ECONOMICS OF AFLATOXIN RISK MANAGEMENT IN CORN IN TEXAS

A Thesis

by

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ABSTRACT

Atoxigenics and crop insurance are available to producers to reduce economic loss from aflatoxin contamination in corn. Atoxigenics have shown in both test and practice to reduce aflatoxin contamination in corn. There have been a few studies on the economic feasibility of atoxigenics. This study expands a previous study that analyzed the economics of using atoxigenics for aflatoxin control in Bell County, Texas. The current study expands the previous study to other major corn producing districts in Texas. The current study also implements the One Sample Strategy aflatoxin testing method.

The objective of this study is to perform an economic analysis on the decision to use atoxigenic treatments on a corn crop and to evaluate the economic outcomes at different crop insurance coverage levels for corn production in Texas. The study used a risk based partial budget simulation model combined with an aflatoxin contamination simulation model to complete a risk analysis on the decision to use atoxigenics in various agricultural districts in Texas. Field-level data for aflatoxin contamination comes from Bell County, Texas. The aflatoxin distributions for the Blacklands were adjusted to reflect the relative mean and variance indicated by Isakeit's ranking of aflatoxin incidence for the remaining districts.

Net incomes of a representative farm of 500 acres were simulated with and without atoxigenic treatments. Each scenario was simulated across a range of crop insurance options available to corn producers in their respective agricultural districts in Texas. A total of 882 scenarios were simulated and compared based on net income.

Results show that, prior to crop insurance, atoxigenics provide financial benefits for seven of the nine Texas agricultural districts in the study. The treated non-insured net incomes of the Blacklands, Coastal Bend, Edwards Plateau, Lower Valley, South Central, South Texas, and Upper Coast districts were $10/acre to $40/acre higher than the untreated non-insured net incomes of the same districts. The Northern High Plains and Southern High Plains districts' results show that it is not cost effective to use atoxigenics. The treated non-insured net incomes from the Northern High Plains and Southern High Plains were $4.07/acre and $7.43/acre lower, respectively, than the untreated non-insured net incomes from the same districts. When crop insurance was incorporated into the model, the results show that six of the nine agricultural districts have financial incentives to use atoxigenics for aflatoxin control. The Blacklands, Coastal Bend, Edwards Plateau, Lower Valley, South Central, and Upper Coast districts had higher net incomes for treated scenarios than non-treated scenarios. The South Texas, Northern High Plains, and Southern High Plains had higher net incomes for non-treated scenarios than treated scenarios.

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1. INTRODUCTION

1.1 General Overview

Mycotoxins are toxic fungal metabolites that occur in a wide variety of feeds and foods (Richard, et al., 1989). Aflatoxin is a mycotoxin that is a chronic problem in agriculture. Aflatoxins are produced primarily by strains of *Aspergillus flavus* and *Aspergillus parasiticus* (Richard, et al., 1989). The species are soil born organisms, that can produce aflatoxins as they attach and build on a food source (Horne, et al., 1991). Consumption of aflatoxin contaminated feeds and foods are known to have detrimental health effects on humans and animals (Sampson, 2014). The International Agency for Cancer Research has classified aflatoxins as a group 1 carcinogen (International Agency for Cancer Research, 1993).

In Texas, grain elevators penalize corn price with a discount if aflatoxin is present (Sampson, 2014). A discount schedule links the level of aflatoxin contamination to the percent discount on corn price. In 2014, Texas producers harvested nearly 2 million acres of corn yielding over 290 million bushels (NASS 2014), and in 2013, corn contributed approximately $1.4 billion to the state’s economy (Sampson, 2014). The risk level for aflatoxin varies throughout regions Texas. Central Texas, eastern Texas, and the coastal bend tend to have higher aflatoxin levels on average than do west Texas and the panhandle regions. Humidity followed by dry weather tends to be the climate that provides the appropriate environment for aflatoxin accumulation (Sampson, 2014).

Mitigation methods have been developed to combat aflatoxin contamination. A non-aflatoxin producing strain of *Aspergillums flavus,* atoxigenics, can be applied to the corn plant to prevent aflatoxin producing strains of the fungus from developing. Crop insurance is another method in which the producer can protect from losses associated with aflatoxin contamination. If losses from aflatoxin push the yield or revenue below the guaranteed amount, an indemnity is paid to the producer. However, tests for aflatoxin at grain elevators are separate tests from the tests for crop insurance. It is possible that the grain elevator test could result in a higher level of aflatoxin than the crop insurance test, leaving the producer with an indemnity that does not cover the loss from the elevator.

Previously, there has been an economic analysis regarding the use of atoxigenics and crop insurance for protection against losses from aflatoxin. Sampson (2014) completed the economic analysis used data from Bell County, Texas. However, there is a need to expand this study from Central Texas to other parts of the state. The current study will also use a different aflatoxin testing method than the previous study.

This paper will highlight the previous information and research performed in this area of study. This study will include the variables needed to expand the previous study to the rest of Texas. Past and similar studies will be reviewed, the methodology used in this study will be described, and finally the results of the economic model will be presented and analyzed.

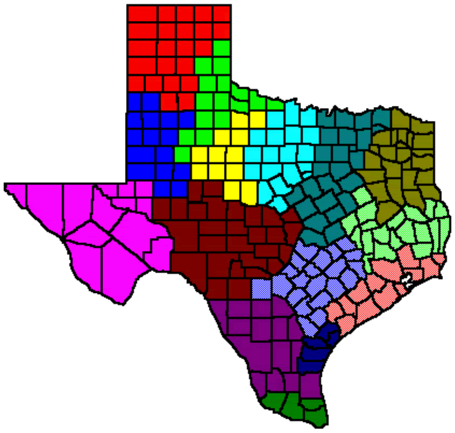
1.2 Problem Statement

Corn producers in the Blacklands agricultural district have access to an aflatoxin risk management decision tool. The decision tool uses data from Bell County, Texas.

The rest of Texas is lacking an economic analysis of the use of atoxigenic mitigations for preventing losses from aflatoxin. Professional opinion and results from the economic analysis for Central Texas may encourage the use of atoxigenic treatments; however, an economic analysis needs to be performed for the other regions of the state.

1.3 Objective

The objective of this paper is to expand a former study of using atoxigenic treatments and crop insurance on corn crops. This study will expand the former study from Central Texas to the rest of the state, and use the One Sample Strategy for aflatoxin testing. The study will analyze the economic outcomes of using atoxigenic treatments along with different crop insurance coverages levels for corn in the major corn producing regions in Texas. This paper will use an updated corn production partial budget simulation model combined with an aflatoxin contamination simulation model to perform a risk management analysis on the decision to use atoxigenic mitigation methods. Data used for the simulation model are unique to major corn producing regions in Texas. The current study will assist decision makers throughout the state of Texas by considering the risk of aflatoxin contamination, level of contamination, discrepancies of aflatoxin testing, cost of the atoxigenic treatment, premiums and indemnities for crop insurance for the decision maker’s region, stochastic yield for the decision maker’s region, and the stochastic corn price localized to the decision maker’s region. Figure 1 shows the crop reporting districts of Texas.



Key	Code	Numeric Name	Geographic Name
🟥	11	District 1-North	Northern High Plains
🟦	12	District 1-South	Southern High Plains
🟩	21	District 2-North	Northern Low Plains
🟨	22	District 2-South	Southern Low Plains
🟦	30	District 3	Cross Timbers
■	40	District 4	Blacklands
■	51	District 5-North	North East Texas
▨	52	District 5-South	South East Texas
🟪	60	District 6	Trans-Pecos
🟫	70	District 7	Edwards Plateau
▨	81	District 8-North	South Central
■	82	District 8-South	Coastal Bend
▨	90	District 9	Upper Coast
🟪	96	District 10-North	South Texas
🟩	97	District 10-South	Lower Valley

Figure 1 Map of Crop Reporting Districts in Texas (NASS, 2015)

2. BACKGROUND

2.1 Affected Area of Aflatoxin in Texas

Aflatoxin has historically been a problem in certain regions of the United States that produce corn, peanuts, and cotton. Aflatoxins develop in the corn kernel whenever the plant is undergoing stress (Horne, et al., 1991). Drought is the most common form of plant stress in Texas. Damage to the corn plant from insects also creates a more favorable environment for aflatoxin. The corn producer's production practices also influence aflatoxin contamination. Cultural practices that lead to reduced soil moisture can cause plant stress, leaving the plant at more risk for aflatoxin contamination (Horne, et al., 1991).

Reports suggest that approximately 25% of the world's food crops are affected by mycotoxins (Richard, et al., 1989). The consumption of aflatoxins has been implicated as a possible cause of liver cell cancer (LCC) in humans (Richard, et al., 1989). Health risk associated with human and animal health is common in developing countries where exposure to aflatoxins are widespread (Sampson, 2014). Developed countries such as the United States have regulatory agencies that do spot checks to insure a wholesome food supply (Horne, et al., 1991). Aflatoxin related problems in developed countries consist of rejection or price discounts at grain elevators and negative impacts on animal health (Sampson, 2014). The economic impact that aflatoxin has on corn is difficult to quantify because affected crops vary across years and regions (Richard, et al., 1989). Aflatoxin contamination is estimated to cost the United States approximately $500 million (Vardon, McLaughlin, & Nardinelli, 2003).

Regulatory agencies are necessary to monitor testing and conduct research regarding aflatoxin and its consequences. It is estimated that $30-$50 million is spent on aflatoxin management in the United States (Robens & Cardwell, 2003).

In the United States, states with hotter climates in the southeast and southwest are more susceptible to aflatoxin cooler states in the North and Midwest (Lubulwa & Davis, 1994).   In Texas, aflatoxin contamination is most commonly found in the East Central Texas and Coastal Bend regions, however aflatoxin is also found in the Northeast region and to a lesser extent the Panhandle region. Regions experiencing drought and other environmental stresses are more likely to develop aflatoxin in corn. However, even in this environment, affected crops may be randomly scattered throughout the stressed region (Horne, et al., 1991). It is difficult to forecast the upcoming or current year's aflatoxin contamination risk because of the randomness of affected crops. Below is the 2014 map of aflatoxin occurrences (Figure 2).

