		80% Revenue Protection	
	Net Returns (\$/acre)	Probability Net Returns $\geq$ Full Prevented Planting Payment ^a	Net Returns (\$/acre)	Probability Net Returns $\geq$ Full Prevented Planting Payment	Net Returns (\$/acre)	Probability Net Returns $\geq$ Full Prevented Planting Payment
<i>With a 50% Prevented Planting Coverage Factor</i>						
Late Planting	\$48 (\$69)	11%	\$42 (\$65)	3%	\$37 (\$47)	0.3%
35% Prevented Planting + Uninsured Soybeans	\$178 (\$65)	75%	\$192 (\$64)	64%	\$200 (\$65)	53%
Insured Soybeans	\$95 (\$62)	27%	\$90 (\$60)	9%	\$72 (\$62)	2%
<i>With a 40% Prevented Planting Coverage Factor</i>						
Late Planting	- ^b	33%	- ^b	16%	- ^b	7%
35% Prevented Planting + Uninsured Soybeans	\$159 (\$66)	89%	\$168 (\$64)	84%	\$175 (\$65)	80%
Insured Soybeans	- ^b	62%	- ^b	40%	- ^b	22%

Note: Standard deviation is in parenthesis.

^a Probabilities were calculated using the expected net returns for each crop, revenue production coverage level, and prevented planting coverage factor shown in Table 4.

^b Simulated net returns for were the same as when the prevented planting coverage factor was 50%.

Table 9. Summary Statistics from the Simulated Net Returns (\$/acre) for Cotton Producer by Prevented Planting Option, Yield Protection Coverage Level, and Prevented Planting Coverage Factor

Option	60% Yield Protection		70% Yield Protection		80% Yield Protection	
	Net Returns (\$/acre)	Probability Net Returns $\geq$ Full Prevented Planting Payment ^a	Net Returns (\$/acre)	Probability Net Returns $\geq$ Full Prevented Planting Payment	Net Returns (\$/acre)	Probability Net Returns $\geq$ Full Prevented Planting Payment
<i>With a 50% Prevented Planting Coverage Factor</i>						
Late Planting	\$51 (\$70)	11%	\$48 (\$66)	3%	\$52 (\$46)	0.4%
35% Prevented Planting + Uninsured Soybeans	\$182 (\$66)	75%	\$193 (\$66)	59%	\$207 (\$65)	48%
Insured Soybeans	\$100 (\$63)	28%	\$91 (\$63)	8%	\$81 (\$61)	0.5%
<i>With a 40% Prevented Planting Coverage Factor</i>						
Late Planting	- ^b	32%	- ^b	17%	- ^b	7%
35% Prevented Planting + Uninsured Soybeans	\$162 (\$64)	89%	\$172 (\$66)	82%	\$180 (\$65)	75%
Insured Soybeans	- ^b	61%	- ^b	38%	- ^b	18%

Note: Standard deviation is in parenthesis.

^a Probabilities were calculated using the expected net returns for each crop, yield production coverage level, and prevented planting coverage factor shown in Table 4.

^b Simulated net returns for were the same as when the prevented planting coverage factor was 50%.

Figures

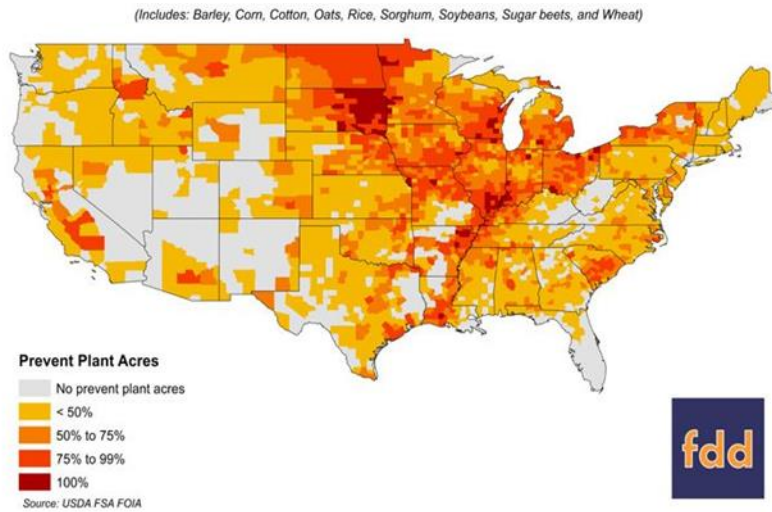


Figure 1. Frequency of Designated Prevented Planting Acres in U.S. Counties from 1996-2014 (Source: USDA Farm Service Agency 2017 and Newton 2015)

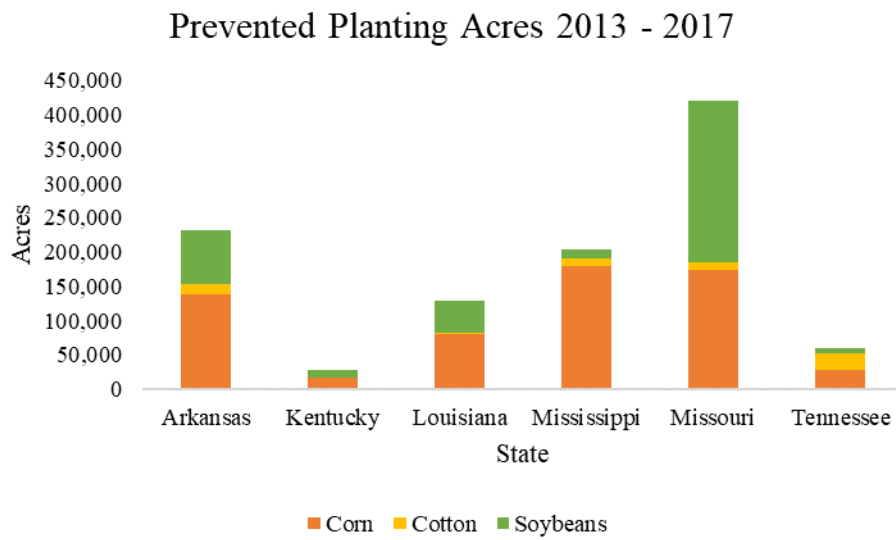


Figure 2. Average Annual Acres Reported to the USDA Farm Service Agency that were Prevented from Planting from 2013-2017. (Source: USDA Farm Service Agency 2017)

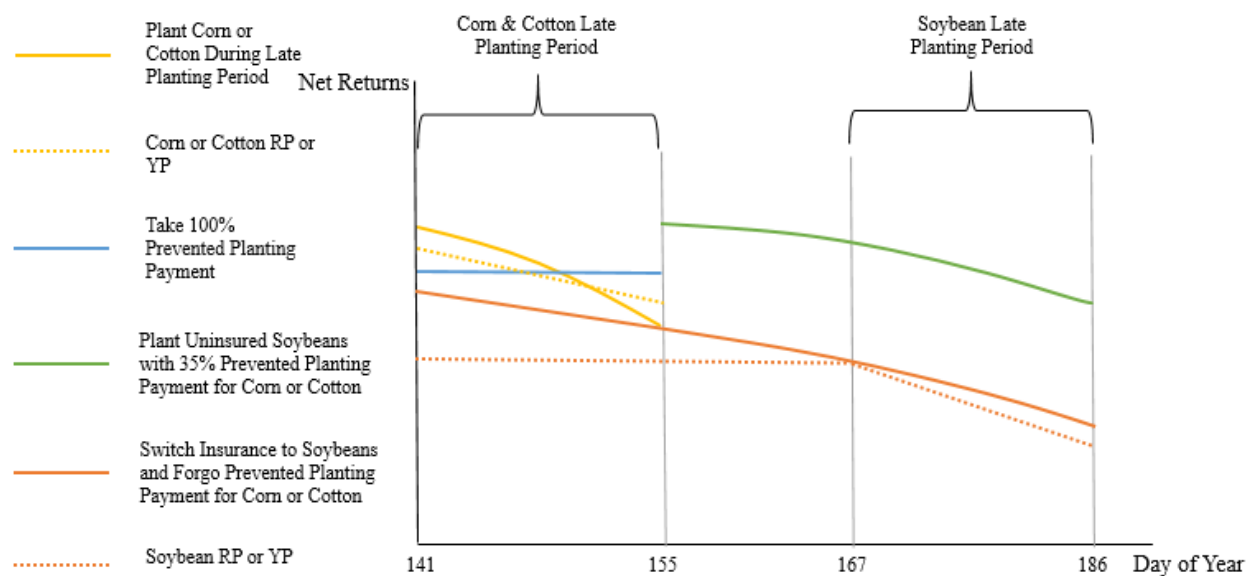


Figure 3. Example of Producer's Expected Net Returns at each Prevented Planting Option for RP or YP