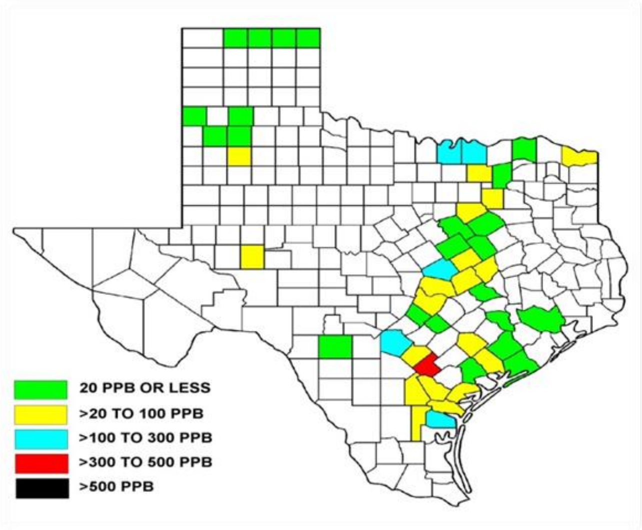


Figure 2 Aflatoxin Cases Reported in Texas from 2014 Corn Crop (OTSC 2014)

2.2 Aflatoxin Regulations

Corn exporting countries, such as the United States, must regulate the aflatoxin levels in corn and other crops or risk losing export markets abroad (Lubulwa & Davis, 1994). The United States limits aflatoxin contamination to 20 ppb for use in human food (Lubulwa & Davis, 1994). Countries importing corn from the United States tend to limit aflatoxin levels more strictly. Corn used in human food in Japan is limited to 10 ppb (Lubulwa & Davis, 1994). Many European countries limit aflatoxin levels to 4 ppb, for corn used in human food (Lubulwa & Davis, 1994). Aflatoxin limits in the United States varies among crops and uses for the crops. Table 1 portrays the U.S. Food and Drug Administration limits for aflatoxin in feed.

Table 1 FDA Action Levels for Aflatoxins in Animal Feeds (FDA, 2015)

Aflatoxin Limit	Commodity	Use of Commodity
20 ppb	Corn, Peanuts, Cottonseed Meal	Dairy animals, non-specific
20 ppb	Corn, Peanuts	Immature animals
100 ppb	Corn and Peanut products	Breeding beef cattle, breeding swine, mature poultry
200 ppb	Corn and Peanut products	Finishing Swine >100 lbs
300 ppb	Cottonseed Meal	Beef Cattle, Swine, or poultry
300 ppb	Corn and Peanut products	Finishing feedlot beef cattle

Texas complies with the FDA limits in the table, but has a few separate rules in addition. To meet the requirement for "Texas Standard for Wildlife Feed," the feed must be less than 50 ppb (OTSC, 2011). Corn with aflatoxin contamination with 300-500 ppb requires a blending permit from the Office of the Texas State Chemist (Sampson, 2014), or must be destroyed. Any grain with more than 500 ppb cannot enter the marketplace and must be destroyed with a record of disposition submitted to the Office of the Texas State Chemist (Sampson, 2014).

2.3 Aflatoxin Testing

The 1990 Farm Bill requires all exported corn to be tested to insure the corn aflatoxin levels do not exceed the acceptable levels (GIPSA, 2009). Domestic corn must comply with the Food and Drug Administration's action levels. Aflatoxin testing services are provided by the USDA Grain Inspection, Packers and Stockyards Administration (GIPSA) (GIPSA,2009). The Food and Drug Administration (FDA) and the Federal Grain Inspection Service (FGIS) have agreed to a Memorandum of

Understanding that when a lot of grain/rice/processed product tests over 20 ppb, the FGIS will notify the FDA (GIPSA, 2009).

There are two types of screening often used to test for aflatoxin. Blacklight testing is the initial test that detects the presence of *Aspergillus flavus* (Munkvold, Hurburgh, & Meyer, 2012). Blacklight testing has limited use because there is no guarantee that aflatoxins are present in the fungus (Munkvold, Hurburgh, & Meyer, 2012). Commercial tests are another testing method that Munkvold and colleges indicate offers a more accurate test. Commercial testing requires a 5 lb to 10 lb sample of grain. The sample is then ground before removing a subsample for the test kit (Munkvold, Hurburgh, & Meyer, 2012). The results from the test kit reveal aflatoxin presence and level of contamination. An alternative to using the blacklight test or commercial test is to send the sample to an official USDA-FGIS laboratory (Munkvold, Hurburgh, & Meyer, 2012).

2.4 Crop Insurance Indemnity Calculations

The crop insurance coverage options used in this study are Yield Protection, Revenue Protection, and Revenue Protection with Harvest Price Exclusion. Indemnities for each of the three coverage options are calculated for each Texas agricultural district in this study. Optional coverage refers to using one of the three insurance options on selected acres of the insured crop (Iowa State University Extension and Outreach, 2013). Enterprise coverage refers to grouping all of the producer’s insured crop in the same county under one insurance policy (Iowa State University Extension and Outreach, 2013). Each agricultural district in the study will have an indemnity for each of the three crop insurance coverage options. When calculating the partial budget, a premium for enterprise and optional coverage will be assigned for Yield Protection, Revenue Protection, and Revenue Protection with Harvest Price Exclusion.

Yield protection (YP) is a crop insurance policy that protects the producer against yield losses from natural causes such as drought, flood, hail, wind, insects, and disease (USDA-RMA, 2015). The producer is assigned an average yield based on his/her past crop yields. The producer selects a percentage of the average yield to insure. The production guarantee (PG) that the producer may select are in 5% increments from 50% - 85% of the average yield.

$$\text{PG} = \text{acres insured} * \text{average yield} * \text{percentage of average yield insured}$$

$$\text{PTC} = \text{acres} * \text{actual yield for growing season}$$

The projected price from the Chicago Mercantile Exchange (CME) is used as a price for the coverage option should there be an indemnity (USDA-RMA, 2015). The producer insures a percentage of the projected price in case of an indemnity. The producer may insure 5% increments from 55% - 100% of the projected price (for this study it is assumed that the producer selected to insure 100% of the projected price). An indemnity is triggered whenever the producer’s actual production to count (PTC) is less than the production guarantee (PG).

$$\text{Indemnity} = (\text{PG} - \text{PTC}) * \text{price guarantee}$$

PTC is the total yield from the acres that are under the insurance policy. The PTC can be discounted if the quality of the corn is low or reduced by a natural disaster or farming practice. Depending on the level of contamination, aflatoxin can be a cause of reduction of quality as demonstrated by Table 2. A load of corn that tests over 20 ppb of aflatoxin is assigned a reduction in value (RIV) (Sampson, 2014). The extent of the RIV increases with the level of aflatoxin. If aflatoxin is found in the corn the producer may receive either no discounts, varying discounts, or a destructive order (RMA, 2012) A discount schedule is used to link the level of aflatoxin to the discount. The RIV rates are determined by the grain elevator where the corn is sold. A discount factor is derived from the RIV, which in turn is used to derive a quality adjustment factor (QAF) (Sampson, 2014). The QAF is used to reduce the PTC for crop insurance purposes.

RIV = determined by the grain elevator

DF = RIV/market price at grain elevator

QAF = 1-DF

The adjusted PTC = total production of insured acres * QAF

The adjusted PTC is used for crop insurance purposes to calculate indemnities (Sampson, 2014). If afltoxin levels are high enough to drop the PTC below the production guarantee, the producer may receive an indemnity for the difference.

Table 2 Discount Schedule for Aflatoxin (RMA, 2012)

Aflatoxin Range ppb	**Discount Factor**
.1 - 20	0
20.1 - 50	0.1
50.1 - 100	0.2
100.1 - 200	0.3
200.1 - 300	0.4
300.1 & Above	.5 or 1*

*If corn is utilized then the discount is .5, or if corn must be destroyed the discount is 1.0

Revenue Protection (RP) is a crop insurance policy that protects against yield losses from natural causes such as drought, flood, hail, insects, or disease, and revenue losses when the harvest price decreased below the projected price (USDA-RMA, 2015). Under this coverage policy, the producer insures a percentage of his average yield and insures the minimum price he will receive at harvest. The producer insures yield from 50% - 85% of the average yield in 5% increments. Projected price is set at 100% of the CME futures price (USDA-RMA, 2015). The producer has the option of using the higher of projected price or the market price at the time of harvest. The percent guarantee of average yield multiplied by the higher of projected price or harvest price gives the producer a revenue production guarantee (RPG). Following harvest, the total PTC is multiplied by the harveset price to calculate the value of production to count (VPTC). The indemnity is equal to the difference between RPG and VPTC if difference is positve.

$$\text{RPG} = \text{acres insured} * \text{production guarantee} * \max(\text{projected price or harvest price})$$

VPTC = PTC * harvest price

Indemnity = RPG – VPTC

Revenue protection with harvest price exclusion (RPHE) is calculated the same way as RP, but harvest price is not used for the RPG. RPG for RPHE is calculated by multipying acres insured * production guarantee * projected price (USDA-RMA, 2015). For both RP and RPHE, PTC is a factor in determining if the producer gets an indemnity and the amount of the indemnity. Aflatoxin contamination could increase the QAF reducing the PTC.

2.5 Aflatoxin Mitigation Methods

There are several methods to prevent aflatoxin contamination. Certain production methods may be followed to decrease the chances of afltoxin contamination. Planting early can guard against late season drought and heat, two key factors of aflatoxin (Horne, et al., 1991). Cultural practices that require minimum soil disturbance should be used to conserve soil moisture (Horne, et al., 1991). If possible, applying irrigation during pollination decreases the chances of *Aspergillus flavus* infestation (Ball, 1998). Fertilization can reduce the risk of aflatoxin as deficiency in nitrogen and phosphorus have shown in studies to increase the risk of aflatoxin contamination (Horne, et al., 1991). Control of insects and weeds reduces plant stress that can increase the risk of aflatoxin (Horne, et al., 1991). Harvesting early when the kernals are near 20% moisture and quickly drying the kernals to 15% moisture prohibits *Aspergillus flavus* from completing its life cycle (Ball, 1998). During harvest, lowering the combine fan speed to reduce the physical damage to the kernals reduces aflatoxin (Horne, et al., 1991).

Post-harvest methods are equally important because *Aspergillus flavus* also spreads on corn in storage (Sampson, 2014). Prior to storage, bins should be cleaned to insure that clean corn is not stored with contaminated corn. Proper aeration and control of pest are necessary to reduce the risk of contaminating the corn while in the storage bin (Sampson, 2014).