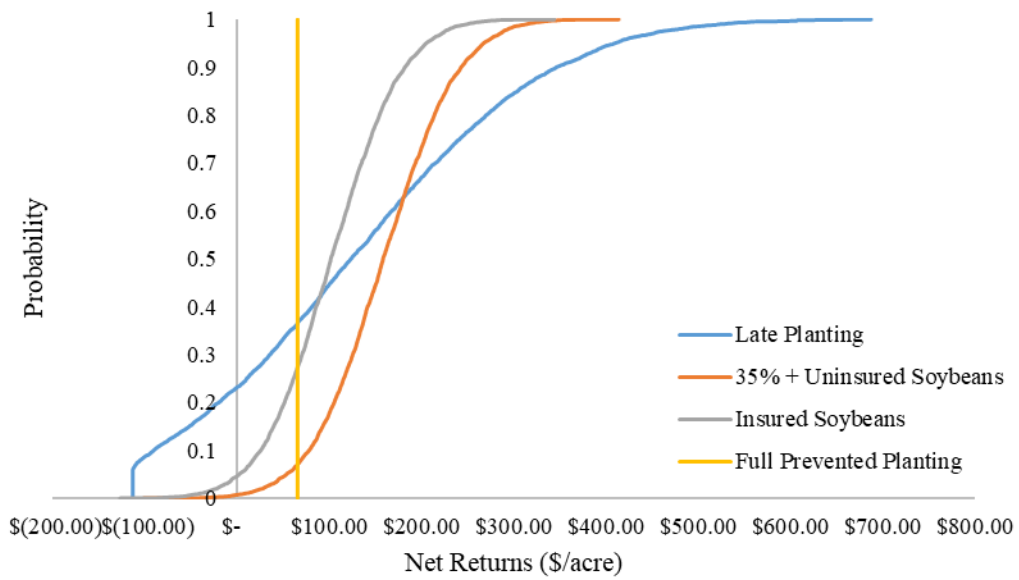


Figure 4. Corn-Soybean Cumulative Distribution Function at 60% Revenue Protection Coverage and 45% Prevented Planting Coverage

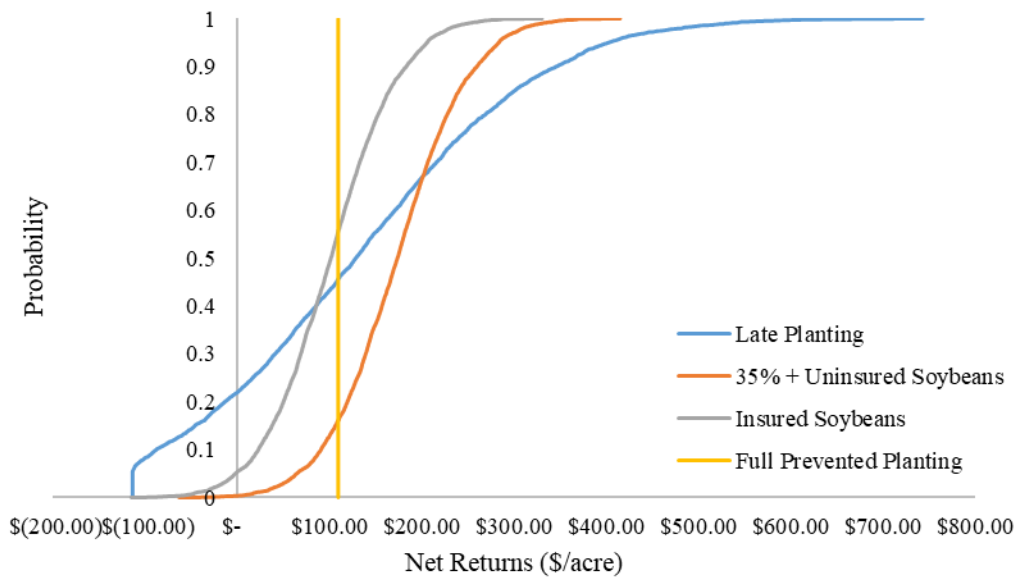


Figure 5. Corn-Soybean Cumulative Distribution Function at 60% Revenue Protection Coverage and 55% Prevented Planting Coverage

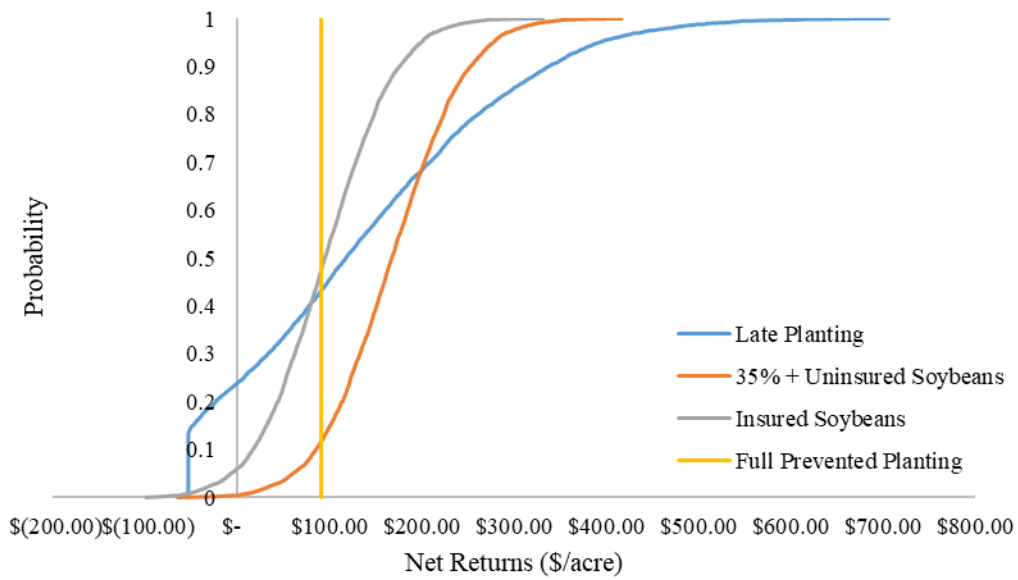


Figure 6. Corn-Soybean Cumulative Distribution Function at 70% Revenue Protection Coverage and 45% Prevented Planting Coverage

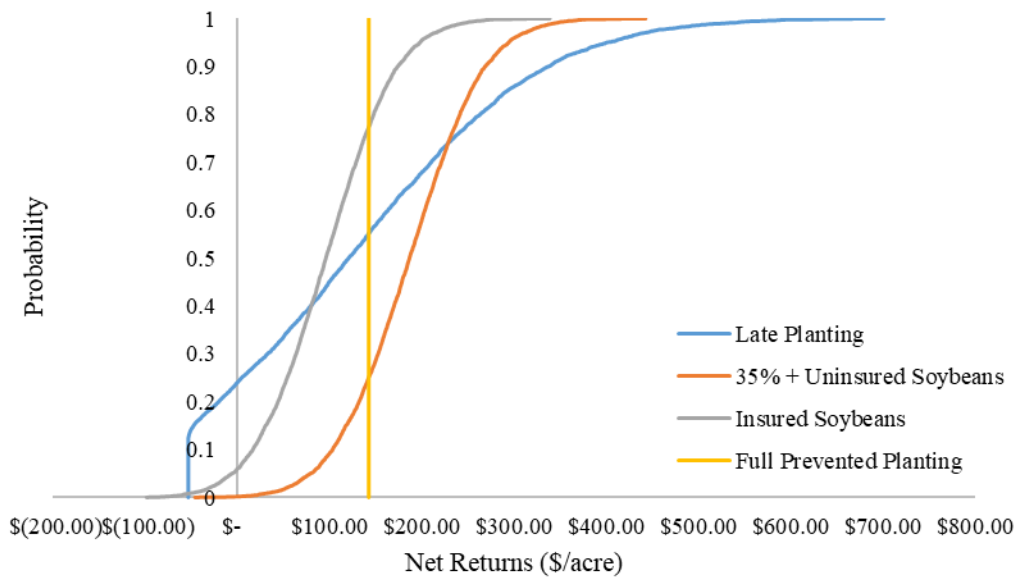


Figure 7. Corn-Soybean Cumulative Distribution Function at 70% Revenue Protection Coverage and 55% Prevented Planting Coverage