Certain varieties of seed corn are more resistent to aflatoxin than others. Bt, *Bacillus thuringiensis,* is a corn variety that significantly reduces mycotoxin contamination (Wu, 2006). However, the mycotoxin that Bt most effectively guards against is fumonisin not aflatoxin (Wu, 2006). Bt corn is resistant to insects which damage the corn kernal. Although insect damage does increase the risk for aflatoxin, there are other substantial factors that lead to aflatoxin contamination. There is a mixed record of Bt corn's resistance to aflatoxin. However, studies have shown that in fields treated with *Aspergillus flavus* inoculum, lower levels of aflatoxin were found in Bt corn than non-Bt corn (Wu, 2006).

Non-Aflatoxin producing strains of *Aspergillus flavus* can be applied to corn fields to reduce the risk of aflatoxin contamination. AF-36 and Afla-Guard® are commercial strains of *Aspergillus flavus.* Both strains are atoxigenic, meaning they do not produce aflatoxin. AF-36 is heat-killed wheat seed colonized by the fungus (Isakeit, 2011a). It is labeled for aflatoxin in Texas corn and cotton and is produced by the Arizona Cotton Research and Protection Council (Isakeit, 2011a). The Texas distributor of AF-36 is Double CT LLC. Afla-Guard® is hulled barley seed coated with spores of the fungus, and labelled for aflatoxin control on Texas corn and peanuts. Syngenta Crop Protection, Inc. produces Afla-Guard® and is distributed by dealers who sell their products (Isakeit, 2011a). The focus of the study will be to determine the cost effectiveness of AF-36 and Afla-Guard®.

The atoxigenic strains work in the same manner, they attempt to crowd out the aflatoxin producing strains of the fungus (Isakeit, 2011a). The dormant fungus begins growing on the seed as a food source. New spores will be produced after a few days, and will spread to the silk of the corn plant. The fungus will then grow into the ear and colonize the kernals before the native aflatoxin producing strains develop (Isakeit, 2011a). The atoxigencs compete with toxic strains for limited growing space. According to Isakiet, "whoever occupies that space first, prevails. They cannot be bumped from the space by their competitors." The strategy is to apply the atoxigenics to the corn field before silking with numerous spores that outnumber the native aflatoxin producing strains (Isakeit, 2011a). AF-36 is labelled for application between the V-7 and silking, and Afla-Guard® is labelled for application between V10-V12 and silking (Isakeit, 2011a).

Texas A&M Agrilife Extension Service has conducted experiments using test plots to measure the effectiveness of Afla-guard® and AF-36. Isakeit conducted a study that discusses the results of the test in terms of parts per billion. The test plots consisted of dry land corn in Texas counties. Aflatoxin levels in test plots treated with atoxigenic strains were compared to those of untreated control test plots. The aflatoxin level in

2011 Nueces county corn treated with Afla-Guard® was 2 ppb, which was 6 % of the untreated control aflatoxin level (31 ppb) (Isakeit, 2011b). Hill, Colorado, and Ellis counties also showed a reduction of aflatoxin levels on the test plots treated with an atoxigenic strain; although only Colorado and Ellis counties had statistically significant reductions (Isakeit, 2011b). In another study, Dorner et al. tested the effectiveness of atoxigenic strains in reducing aflatoxin contamination. Afla-Guard® was applied to entire fields in two areas of Texas with non-treated control fields in the same respective areas. The two year study (2007 and 2008) indicated significant reduction of aflatoxins. The 2007 and 2008 mean aflatoxin levels for treated fields were 85% and 88% less than their respective non-treated control test plots (Dorner, 2010). While these studies show that atoxigenic strains can reduce aflatoxin levels, they do not provide analysis regarding economic effectiveness.

2.6 Sources of Risk

As both Horne et al. (1991) and Richard et al. (1989) pointed out, aflatoxin contamination is a random event. Although environmental factors such as drought increase the risk for aflatoxin; there are no guarantees aflatoxin will be present in a given field. The risk of aflatoxin varies from year to year, however the cost of purchasing and applying atoxigenics is fixed. There are two negative scenarios that producers face when deciding whether to purchase atoxigenics. One scenario is that the producer does not purchase the atoxigenic, but the year presents extreme growing conditions. If this happens and aflatoxin contaminates the corn, the producer must accept a RIV or possibly the loss of a crop. The second scenario is the inverse: the producer purchases the atoxigenic, but the growing conditions are favorable. Favorable growing conditions typically do not result in aflatoxin contamination (Horne, 1991). In the latter scenario the economic benefits of the atoxigenic are less than the cost to purchase and apply the atoxigenic (Sampson, 2014). The decision to use an atoxigenic is a risk because the decision could be a net cost rather than a net benefit.

Testing variability is another source of risk. As described in the report by Munkvold and colleges, a 5 to 10 pound sample of corn is taken to test the load of approximately 1,000 bushels (60,000 lbs). It is difficult to insure that the results from a 5 to 10 pound test represent the aflatoxin level for the entire load or field. Inaccurate test results can have extreme negative consequences on both the buyer and seller (Sampson, 2014). There are two potentially negative scenarios: a false positive and a false negative. A false positive portrays more aflatoxin than there acutally is. Inversly, a false negative portrays less aflatoxin than there actually is (Sampson, 2014). A false test will either harm the buyer or the seller.

A common practice in the industry is to find an elevator that performs a test with favorable results. If the test results at an elevator show an aflatoxin level greater than 300 ppb, the seller can drive to another elevator in hopes of test results lower than 300 ppb. Grain elevators, feedlots, and other downstream corn buyers risk buying a load with a higher level of aflatoxin than they believe it is. The consequence the false negative on the part of the grain elevator is not being able to sell the contaminated load to downstream buyers.

Originally there are two separate aflatoxin tests. Producers have their corn tested at the grain elevator before sale, and a crop insurance adjustor also tests the corn to determine loss of production due to aflatoxin contamination. Depending on the tests, the local grain elevator may discount the price with an RIV**.** RIVs in this study are calculated by deducting a percent of the market price. However, it is common to deduct a pre-determined amount for different levels of aflatoxin contamination. Also different grain elevators may have their own unique discount schedules, which may be changed at the grain elevators discretion. If a RIV is given, the producer now relies on collecting an insurance indemnity to cover the loss. For the crop insurance tests, an adjustor either takes a sample from the corn field or uses a sample saved by the producer or grain elevator. Because the insurance test is a separate affair, there is a possibility that the insurance test could result in less aflatoxin than the grain elevator test. In this situation, the producer would take a price discount at market, but would not recover all of the loses through a crop insurance indemnity. The potential risk for two separate tests is having a severe aflatoxin caused price discount, but the insurance test not triggering an indemnity payment (Sampson, 2014).

The risk of different testing results between local grain elevators and crop insurance agencies has prompted a more regimented approach to aflatoxin testing. One Sample Strategy is the testing method that brings Texas producers, crop insurance agents, and local grain elevators, feed mills, and regulators proper information about the true level of aflatoxin going into and out of corn bins (OTSC, 2015). The One Sample Strategy method standardizes the testing process and reduces the variability between separate aflatoxin tests. The program participants must use testing equipment approved by GIPSA to sample and grind corn, and must use GIPSA performance verified testing kits that have been validated by the Office of the Texas State Chemist. The One Sample Strategy tests are recognized as official results for crop insurance purposes as well as regulatory compliance (OTSC 2015). Using only one test will diminish the variability of using separate testing methods. However, there is still a risk for a false positive or false negative test (Sampson, 2014). As of 2014, there are 29 Texas grain elevators certified for the One Sample Strategey (OTSC 2015).

2.7 Aflatoxin Effects on Average Yield

Yield history is a key component of calculating crop insurance indemnites. The crop insurance coverage options used in this study protect against yield loss due to natural causes. The average yield is used to set a yield or revenue guarantee. Aflatoxin can be a cause of an adjusted PTC, which can trigger an indemnity for the current growing year. Although receiving an indemnity for losses triggered by low yield is beneficial to producers, the reduced PTC is in the yield history for 10 years. The 10 year yield history is used to calculate the average yield used for insurance premiums and indemnities (Iowa State University Extension and Outreach, 2013). Atoxigenics guard against yield losses caused by aflatoxin contamination. In addition to possible cash flow benefits for a single production year, the reduction of afltoxin via atoxigencs could increase the 10 year averge yield history. The increase in yield history, increases the production guarantee that is used determine insurance indemnities for the future growing season.

3. LITERATURE REVIEW

Studies have indicated that atoxigenics can effectively reduce aflatoxin contamination in corn. Many studies document both the human and animal health effects of consuming aflatoxin and other mycotoxins. Economic analysis is less common than the agronomics and health effects of aflatoxin, but there are a handful of studies that have attempted to determine the economics of aflatoxin risk management.

Sampson (2014) analyzed the economic benefits of using AF-36 and Afla-Guard® on corn in Bell County, Texas. The analysis consisted of aflatoxin contamination levels, county yields and price, and crop insurance coverage options for Bell County. Aflatoxin levels from fields treated with AF-36 or Afla-Guard® were used to create a distribution for aflatoxin contamination in treated fields. Likewise, aflatoxin levels from non-treated fields were used to create a distribution for fields not treated with the atoxigenics. A Texas A&M Agrilife Extension corn production budget for extension district 8 was used simulate a partial budget for a 500 acre field. Net revenues for the field were simulated using the treated aflatoxin probability distribution and the non-treated aflatoxin probability distribution. In addition to two aflatoxin probability distributions yield protection, revenue protection, and revenue protection with harvest price exclusion crop insurance policies were used in calculating the partial budget. Each policy had coverage options ranging from 50% - 85% with 5% increments. Non-insured treated and non-treated net revenues were the key output variables. In total there were 50 scenarios simulated net revenues.

Sampson (2014) reported that aflatoxin tests were recordered from 110, 92, and 114 fields during the years 2011, 2012, and 2013 respectively. The recorded tests were separated into treated and non-treated fields to estimate the probability distribution for aflatoxin. Using empirical distributions, stochastic aflatoxin in ppb was simulated for treated and non-treated fields. Aflatoxin results from the simulation, calculated that treated fields tested by local elevators had an average aflatoxin level in ppb of 2.62, with a standard deviation of 13.92. The simulation for non-treated fields tested at local elevators had an average aflatoxin level in ppb of 39.65 with a standard deviation of 75.71. Simulation results for treated fields tested by crop insurance adjustors had an average aflatoxin level of 4.87 ppb, with a standard deviation of 25.85. The simulation for non-treated fields tested by crop insurance adjustors had an average aflatoxin level of 73.60 ppb, with a standard deviation of 140.49 (Sampson, 2014).