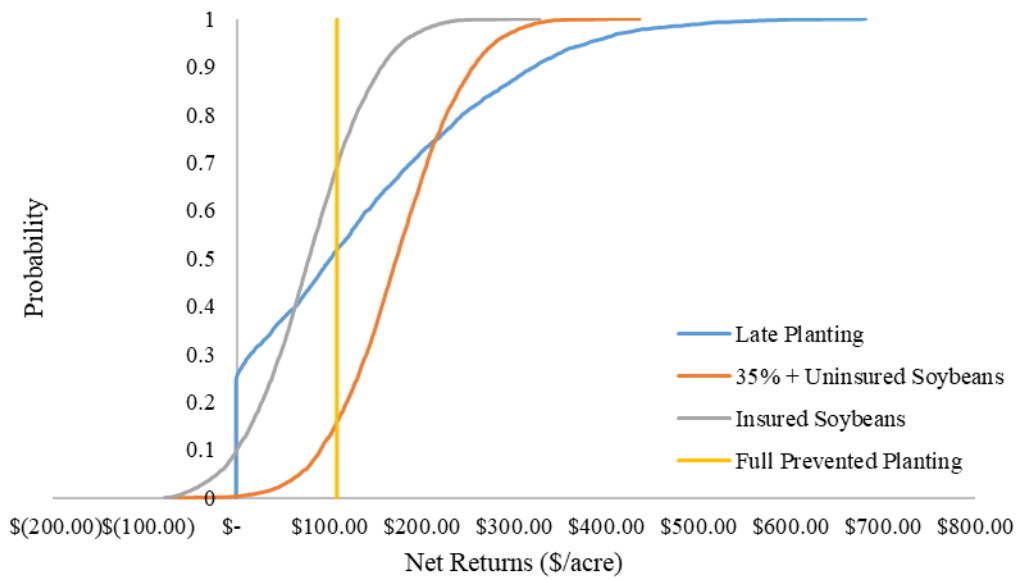


Figure 8. Corn-Soybean Cumulative Distribution Function at 80% Revenue Protection Coverage and 45% Prevented Planting Coverage

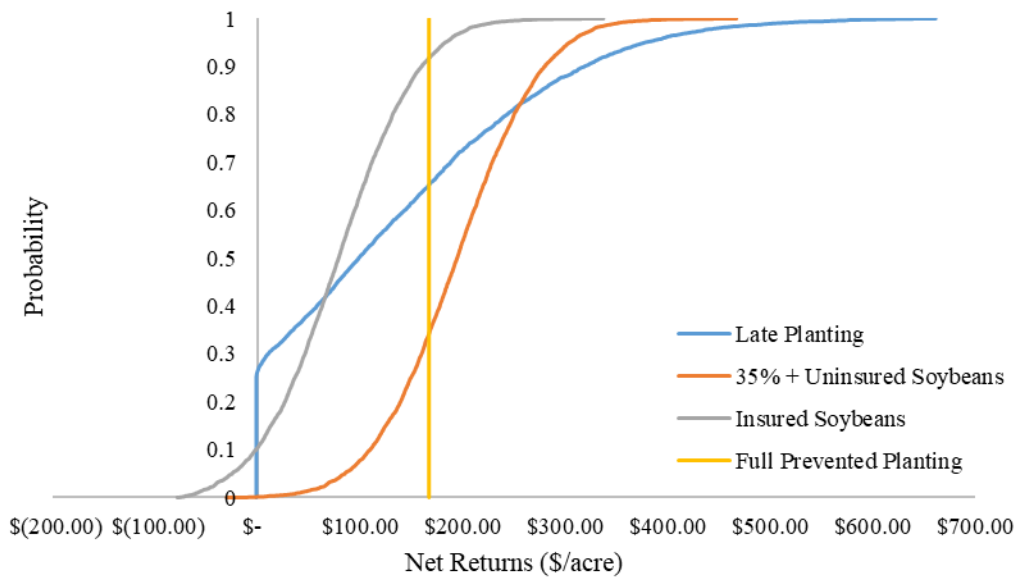


Figure 9. Corn-Soybean Cumulative Distribution Function at 80% Revenue Protection Coverage and 55% Prevented Planting Coverage

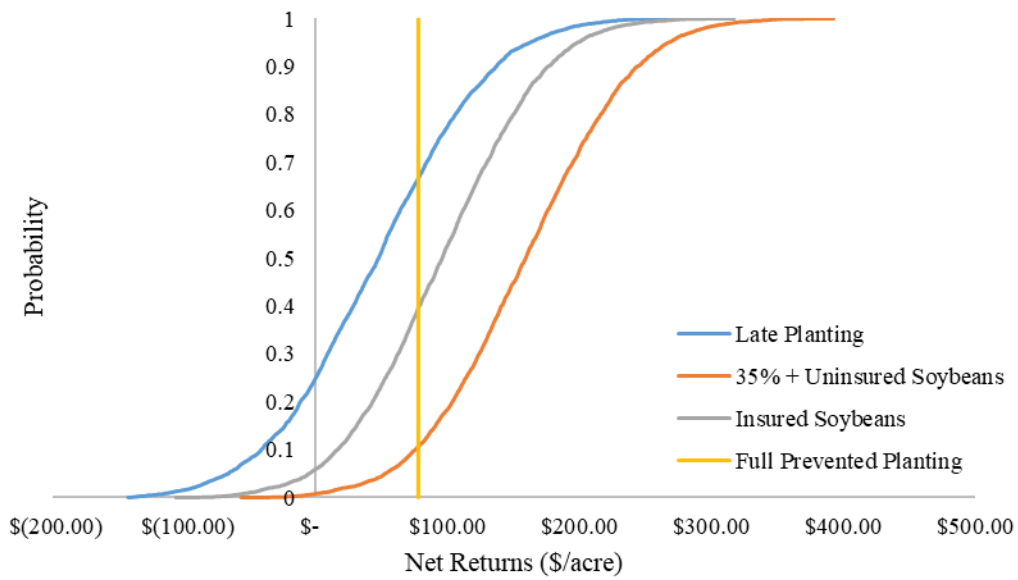


Figure 10. Cotton-Soybean Cumulative Distribution Function at 60% Revenue Protection Coverage and 40% Prevented Planting Coverage

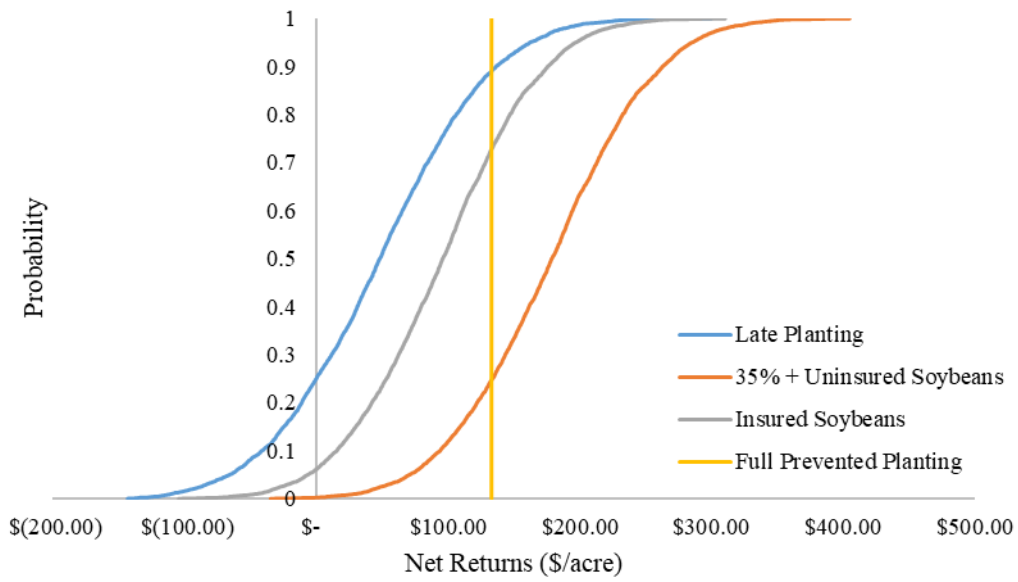


Figure 11. Cotton-Soybean Cumulative Distribution Function at 60% Revenue Protection Coverage and 50% Prevented Planting Coverage

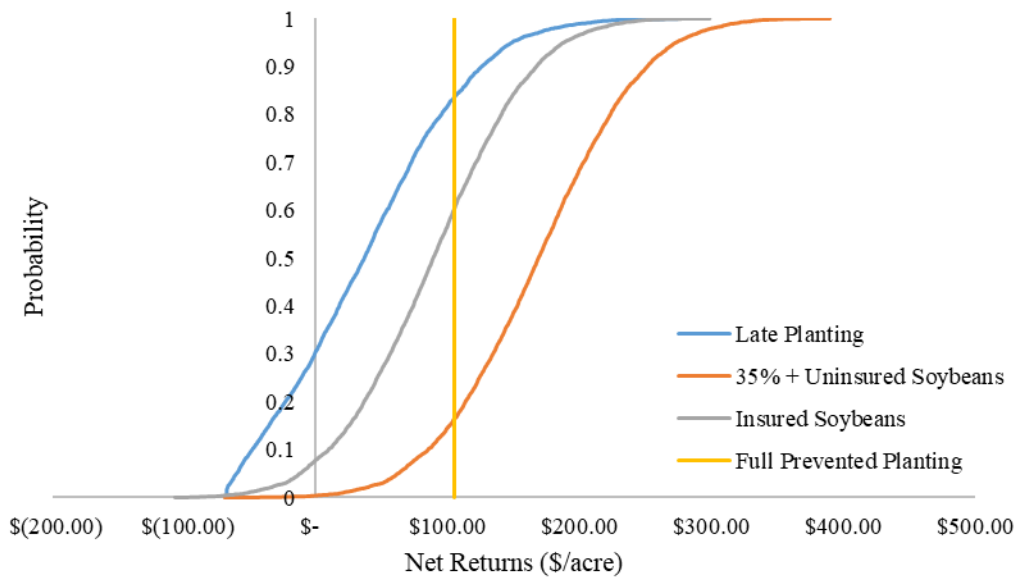


Figure 12. Cotton-Soybean Cumulative Distribution Function at 70% Revenue Protection Coverage and 40% Prevented Planting Coverage

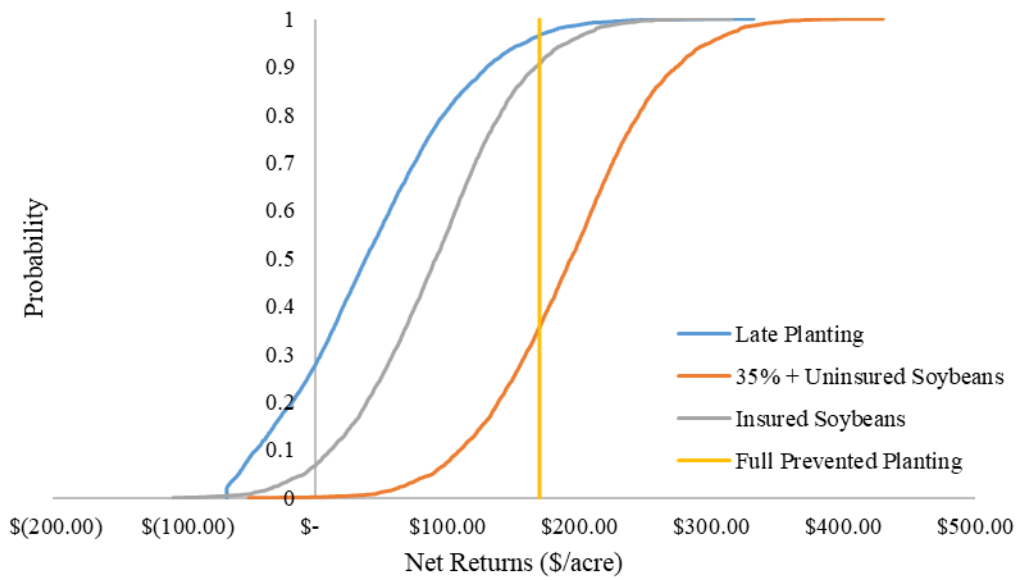


Figure 13. Cotton-Soybean Cumulative Distribution Function at 70% Revenue Protection Coverage and 50% Prevented Planting Coverage

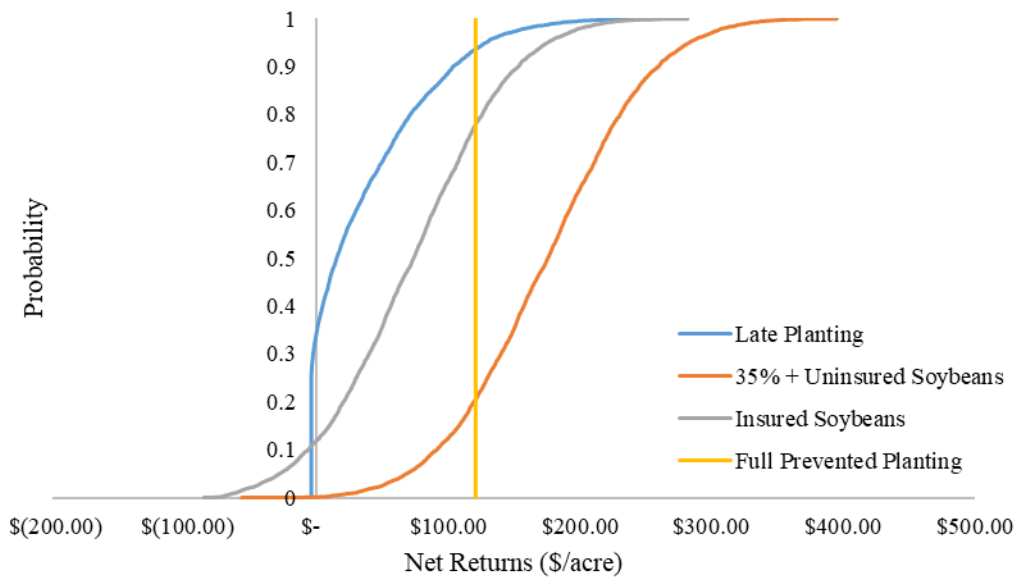


Figure 14. Cotton-Soybean Cumulative Distribution Function at 80% Revenue Protection Coverage and 40% Prevented Planting Coverage

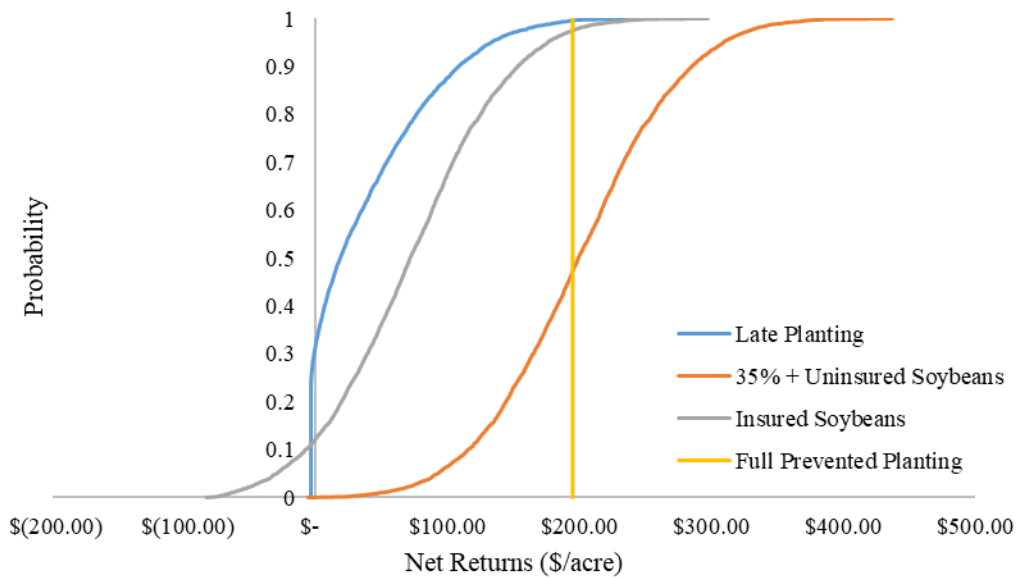


Figure 15. Cotton-Soybean Cumulative Distribution Function at 80% Revenue Protection Coverage and 50% Prevented Planting Coverage