Sampson (2014) used the simulated grain elevator aflatoxin levels to calculate the RIV; and the crop insurance aflatoxin levels were used to calculate the QAF for insurance purposes. The market price and total PTC were then used to calculate market revenue for treated and non-treated corn. The summary statistics for market revenue were then simulated. The average market revenue for the treated scenario was $376.68/acre, with a standard deviation of $105.90/acre. The average market revenue for the non-treated scenario was $350.73/acre, with a standard deviation of $98.99/acre (Sampson, 2014). Net revenue was then calculated by subtracting production cost. Production cost for treated fields were greater than that of non-treated fields by $16/acre because of the cost and application of the atoxigenic. Without the inclusion of crop insurance, the average net revenue for treated fields was $107.22/acre, with a standard deviation of $105/acre. The average net revenue for non-insured non-treated fields was $97.19, with a standard deviation of $97.35 (Sampson, 2014). However, when crop insurance was factored into the partial budget, the higher net revenues were for the non-treated scenarios. On average the treated field's indemnities were lower than the premiums paid for crop insurance, but the non-treated average indemnites were considerably higher than the premuims (Sampson, 2014). Sampson's study was that crop insurance premiums, priced by the USDA – Risk Management Agency, for treated fields are too high. The study indicated that in Bell County, Texas, purchasing crop insurance but not atoxigenics is more profitable than purchasing crop insurance and atoxigenics.

The Sampson study is beneficial to understanding the factors that influence the decision to use atoxigenics. The current study will expand this study from one district to the rest of the major corn producing districts in Texas. Sampson (2014) used a testing variance of 53%, meaning the aflatoxin tests at grain elevators were 53% lower than aflatoxin test at crop insurance agencies. The current study will implement the One Sample Strategy, which will reduce the testing variance between entities to 0%. Sampson (2014) allowed each load to be tested 3 times using 3 random tests. If load 1 tested over 300 ppb, a new test is performed, and so on until the third test. The first test with a result under 300 ppb is used in the model. Each additional test cost $0.17/bushel. The current test will perform a max of 2 tests. If the first test's results are over 20 ppb, a second test will be conducted. The second test uses the first test's result as mean, and has a relative variation of 20% of the first test. If 2 tests are performed, the average of the 2 are used in the model. Both test are performed at the same location, so no additional cost will be associated with the second test.

The USDA-ARS and Delta Research and Extension Center of Mississippi State University conducted an experiment to analyze both efficacy of biological control of aflatoxin and its economic feasibility. Weaver, Abbas, Falconer, Allen, Pringle, and Sciumbato (2015) conducted trials of Afla-Guard® and another atoxigenic strain of *Aspergillus flavus*, K49. The experiment consisted of fourteen field trials in Stoneville, Mississippi and additional trials on private farms in the region. The aflatoxin levels from the treated portion of the field were compared to the non-treated portion of the field. The atoxigenic treatments resulted in a decrease in the level of aflatoxin (Weaver et al., 2015). Their economic analysis compared the benefits of using Afla-Guard® and K49 with their respective cost. The benefits consisted of higher grain price because of the higher quality of grain. For their experiment, aflatoxin levels above 20 ppb were penalized $0.394 per metric ton per ppb aflatoxin up to 300 ppb (Weaver et al., 2015). Corn that was above 300 ppb was rendered unmarketable and was destroyed. The discount gives a price advantage to treated corn because the treated corn has a smaller probability of having high levels of aflatoxins. The negative factor of using Afla-Guard® or K49 was the cost of the treatments. Ten of the fourteen test plots did not contain enough aflatoxin to cause economic harm (aflatoxin was less than 20 ppb) (Weaver et al., 2015). The profitability of the treatments came from the four fields that experienced higher levels of aflatoxin in the control portion of the field (Weaver, Abbas, Falconer, Allen, Pringle, & Sciumbato, 2015). The economic analysis concluded that the use of Afla-Guard® and K49 as a form of atoxigenic control for aflatoxin is only profitable if the corn field experiences high levels of aflatoxins (Weaver et al., 2015). The article stated that to increase the profitability of using atoxigenics such as Afla-Guard®, better aflatoxin forecasting methods are needed. An accurate aflatoxin forecasting model is a key factor for determining whether the use of atoxigenic strains of *Aspergillus flavus* is economically feasible.

The Weaver et al. (2015) study demonstrates the basics of cost effectiveness of atoxigenics. The aflatoxin testing methodology is unclear, but probably was performed in a laboratory. The study shows the financial incentives of using atoxigenics in the Mississippi Delta without insurance coverage levels. The current study factors insurance coverage levels into the model. Analyzing indemnities for yield losses due to aflatoxin allows for a more complete analysis.

Testing variability is a key risk component of aflatoxin contamination, determining the effectiveness of atoxigenics, and ultimately the producer’s net revenue (Sampson, 2014). Testing variability impacted both the Sampson study and the study by Weaver et al. (2015). In the Sampson study, aflatoxin testing for crop insurance was on average approximately 53% higher than tests conducted by grain elevators (Sampson, 2014). The discrepancy resulted in lower RIVs at market and higher indemnities for corn testing positive for aflatoxin. The testing variance between the crop insurance test and the grain elevator test potentially undermined the economic feasibility of the atoxigenic treatments. The study by Weaver et al. (2015) indicated that more accurate aflatoxin forecasting methods could improve the economic feasibility of atoxigenic treatments.

A study conducted by Johansson et al. (2000) attempted to calculate aflatoxin test variance in a mathematical equation. The objective of their study was to determine functional relationships between variance components and aflatoxin concentration. The study consisted of two experiments estimating test variance using variable sample sizes (kg), subsample size (g), and number of aliquots to measure a certain aflatoxin contamination level (ppb) using a Romer mill and liquid chromatography (LC) testing procedures. The first experiment was an unbalanced nested procedure designed to measure three types of variance: total variance, combined variance of sample preparation and analysis, and sampling variance. According to Johansson et al. (2000), "total variance is the sum of sampling, sample preparation, and analytical variance and depends on sample size, mill type, subsample size, number of aliquots, and analytical procedure." Sample variance represented the variance of different test samples taken from the same lot of shelled corn. Sample preparation variance represented the variability of replicate subsamples taken from the same test sample (comminuted in the same mill). Analytical variance is the variance of replicate aliquots of extracts of a single subsample (Johansson et al. 2000).

The Johansson et al. (2000) experiment used 18 lots of shelled corn. A bulk sample of 45.4 kg was taken from each of the 18 lots. Each bulk sample was divided into 32 test sample each weighing 1.13 kg. Each of the 32 test samples were comminuted in a Romer mill. Two 50 gram subsamples were removed from 16 of the 32 comminuted samples (32 total subsamples), and one 50 gram subsample was taken from the remaining 16 comminuted samples (16 total subsamples). Each of 50 subsamples was tested for aflatoxin. The second experiment was designed to measure the analytical variance of subsamples in experiment 1. Ten subsamples were chosen from selected samples in the first experiment (Johansson et al., 2000).

Results of aflatoxin levels and variances were reported in a chart (Johansson et al., 2000). The results indicated a positive correlation between aflatoxin concentration and test variance. Johansson et al. (2000) used variances specific to 1.13 kg test samples and 50 g subsamples to predict the test variance of any given sample size. Equation 10 was modified to predict the variance of a sample depending on variables: aflatoxin concentration ($\hat{C}$), sample size in kg (Ns), subsample size in grams (nss), number of aliquots (na). The total variance estimate of the aflatoxin test, $S^2\hat{c}(t)$, is the result of the equation.

$$S^2\hat{c}(t) = \left[(12.95/ns) * \hat{C}^{.98}\right] + \left[(62.70/nss) * \hat{C}^{1.27}\right] + \left[(.143/na) * \hat{C}^{1.16}\right]$$

Using equation 10, a lot is corn tested with an aflatoxin concentration of 20 ppb, sample size of 1.13 kg, Romer mill comminuted subsample of 50 g, and quantifying 1 aliquot per subsample. The total variance, sampling, sample preparation, and analytical variances are 274.9 (CV = 82.9%), 214 (CV = 73.1%), 56.3 (CV = 37.5%), and 4.6 (CV = 10.7%) respectively (Johansson et al., 2000). The results indicate that sampling variance accounted for 77.8% of the total variance, while sample preparation accounts for 20.5% and analytical accounts for only 1.7% (Johansson et al., 2000).

In 2007, Parks et al. (2007) conducted a similar study. Their objective was to determine variability in aflatoxin test using the Aflatest method and the high-performance column liquid chromatography (HPLC). Ten different grain elevators tested corn for aflatoxin contamination using the Aflatest method, and the Louisiana Agricultural Chemistry (LAC) Laboratory tested corn using both the Aflatest method and the HPLC method (Park et al., 2007).

Corn from 10 grain elevators were used by Park et al. (2007). One truck load at each grain elevator was used to collect samples. Two 4.5 kg test samples were taken from each truckload. One of the 4.5 kg test was ground at the grain elevator and the other ground at the LAC laboratory. Three 50 g subsamples were then taken from each comminuted 4.5 kg test sample at each location. The cooperating grain elevator then performed an aflatoxin test for two 50 g subsamples (one from the sample ground at the elevator and one from the sample ground at the LAC laboratory). The LAC performed an aflatoxin test for four 50 g subsamples (two from the samples ground at the grain elevator and two from samples ground at the LAC laboratory). The two subsamples tested by the grain elevator quantified aflatoxin in only1 aliqout, while the four subsamples tested by the LAC laboratory quantified aflatoxin in two aliqouts from each subsample.

Results showed that Aflatests at the LAC laboratories were 46.2% higher than the Aflatest at the grain elevators (Park et al., 2007). The null hypothesis that LAC Aflatest would have no difference than grain elevator Aflatest was rejected at the 95% confidence limit at 4 grain elevators, and no significant difference was detected at 5 grain elevators (Park et al., 2007). When only examing the LAC results, the HPLC tests were about 18% higher than the Aflatest tests (Park et al., 2007).