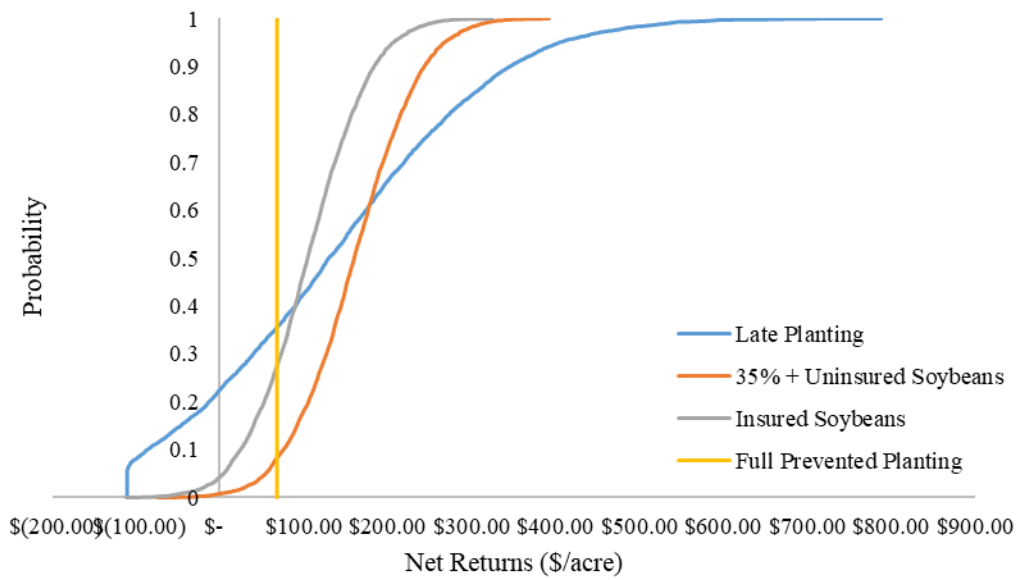


Figure 16. Corn-Soybean Cumulative Distribution Function at 60% Yield Protection Coverage and 45% Prevented Planting Coverage

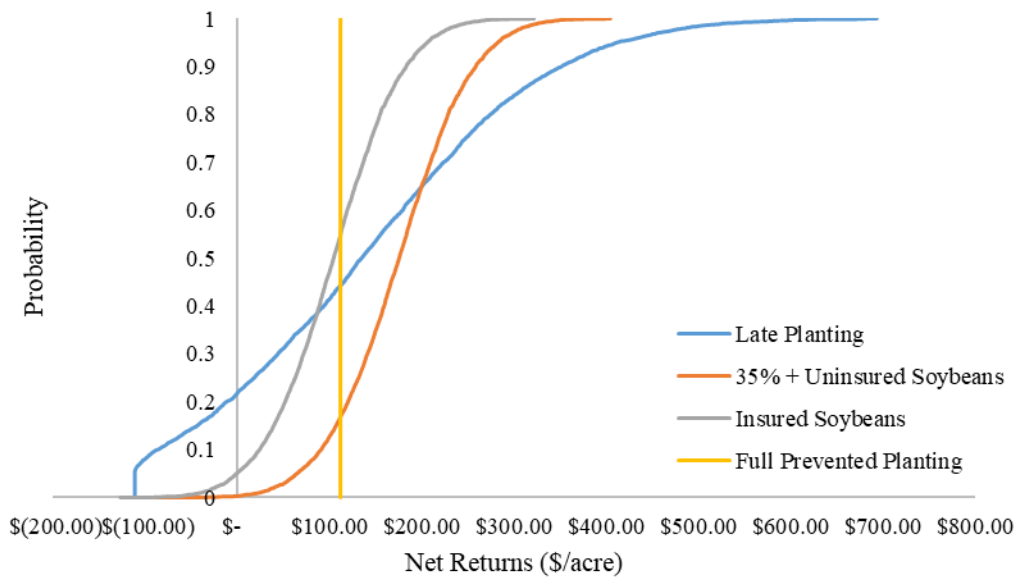


Figure 17. Corn-Soybean Cumulative Distribution Function at 60% Yield Protection Coverage and 55% Prevented Planting Coverage

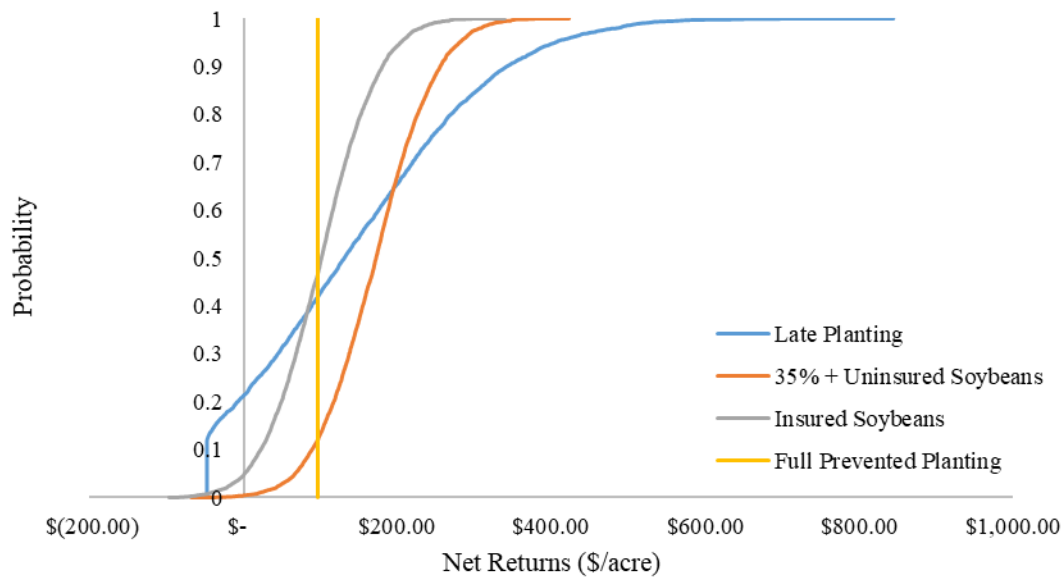


Figure 18. Corn-Soybean Cumulative Distribution Function at 70% Yield Protection Coverage and 45% Prevented Planting Coverage

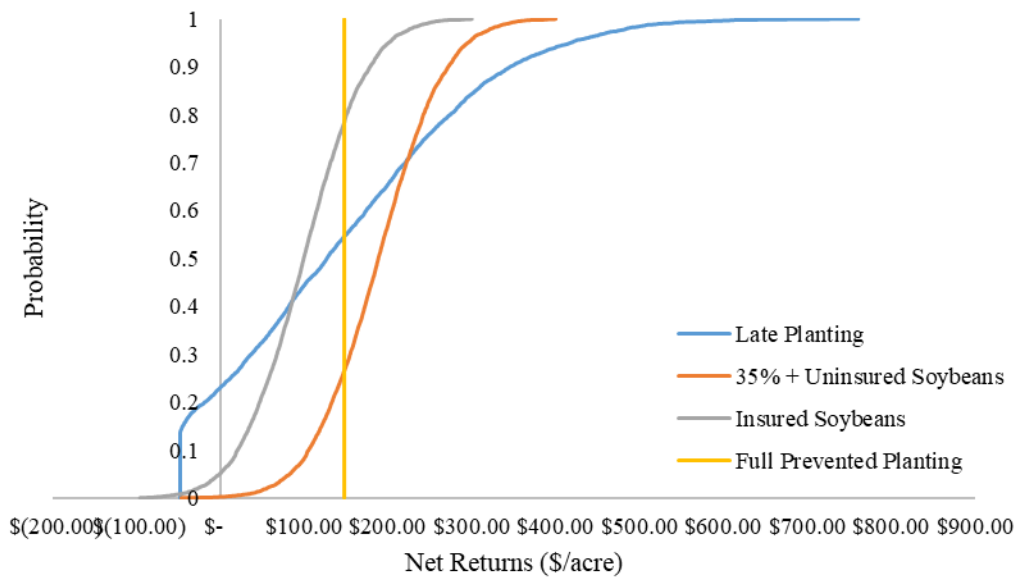


Figure 19. Corn-Soybean Cumulative Distribution Function at 70% Yield Protection Coverage and 55% Prevented Planting Coverage