Total variability was caluculated by summing the sampling, sample preparation, and analytical variances (Park et al., 2007). Total variances associated with HPLC and Aflatest were plotted with full log plots versus aflatoxin contamination. The total variances appeared to be a function of aflatoxin concentration (Park, et al., 2007). Equations 11 and 12 describe the variances for the Aflatest (S^2tla) and the HPLC test (S^2tlh) methods. C represents aflatoxin concentration.

$$S^2tla = 2.80\ x\ C^{1.282}$$

$$S^2tlh = 4.714\ x\ C^{1.203}$$

The conclusion to the Park et al. (2007) study suggested several reasons why the aflatoxin test at LAC were different from the aflatoxin test at the grain elevators. LAC laboratories probably have better equipment and technology for testing as well as scientists to properly run the test. Parks et al. (2007) also indicated that the work environment could be a factor. A laboratory could offer a more favorable work environment to perform the tests properly, whereas conducting the tests at the grain elevators facility could be more difficult. The total variance estimates for the HPLC and Aflatest testing methods were 173.2 (CV = 65.8%) and 130.7 (CV = 57.2%), respectively. The sampling variance was the highest of the variances used to calculate total variance (Park et al., 2007).

Total variability results from Park et al. (2007) are similar to those of the Johansson et al. (2000) study. In both studies sampling variability accounts for most of the total variability. An important find in the study by Park et al. (2007) was that aflatoxin testing in grain elevators were 46.2% lower than tests performed by the LAC laboratories. The descrepancy results in a lower RIV for contaminated corn and a higher indemnity. From the producer's position, the descrepancy diminishes the value of atoxigenics. The difference between the grain elevator tests and crop insurance test also creates a problem for grain elevators. When the grain elevator tests a truckload of corn, they test and assign an RIV for aflatoxin levels. When the grain elevator sells the corn, the business purchasing the corn also performs a test. If the business buying the corn from the grain elevator tests the corn at a laboratory, there is a 46.2% chance the results will show higher aflatoxin levels. There are two negative scenarios for the grain elevator in this situation. One is the corn might have tested under 300 ppb at the grain elevator but over 300 ppb at the buyer's laboratory. In this case, the grain elevator cannot make the sale and loses the cost of the corn and its hauling. The second case is the grain elevator tested the corn at a lower aflatoxin level than the laboratory, but the corn was still under 300 ppb. In this case, the RIV the grain elevator assigned to the producer was less than the RIV the business buying the corn assigned to the grain elevator. Consequently, the grain elevator sells the corn for less than the price for which it was bought (Welch, 2015). The risk of test descrepancy can be applied to any downstream business that buys and sells corn.

An example of a grain elevator that uses the One Sample Strategy is William County Grain Elevator. After the grain elevator has tested a truck load of corn, the seller recieves a testing certificate that is accepted by crop insurance agencies. The grain elevator uses the same type of testing equipment as the Office of the Texas State Chemist (OTSC). The manager of the grain elevator oversees the testing facilities to insure the test are as accurate as possible. Sampling is done in a meticulous manner to improve accuracy. Nine different sections of the truck load are probed to gather corn from all parts of the trailer, totaling between five and ten pounds of sample. The nine samples are thouroghly blended and ground. A 50 gram subsample is taken from the sample and tested for aflatoxin. The producer may request a retest if he feels the first test wasn't accurate. The second test is taken from different 50 gram subsample of the original 10 pound sample. The grain elevator takes the average of the two tests as the final test result. The final test result is used to assign RIVs and is a valid test for the crop insurance agency as well (Owen, 2015).

Management at the Williamson County Grain Elevator makes it a priority to create an adequate testing environment to assist the employees perform an accurate test. OTSC tested a corn sample and sent the same sample to William County Grain Elevator. Twice daily the grain elevator tests the sample to calibrate their test equipment. By checking to make sure the grain elevator's test results are the same as the OTSC test results, testing descrepancies are reduced. Additionally the grain elevator sends their own tested samples to OTSC to compare testing results. According to the manager of the grain elevator, the results are similar. The manager also said that the results of the tests of subsample 1 and subsample 2 (if requested by the seller) usually have a variance of 20% or less. Testing methods of William County Grain Elevator reduce testing descrepancies between the elevator and crop insurance agencies as well as OTSC. Also the sampling methods and testing methods reduce the variance of testing the same truck load.

The literature review of relative studies gives an insight into what has been done and what problems still remain. Atoxigenics have been effective at reducing aflatoxin in most studies, but testing variability and crop insurance coverage can prevent them from being cost effective. The Johansson et al. (2000) and the Park et al. (2007) studies described testing variance as a function on afltoxin concentration. By lowering aflatoxin levels, atoxigenics could effectively lower testing variance. Another way to combat the testing variability is to use the One Sample Stragtegy method with repeated recalibration. The use of this method will reduce the descrepancies between grain elevetor and crop insurance tests. One official test will also protect downstream businesses from sampling variance. If grain elevators and crop insurance agencies used the same test, the 46.2% difference could be eliminated. Putting RIVs and indemnities on equal playing fields could increase the cost effectiveness of atoxigenics.

4. THEORY

This chapter will explain the theory behind the methodology. Because of the high levels of risk in this study, risk and uncertainty will be discussed, along with degrees of risk aversion. The theory behind ranking risky scenarios will also be described, along with subjective utility functions used in this study.

4.1 Risk and Uncertainty

Risk and uncertainty has a been a part of agriculture since the first seed was planted and the first animal was domesticated. Farmers do not know whether any given year will be rainy or a drought. As generalized by Richardson (2008), “risk is the part of a business, the manager cannot control.” Market prices, yields, and changes in input cost were rated the most important sources of risk and uncertainty by farmers in Texas and parts of Kansas (Richardson, Simulation for Applied Risk Management with an introduction to Simetar, 2008). In regards to this study, corn producers do not know whether the upcoming or current year will have no, low, or high aflatoxin levels. According to Hardaker et al. (2004a), risk is imperfect knowledge where the probabilities of the possible outcomes are known, and uncertainty exist when the probabilities of known outcomes are not known. Risk can be defined as uncertain consequencs, and uncertainy as imperfect knowledge (Hardaker et al., 2004a). Anderson and Dillon (1992) state that uncertainty is always present in decision making in agriculture, but risk is present when the consequences of uncertainty will affect the well-being of the decision maker (DM). When making a risky decision, the DM must compare the possible outcomes of different risky choices.

4.2 Risk Classification

Different DM's have different tolerances for risk. Generally, there are three categories that a DM falls into. The categories include risk averse, risk neutral, and risk loving (Nicholson & Snyder, 2012). According to Syder and Nicholson (2012), individuals are risk averse if they exhibit a diminishing marginal utiltity of wealth. A risk averse DM prefers a guaranteed income over a risky income, so long as the expected values are the same. In addition, the DM is willing to pay a certain amount to avoid participating in the risky gamble (Nicholson & Snyder, 2012). The majority of farmers are assumed to be risk averse (Hardaker et al., 2004a), and for the purposes of this study the assumption will be that the DM is risk averse.

The risk aversion levels in farming varies depending on variables such as size and location of the operation, whether the crops are irrigated or dryland, and the personality of the farmer in general. The generalization that all farmers are risk averse, does not mean every farmer has the same utility function as there are degrees of risk aversion. Some degrees of risk aversion used by Richardson (2008) text are hardly risk averse, normal risk averse, rather risk averse, very risk averse, and extremely risk averse. Appropriate degree classification is crucial to conduct an accurate risk analysis. The von-Neumann-Morgenstern utility function U(W), is the most convenient representation of the DM's level of risk aversion (Meyer & Meyer, 2007). The utility function determines the highest expected value among available alternatives. However, the utility function is only unique to a positive linear transformation. The lack of uniqueness to different DM's makes using the utility function to compare levels of risk aversion difficult (Meyer & Meyer, 2007). According to Hardaker et al. (2004a), an accurate measure of degree of risk aversion is more important than the choice of the utility function.

Pratt (1964) and Arrow (1965) proposed a way to measure the degree of risk aversion by calculating an absolute risk aversion coefficient (ARAC). The ARAC is measured in the following equation: $A(W) = - U''(W)/U'(W)$. The equation to calculate ARAC for a person with normal risk aversion is derived as $1/W$, which indicates the ARAC decreases as wealth (W) increases (Pratt, 1964). Risk aversion levels could increase, decrease, or remain constant depending on changes in wealth (McCarl and Bessler, 1989). Pratt (1964) and Arrow (1965), classified risk aversion depending on its relationship with change in wealth. The classifications include decreasing absolute risk aversion (DARA), increasing absolute risk aversion (IARA), and constant absolute risk aversion (CARA) (Arrow, 1965). DARA indicates that the DM is less averse to risk as wealth increases. IARA indicates that the DM is more risk averse as wealth increases. Finally, CARA indicates that DM's risk aversion level is unchanged as wealth increases (Arrow, 1965) and (Pratt, 1964).

ARAC uniquely measures risk aversion for individual DM's by using the first and second derivatives of their utility function. However, there is a disadvantage of using ARAC. ARAC cannot properly scale the outcome variable (Meyer & Meyer, 2007). Whenever the same output variable is described in a different unit of measure, ARAC cannot change to fit the new unit of measure. This is a problem when dealing with wealth in different forms of currency, comparing nominal wealth of different time periods, or converting decimals to percentages during studies (Meyer & Meyer, 2007). To combat this problem Pratt (1964) and Arrow (1965) proposed a relative risk aversion coefficienct. RRAC was designed to make units of measure consistent across varies studies. RRAC was created multiplying wealth by ARAC. RRAC can be described as: $R(W) = ARAC * W$. RRAC added the advantage of consistent value that does not change when the outcome variable is measured by a different unit (Meyer & Meyer, 2007).

4.3 Subjective Utilities

Subjective probability refers to beliefs held by individual DM's that reflect their degree of uncertainty about an event (Bessler, 1984). Individual DM's have unique expectations about outcomes of various events. The DM's view on probabilities of events occuring and probabilities of consequences are their subjective expected utility (SEU) (Hardaker et al., 2004a). The DM's SEU is defined: $U(Wi) = \sum(Pi*(U(Wi)))$, where $U(Wi)$ is the utility of wealth in state i, and Pi is the probability of weath (W) occuring in state i. When choosing between different risky scenarios, most DM's will choose the scenario that yields the highest utility. The problem with using SEU is that the probabilities are subjective to individual DM's expectations, but to accurately obtain a SEU from each DM is not possible for a large study.

4.4 Certainty Equivalent

Another approach to ranking risky alternatives is using certainty equivalents (CE). The CE of a risky prospect is the sure sum with the same utility as the expected utility of the risky prospect (Hardaker, 2004b). Given a utility function, the CE is the point of indifference between the sure sum and the risky prospect. In other words, the DM will only prefer the risky prospect if its utility is higher than the sure (guaranteed) sum. In Figure 3, Nicholson and Snyder (2012) relate CE to a fair bet. The bet offers a 50-50 chance of winning or losing $h. The utility of current wealth is U(Wo), which is also the expected value of current wealth. The expected utility of participating in the gamble is EU(A), EU(A) = $\frac{1}{2}U(Wo+h)+\frac{1}{2}U(Wo-h)$, which also is the CE$_A$. The expected utility of the gamble is equal to the utility of current wealth, EU(G) = U(Wo). In this case the CE$_A$ has the same expected utility as not participating in the bet, thus a risk averse DM would not participate in the bet. Risk averse producers do not participate in fair bets because the certainty equivalent is not greater than initial utility. If the gamble doubled to a 50-50 chance of winning or losing $2h, then the DM would be even more unwilling to participate in the bet (Nicholson & Snyder, 2012). A disadvantage of using CE to rank risky scenarios is it also requires a utility function unique to the DM.

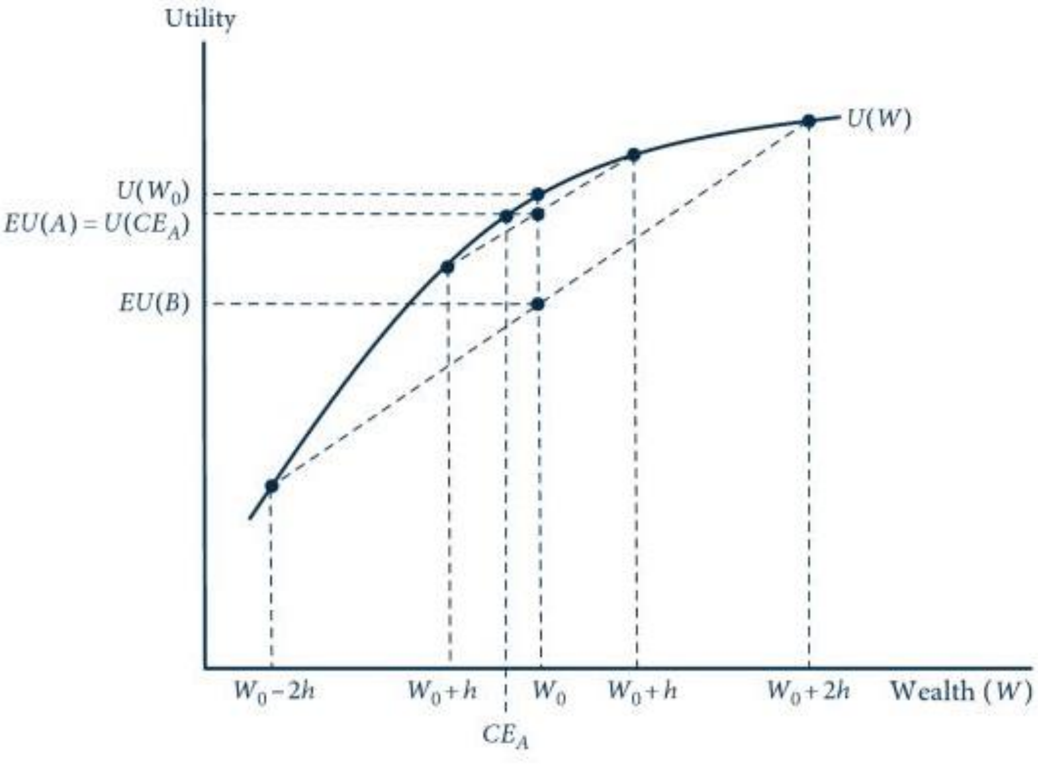


Figure 3 Utility of Wealth from Two Fair Bets (Nicholson and Snyder 2012)

4.5 Second Degree Stochastic Dominance

Second Degree Stochastic Dominance (SSD) is a method to assist DM's with varying degrees of risk aversion rank risky scenarios. Hardaker et al. (2004b) made the assumptions that more wealth is preferred to less wealth and the DM is not risk loving. Risk aversion bounds for SSD are between 0 and positive infinity for risk averse DMs (Hardaker et al., 2004b). SSD can rank risky scenarios in Excel by calculating the sum of the differences between distributions over all iterations for two cumulative distribution functions (CDFs) (Richardson 2008). The disadvantage of SSD is that it does not discriminate enough to yield useful results, meaning the efficient set can still be too large to manage easily (Hardaker et al., 2004b).

4.6 Stochastic Dominance with Respect to a Function

Meyer (1977) proposed stochastic dominance with respect to a function (SDRF) as a way to rank risky scenarios using a lower risk aversion coefficient and an upper risk aversion coefficient. SDRF ranks risky scenarios at both the lower and upper RACs, which is useful to choose scenarios when their respective CDFs cross (Richardson 2008). The consistency of SDRF is limited when the lower RAC and the upper RAC are too far apart, causing a lack of discrimination between the RAC bounds (Richardson 2008).

4.7 Stochastic Efficiency with Respect to a Function

Hardaker et al. (2004b) created stochastic efficiency with respect to a function (SERF) by merging the CEs with lower and upper RACs used by Meyer (1977). SERF evaluates many RACs between the lower and upper bounds, giving SERF the advantage over SDRF (Richardson 2008). In addition, SERF will use a lower ARAC of 0 for risk neutral DMs and an upper ARAC of 4/wealth to represent an extremely risk averse DM by analyzing risk ranking over neutral to very risk averse. This method considers all levels of risk aversion in SERF.

In this study, SERF is used to rank empirically estimated probability distributions of net income for alternative treated, not treated, and insurance scenarios. There is little change of income in respect $W_{0,}$ therefore a negative exponential function form with CARA assumptions will be used. SERF will rank a set of risky scenarios under the assumption of a risk averse DM.

5. METHODOLOGY

5.1 Simulation

According to Richardson (2008), the purpose of simulation in risk analysis is to estimate distributions of economic returns for alternative strategies so the DM can make more educated decisions. Simulation is useful when making decisions in risky situations. Simulating the returns of each risky alternative gives the DM the estimates of their probability distribution function (PDF) and cumulative distribution function (CDF). The PDF and CDF offer a visual representation of the potential outcomes and demonstrate the probability of each outcome occurring.

Monte Carlo simulation techniques offer a method of analyzing investments under conditions of uncertainty (Richardson & Mapp 1976). Subjective probablility distributions can be specified for the stochastic variables influencing the performance of an investment. Random values are drawn to obtain simulated values for the key economic variables. Results from the simulated values can concentrate the associated risk to a single value, such as net income. The PDF or CDF for the single value can then be used by the DM to make an educated decision (Richardson & Mapp 1976). This study will use Monte Carlo simulation techniques with Latin Hypercube sampling. Simetar®, an add in to Excel, is used to simulate 500 iterations for the stochastic variables to test their possible outcomes of net income. The first step for developing a model is to determine the stochastic variables that influence the DM’s decision to use atoxigenics and estimate probability distributions for the stochastic variables. The influential stochastic variables are simulated and used as input variables in the model to simulate the impact of the stochastic variables on the key economic variables (net-income). For simulation of random variables, the distribution of the variable must be defined and their parameters must be estimated (Reutlinger, 1970).

The current study will simulate and estimate probability distribution using empirical distributions for the following stochastic variables: yield, price, and aflatoxin levels. The stochastic variables are specific to the individual agricultural districts in Texas. Aflatoxin levels have two separate distributions, one for fields treated with atoxigenics and one for fields not treated. The separate aflatoxin probability distributions are used to calculate QAF for yield and RIV for price. The RIVs are for both grain elevators and crop insurance agencies, while QAFs are used only by crop insurance agencies. Crop insurance indemnities are calculated for both non-treated and treated fields. Crop insurance coverage policies include: yield protection, revenue protection, and revenue protection with harvest price exclusion. Each policy will have coverage options ranging from 50%-85%, in 5% increments. The resulting 50 crop insurance coverages will be used for both enterprise and optional policies. Partial budgets will be used to calculate net income for each of the coverage options. In addition to insurance coverage options, net income will be simulated for non-treated and treated fields that are not insured . In total there are eight crop insurance options, each option is simulated for non-treated and treated fields, all crop insurance calculations are for both enterprise and optional coverage policies, and addtionally there are non insured options for both non-treated and treated. The total number of simulations sums to 100 simulated options for each corn producing agricultural district in Texas.

5.2 Validation and Verification

Simulated variables will be verified and validated after simulation. Key economic variables such as net income must be verified. Verification includes checking the soundness of calculated equations and insuring that cell references are accurate. In Excel, the trace precedents/dependents function will be used to insure equations are calculated with the correct cell references. Validation will be performed via hypothesis testing. Simulated means of stochastic variables are compared to their respective historical means. Likewise, simulated variances are compared to historical variances. To fail to reject the null hypothesis indicates that the simulated means are statistically equal to historical means, validating the soundness of the stochastic variables (Richardson 2008).

5.3 Model Development

Once the empirical distributions for the stochastic variables are developed, they are linked to the deterministic variables to calculate indemnities and revenues. Stochastic yield is multiplied by total acres and QAF to calculate crop insurance indemnities. Market revenue and indemnites are summed to calculate total revenue. Finally, cost is subtracted from total revenue to calculate a stochastic net income.

The necessary mathematical equations are programmed to incorporate the stochastic variables to calculate the key economic variable, net income. Once calculated, net incomes for 100 scenarios are analyzed using SERF. The SERF analysis determines the efficient set of options, given crop insurance coverage levels and the choice of using atoxigenics.

5.4 Data

The estimated corn budgets for the agricultural districts were taken from the Texas A&M Agrilife Extension website (Extension 2015). The cost of the atoxigenics used, $11, and the aerial cost of application, $5, were taken from the Sampson study (Sampson 2014). Sampson obtained the the prices from contact with Georgia Pirtle of Pirtle Crop Insurance, in Bell County, Texas. Yield history since 1968 used to simulate corn yields for each agricultural district in the model were found on the national agricultural statistics service webpage (NASS 2015). Historic prices since 1980 used to simulate the Texas price were also from NASS. The model assumes a $3.90/bu mean price for 2015. The mean price is based on projections by extension economists at Texas A&M Agrilife Extension. Basis information was taken from CME to add to the Texas price.

Crop Insurance information used in the model were found on the USDA- Risk Management Agency webpage (USDA-RMA 2015). The webpage provides premiums that are factored into the cost of each coverage option/scenario. The webpage also displays the projected price used to calculate indemnity payments. Harvest prices used to calculate indemnities were taken from the Chicago Mercantile Exchange webpage (CME 2015).