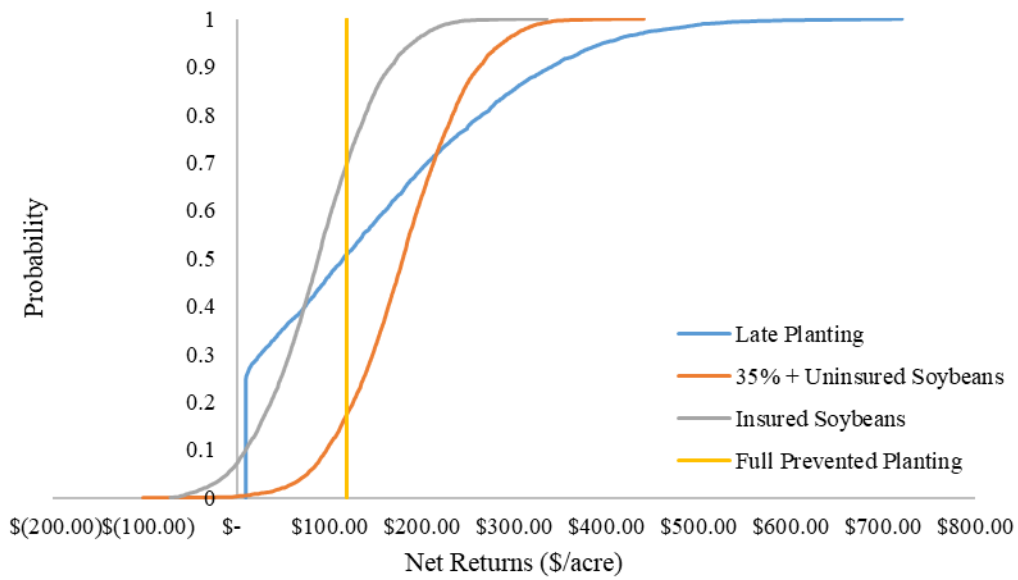


Figure 20. Corn-Soybean Cumulative Distribution Function at 80% Yield Protection Coverage and 45% Prevented Planting Coverage

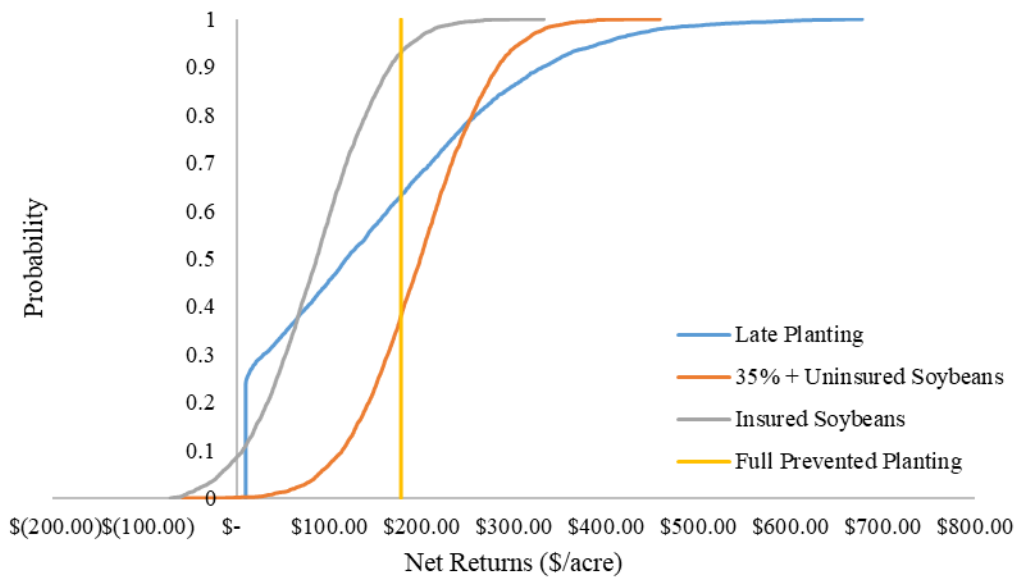


Figure 21. Corn-Soybean Cumulative Distribution Function at 80% Yield Protection Coverage and 55% Prevented Planting Coverage

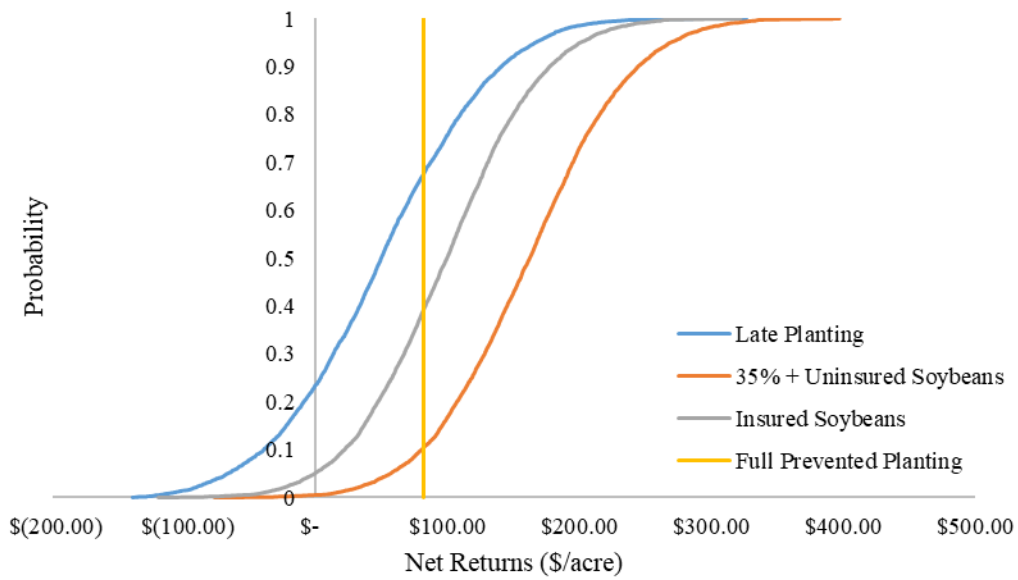


Figure 22. Cotton-Soybean Cumulative Distribution Function at 60% Yield Protection Coverage and 40% Prevented Planting Coverage

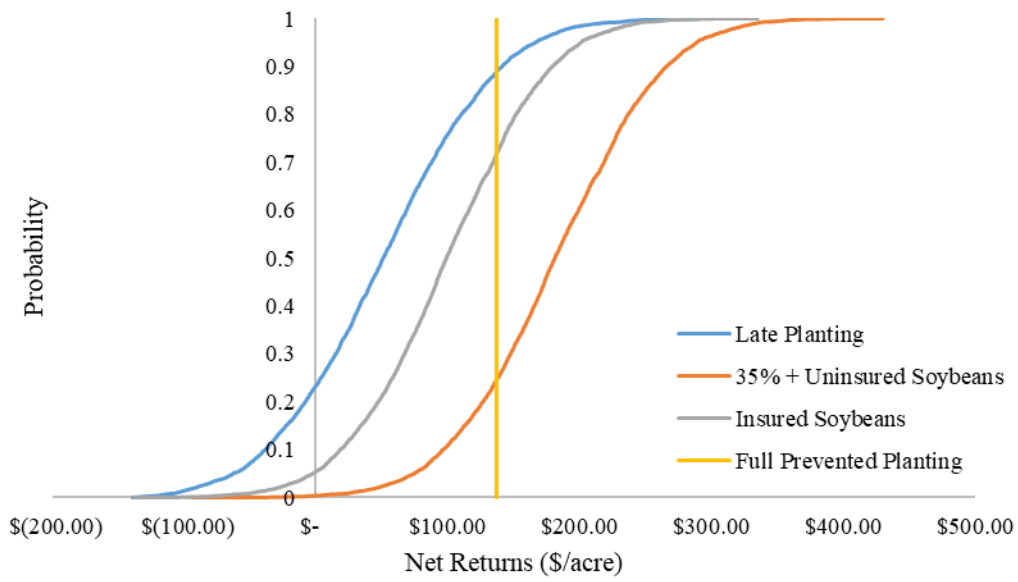


Figure 23. Cotton-Soybean Cumulative Distribution Function at 60% Yield Protection Coverage and 50% Prevented Planting Coverage

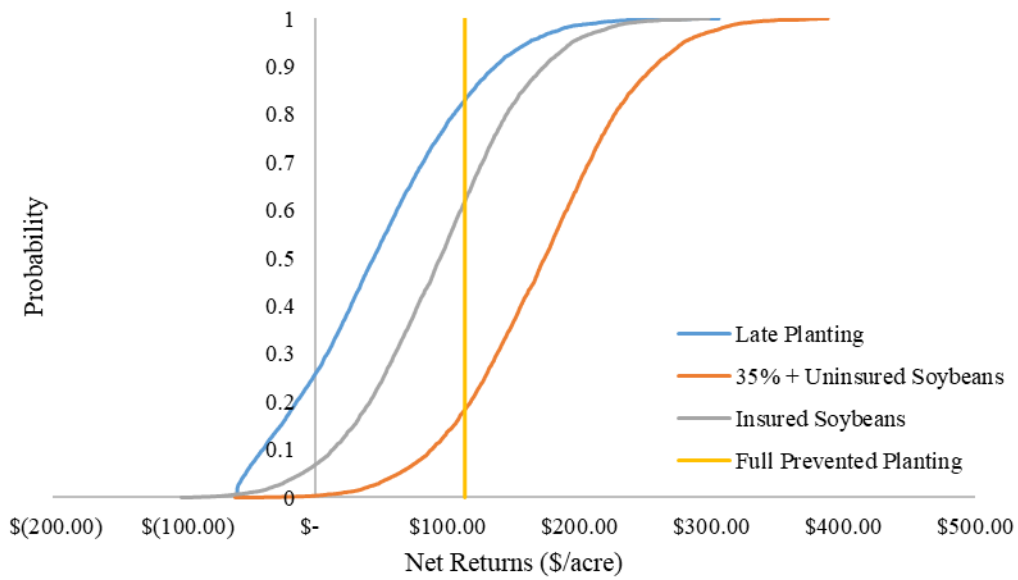


Figure 24. Cotton-Soybean Cumulative Distribution Function at 70% Yield Protection Coverage and 40% Prevented Planting Coverage

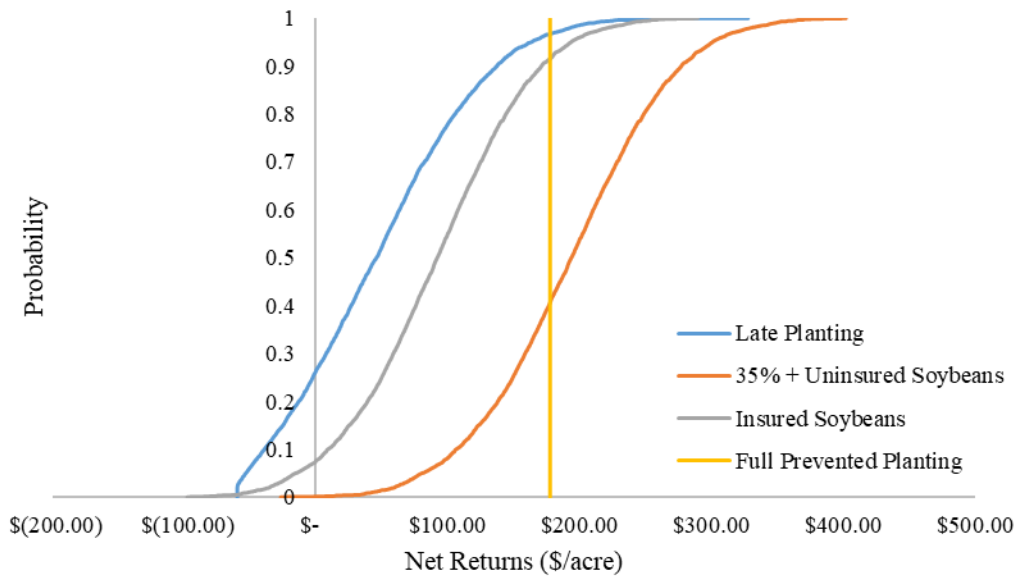


Figure 25. Cotton-Soybean Cumulative Distribution Function at 70% Yield Protection Coverage and 50% Prevented Planting Coverage

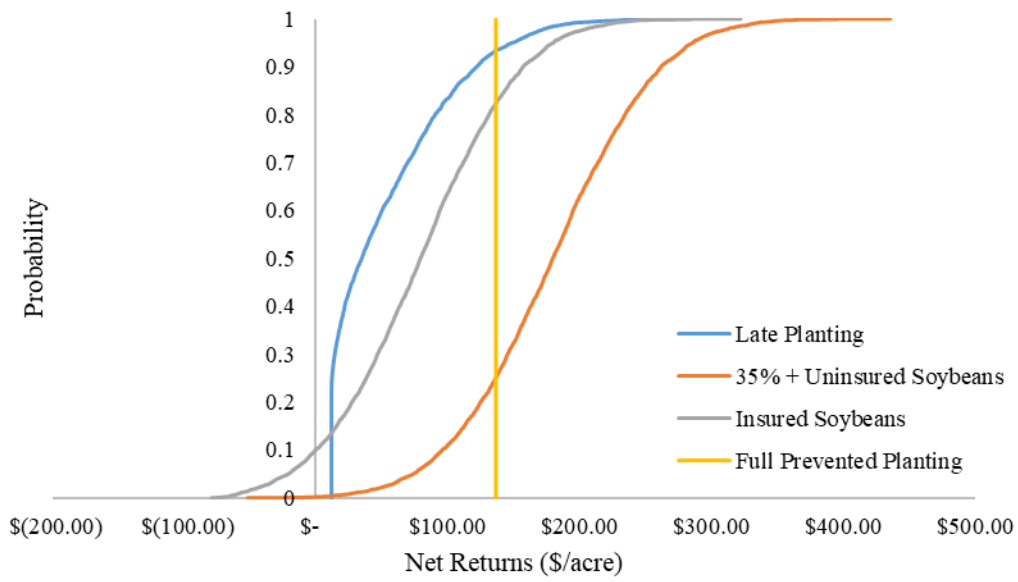


Figure 26. Cotton-Soybean Cumulative Distribution Function at 80% Yield Protection Coverage and 40% Prevented Planting Coverage

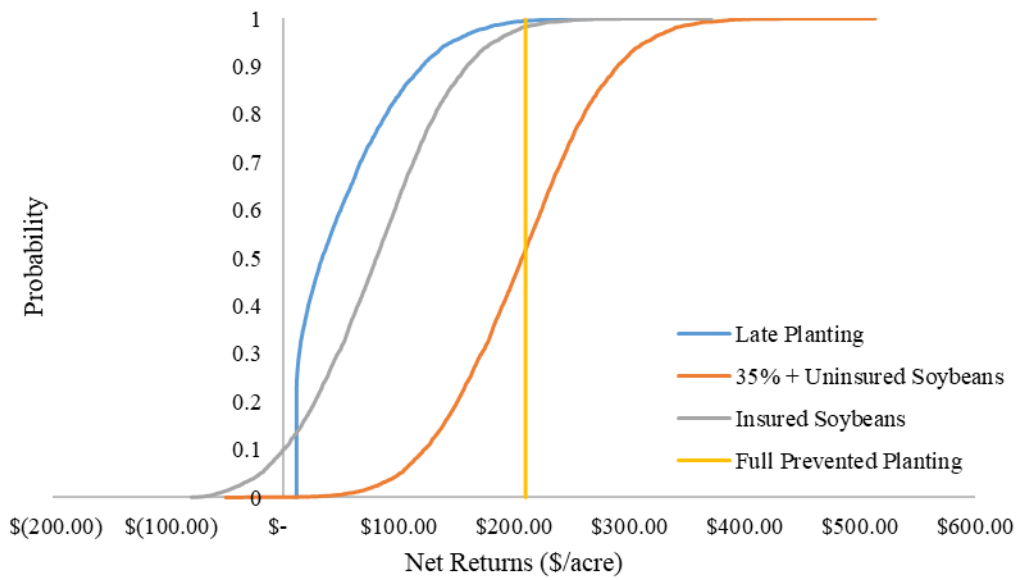


Figure 27. Cotton-Soybean Cumulative Distribution Function at 80% Yield Protection Coverage and 50% Prevented Planting Coverage