Aflatoxin data were obtained from several entities. Pirtle provided aflatoxin information for the project. Pirtle reported aftatoxin test results in ppb for years 2011, 2012, and 2013. Along with the test results, Pirtle also reported whether or not the fields were treated with atoxigenics (Pirtle 2014). Bowers, grain specialist at United Ag Cooperative, in El Campo, Texas provided aflatoxin levels of treated fields in the Coastal Bend agricultural district (Bowers, 2015). Bowers reported 19 fields treated with varies levels of atoxigenics, 10 of the fields were 100% treated, while the remaining 9 fields ranged from 83% to 20% treated. Aflatoxin data provided by OTSC were also used to estimate probability distributions of aflatoxin for varies agricultural districts.

The Blacklands district will use a probability distribution estimated from the data reported by Pirtle. The remaining agricultural districts will be distributed based on expert opinion of aflatoxin levels of each remaining district. Dr. Isakiet ranked the aflatoxin contamination levels of the remaining districts on a scale of 1 to 10, with the Blacklands being a 10. The aflatoxin distributions for the Blacklands will be adjusted to reflect the relative mean and variance indicated by Isakeit's ranking of aflatoxin incidence. The aflatoxin information reported by Bowers will be used to validate the distribution by comparing the given data to the estimated distribution.

6. RESULTS

The results are presented in this section for the Texas agricultural reporting districts used in this study. Stochastic simulation results are presented for stochastic variables, market revenue, and indemnity payments. Market revenue, indemnity payments, and atoxigenic cost are incorporated into the partial budgets used to simulate net income. Net incomes of non-treated fields are compared to net incomes of treated fields, all with various coverage options.

6.1 Stochastic Variable Results

Three stochastic variables were included in this study. The variables consist of yield in bushels, price in $/bushel, and afltoxin contamination for non-treated and treated field measured in ppb. Each district in the study used variables unique to their area. District results are as follows. An empirical distribution was used for simulations. Every district uses the same Texas mean market price of $3.89/bushel and was simulated with a coefficient of variation of 14.83%. Districts were given a unique basis.

The district yields were simulated for each district for the 2015 growing season. The simulated average yield for the Blacklands was 80.64 bushels/acre with a coefficient of variation (CV) of 33.34%. The average historical basis was applied for each district market price. The average historic basis for the blacklands market price is -$0.25. The simulated average yield for the Coastal Bend was 65.64 bushels/acre with a CV of 37%. The average historic basis for the Coastal Bend is -$0.72. The simulated average yield for the Edwards Plateau district was 109.66 bushels/acre with a CV of 19.04%. The average historic basis for the Edwards Plateau is -$0.20. The simulated average yield for the Lower Valley was 82.18 bushels/acre with a CV of 29.02%. The average historic basis for the Lower Valley is -$0.70. The Northern High Plains simulated average yield was 189.87 bushels/acre with a CV of 14.63%. The average historic basis for the Northern High Plains is $0.30. The Southern High Plains simulated average yield was 128.85 bushels/acre with a CV of 17.74%. The South Central district simulated average yield was 75.02 bushels/acre with a CV of 28.56%. The average historic basis for the Southern High Plains is -$0.70. The South Texas district simulated average yield was 60.44 bushels/acre with a CV of 34.14%. The average historic basis for the South Texas district is -$0.70. The Upper Coast simulated average yield was 88.08 bushels/acre with a CV of 33.75%. The simulated yields in Figure 4 shows the CDF of the districts' simulated corn yields and do not take afltoxin contamination into account. The simulated yields in Figure 4 represent the overall yield before QAFs reduce the yield.

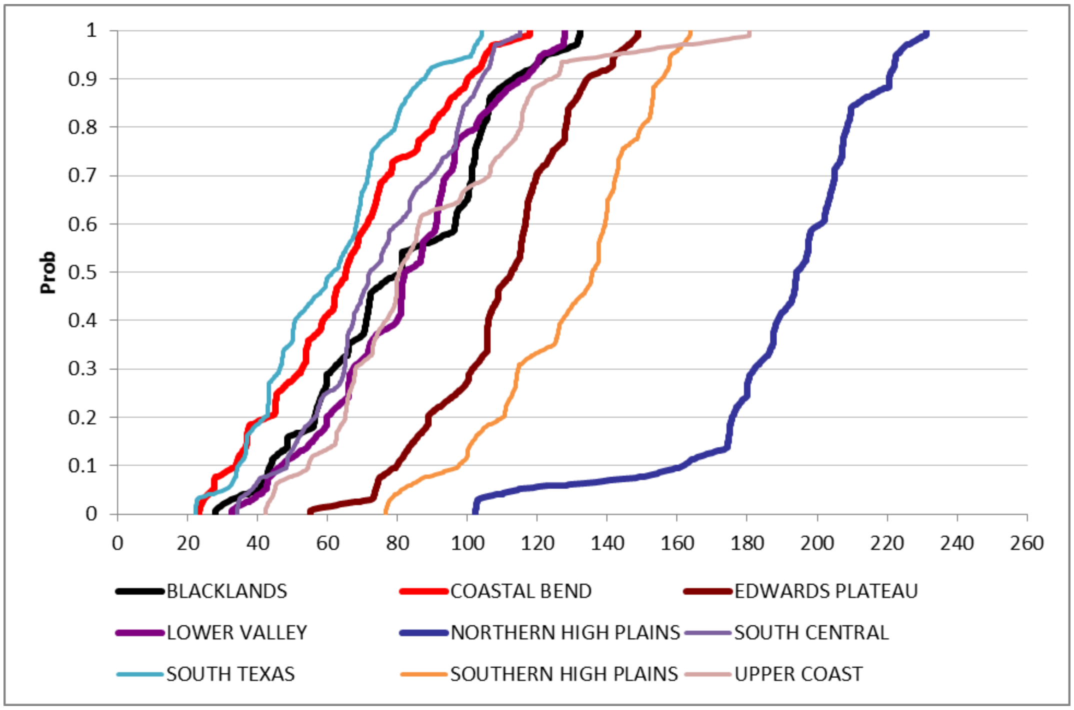


Figure 4 CDF of Texas Corn Not Treated with Atoxigenics by District

The One Sample Strategy was used to test for afltoxin. The One Sample Strategy uses one test for both grain elevator and crop insurance purposes. There are two afltoxin simulations for each district, corn from non-treated and treated fields. Districts ranked as a ten by Isakeit had the highest chance of having aflatoxin contamination while a district ranked as a zero has no chance of having aflatoxin contamination (Isakiet 2015). The Blacklands, Coastal Bend, and South Central districts were ranked ten. The Upper Coast and Lower Valley districts were ranked a nine. The Edwards Plateau and South Texas districts were ranked a seven. The Northern High Plains and Southern High Plains were ranked as a one (Isakeit 2015). Table 3 shows the simulated average aflatoxin contamination for the ranks 1, 7, 9, and 10. The summary statistics (Table 3) show that aflatoxin levels in non-treated fields have much higher mean, maximum, and standard deviations than do fields treated with atoxigenics. Non-treated fields have a much greater chance of having an aflatoxin conatmination greater than 20 ppb.

Table 3 Simulated Summary Statistics for Aflatoxin Contamination by Rank (ppb)

Variable	Rank 10 NT	Rank 10 T	Rank 9 NT	Rank 9 T	Rank 7 NT	Rank 7 T	Rank 1 NT	Rank 1 T
Mean	73.58	4.88	66.29	4.43	51.57	3.35	7.36	0.49
StDev	140.38	25.94	126.71	23.56	98.45	17.67	14.05	2.62
CV	190.79	531.26	191.14	532.15	190.91	527.95	190.87	532.21
Min	0	0	0	0	0	0	0	0
Max	730.33	270.02	657.29	243.02	511.23	189.02	73.03	27.00
Prob(Mean>20)	37.9%	5.3%	37.7%	5.1%	36.2%	4.8%	13.0%	0.6%

Figure 5 shows the probabilities of each district with a rank of 1, 7, 9, and 10 having aflatoxin contamination on the vertical axis. Non-treated fields in the districts with a rank of ten (Blacklands, South Central, and Coastal Bend) have a 37.9% chance of having aflatoxin contamination greater than 20 ppb (Table 3). Treated fields in the districts with a rank of ten (Blacklands, South Central, and Coastal Bend) had a 5.3% chance of having aflatoxin contamination greater than 20 ppb (Table 3). Non-treated fields in a district with a rank of nine (Upper Coast and Lower Valley) had a 37.7% chance of having aflatoxin contamination greater 20 ppb (Table 3). Treated fields in districts with a rank of nine (Upper Coast and Lower Valley) had a 5.1% chance of having aflatoxin contamination greater than 20 ppb (Table 3). Non-treated fields in districts with a rank of seven (Edwards Plateau and South Texas) had a 36.3% chance of having aflatoxin contamination greater than 20 ppb (Table 3). Treated fields in districts with a rank of seven (Edwards Plateau and South Texas) had a 4.8% chance of having aflatoxin contamination greater than 20 ppb (Table 3). Non-treated fields in districts with a rank of one (Northern High Plains and Southern High Plains) had a 13.0% chance of having aflatoxin contamination greater than 20 ppb (Table 3). Treated fields in districts with a rank of one (Northern High Plains and Southern High Plains) had a 0.6% chance of having aflatoxin contamination greater than 20 ppb (Table 3).