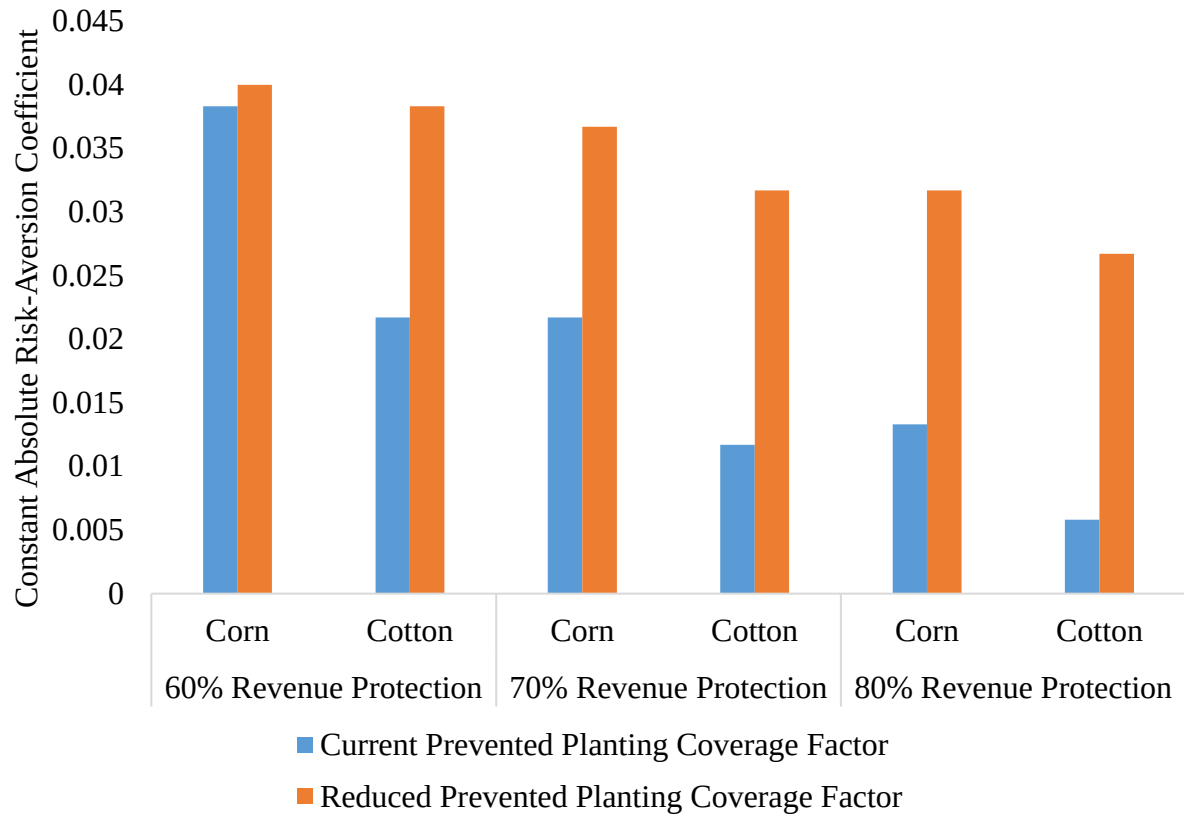


Figure 28. Constant Absolute Risk-Aversion Coefficients Levels where a Risk-Averse Producer with RP would Prefer the Full Prevented Planting Payment over the 35% Prevented Planting Payment and Plant Uninsured Soybeans

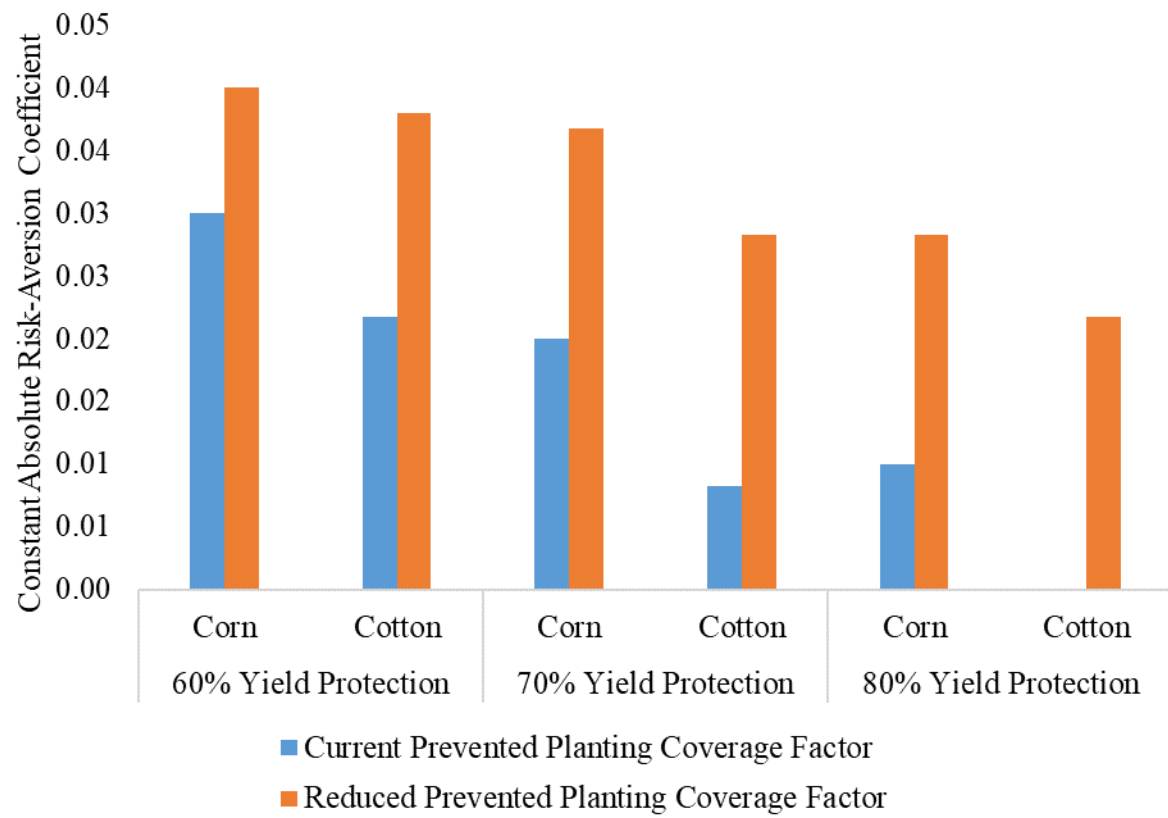


Figure 29. Constant Absolute Risk-Aversion Coefficients Levels where a Risk-Averse Producer with YP would Prefer the Full Prevented Planting Payment over the 35% Prevented Planting Payment and Plant Uninsured Soybeans

VITA

Kevin Adkins was born in Clarksville, Tennessee to the parents of Tom and Teresa Adkins. He grew up in Cedar Hill, TN. Kevin graduated from Jo Byrns High School in 2014 and started school at the University of Tennessee, Knoxville in August, 2014. He graduated with a Bachelor of Science degree in Agricultural and Resource Economics in December, 2017. Then, Kevin furthered his education by pursuing a Master of Science degree in Agricultural and Resource Economics at the University of Tennessee, Knoxville. He graduated in May, 2019.