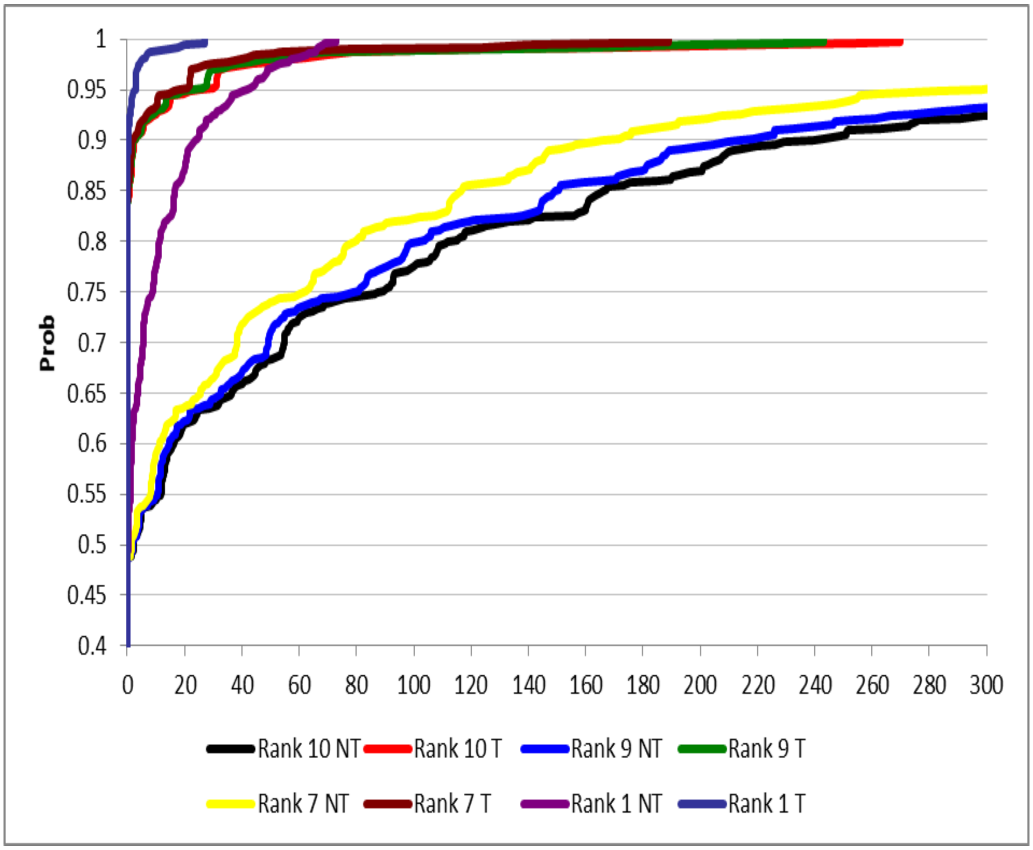


Figure 5 CDF of Simulated Aflatoxin Contamination by District Ranking (ppb)

6.2 Market Revenue

The stochastic variables discussed in the previous section were incorporated into equations used to calculate total production and total market revenue. Stochastic yield multiplied by 500 acres returns the total production. It is assumed that the farmer delivers the corn to the grain elevator in truckloads of 1,000 bushels. The grain elevator tests the truckloads of corn for aflatoxin. A second test is performed without charge at the seller’s request. If the tests resulted in an RIV, the discount was subtracted from the market price. The truckload was valued at 1,000 bushels multiplied by the price after the RIV was subtracted. Total market revenue was calculated by summing the value of each truckload. Equations 13, 14, and 15 demonstrate the calculation of total market revenue.

$$\text{Value of Truckload} = 1{,}000 * (\text{Market Price-RIV})$$

$$\text{Number of Truckloads} = (\text{Stochastic Yield} * 500)/1{,}000$$

$$\text{Total Market Revenue} = \text{Number of Truckloads} * \text{Value of Truckload}$$

Total market revenues were calculated for each agricultural district used for a non-treated 500 acre field and a treated 500 acre field. Table 4 shows the results of non-insured market revenues by district.

Table 4 Market Revenues for Texas Agricultural Districts in $/Acre

Variable	Blacklands NT	Blacklands T	Coastal Bend NT	Coastal Bend T
Mean	275.99	321.97	207.09	241.50
StDev	102.33	117.18	84.49	97.55
CV	37.08	36.39	40.80	40.39
Min	83.67	106.95	49.85	57.29
Max	594.63	687.54	500.32	538.00

	EP NT	EP T	Lower Valley NT	Lower Valley T
Mean	469.70	527.68	278.70	320.88
StDev	106.33	117.71	91.67	104.41
CV	22.64	22.31	32.89	32.54
Min	199.75	229.09	88.52	103.29
Max	801.79	900.06	580.63	630.67

	South Central NT	South Central T	South Texas NT	South Texas T
Mean	306.83	358.11	211.55	237.90
StDev	94.00	108.40	79.78	88.89
CV	30.64	30.27	37.71	37.36
Min	109.97	127.30	66.49	74.62
Max	586.06	684.33	491.75	526.77

	Upper Coast NT	Upper Coast T	NHP NT	NHP T
Mean	302.69	347.59	796.05	807.98
StDev	107.45	120.14	160.36	162.59
CV	35.50	34.56	20.14	20.12
Min	100.74	127.96	321.69	327.14
Max	657.28	721.10	1242.92	1268.06

	SHP NT	SHP T
Mean	569.66	578.23
StDev	125.61	127.36
CV	22.05	22.02
Min	249.04	252.27
Max	901.38	913.80

EP = Edwards Plateau, NHP = Northern High Plains, SHP = Southern High Plains
NT = Not Treated, T = Treated

Treated fields had an advantage in terms of market revenue (Table 4). Without RIVs the treated market revenues were higher than the non-treated market revenues. However, to understand the benefits of using atoxigenics the cost of purchasing and application needs to be subtracted. The cost of using atoxigenics includes purchasing cost of $11/acre plus $5/acre to apply, totaling $16/acre. The costs of purchasing and applying atoxigenics (CA) were subtracted from the difference of treated (TMR) and non-treated market revenue (NTMR). Equation 16 demonstrates the calculation.

$$\text{Benefit of Atoxigenic} = (TMR - NTMR) - CA$$

Where TMR = Treated Market Revenue

NTMR = Non-treated Market Revenue

CA = Cost of Purchasing and Applying Atoxigenics

Table 5 Monetary Benefit of Using Atoxigenics on Non-Insured Fields by District

District	Benefit $/Acre
Blacklands	29.98
Coastal Bend	18.41
Edwards Plateau	41.98
South Central	35.28
South Texas	10.36
Lower Valley	26.19
Upper Coast	28.90
Northern HP	-4.07
Southern HP	-7.43

Estimates prior to crop insurance show that seven of the nine agricultural districts benefit from using atoxigenics. The Northern High Plains and Southern High Plains were the only districts that did not benefit from the atoxigenics. Table 5 shows the results of equation 16 for each agricultural district. Table 5 shows prior to crop insurance the Edwards Plateau district benefits the most from the use of atoxigenics. As shown in Table 5, the difference between treated scenarios and non-treated scenarios for the Edwards Plateau district is $41.98/acre. The South Central district benefited the second most with a treated and non-treated difference of $35.28/acre (Table 5). The Blacklands had the third highest benefit of using atoxigenics with a treated to non-treated difference of $29.98/acre (Table 5). Upper Coast had the fourth highest benefit with a treated to non-treated difference of $28.90/acre (Table 5). The Lower Valley had the fifth highest benefit with a treated to non-treated difference of $26.19 (Table 5). The Coastal Bend had the sixth highest benefit with a treated to non-treated of $18.41 (Table 5). South Texas was the seventh and last district to benefit from atoxigenics with a treated to non-treated difference of $10.36 (Table 5). The Northern Highest had the lowest negative effect from using atoxigenics with a loss of $4.07/acre (Table 5). The Southern High Plains had highest negative effect from using atoxigenics with a loss of $7.43/acre (Table 5).

6.3 Crop Insurance Results

The stochastic yield, market price, and aflatoxin values were used to calculate stochastic crop insurance indemnities. The crop insurance coverage options are yield protection (YP), revenue protection (RP), and revenue protection with harvest price exclusion (RPHE). With each coverage option, a percentage of the average yield must be selecting from a range of 50% - 85% in 5% increments. Also each coverage option is under an enterprise and optional insurance policy. For example, CBETR70 means "Coastal Bend district, enterprise policy, treated scenario, and revenue protection coverage at 70% of the average yield." Each district also has non-treated and treated options that are not insured (NI).

A production guarantee (PG) or value of production guarantee (VPG) was determined for each insurance option. The guarantee was based on the average yield from the previous 10 years for each district. For YP, production to count (PTC) was subtracted from PG. If there was a positive difference, the difference was multiplied by a projected price to calculate an indemnity. For RP and RPHE, the value of PTC was subtracted from VPG and the positive difference was the indemnity. The One Sample Strategy mandates tests performed by the grain elevator are also used by the crop insurance agency. Stochastic crop insurance indemnities were calculated for all crop insurance coverage options and coverage levels, and a no insurance option, for both non-treated and treated scenarios.

The stochastic indemnities were simulated, and the overall results show that treatment scenarios consistently have lower indemnities than non-treated scenarios (Table 6). The probability of having an indemnity is also lower for treatment scenarios than non-treated scenarios. Lower indemnities for treatment options are attributed to lower and less frequent QAFs (Table 6). Atoxigenics reduce aflatoxin contamination, which directly lower QAFs. Lower QAFs trigger less indemnity payments. Table 6 shows the RP indemnities for all coverage scenarios. Table 7 shows the probabilities of receiving an indemnity for all RP coverage options.

Table 6 Indemnities for Revenue Protection Insurance Coverages in $/Acre

	BENR85	BENR80	BENR75	BENR70	BENR65	BENR60	BENR55	BENR50
Avg	48.66	41.88	35.64	29.96	25.18	20.68	16.89	13.84
StD	70.50	65.62	60.80	56.07	51.28	46.79	42.46	38.26
CV	145	157	171	187	204	226	251	276
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	239.87	225.76	211.65	197.54	183.43	169.32	155.21	141.10
P(0)	0.50	0.54	0.57	0.63	0.67	0.70	0.75	0.81

	BETR85	BETR80	BETR75	BETR70	BETR65	BETR60	BETR55	BETR50
Avg	24.84	19.55	14.84	10.73	7.86	5.39	3.29	1.84
StD	39.55	34.23	29.13	24.38	19.68	15.26	11.38	8.18
CV	159	175	196	227	250	283	346	446
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	147.99	133.86	119.73	105.60	91.47	77.34	63.21	49.08
P(0)	0.61	0.64	0.68	0.75	0.82	0.83	0.87	0.93

	CBENR 85	CBENR 80	CBENR 75	CBENR 70	CBENR 65	CBENR 60	CBENR 55	CBENR 50
Avg	87.83	75.51	63.98	53.20	43.22	33.77	25.45	18.52
StD	49.04	47.80	45.53	42.51	38.87	35.13	30.91	26.25
CV	56	63	71	80	90	104	121	142
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	174.08	161.02	147.96	134.90	121.84	108.78	95.72	82.66
P(0)	0.03	0.09	0.14	0.21	0.26	0.31	0.41	0.52

	CBETR 85	CBETR 80	CBETR 75	CBETR 70	CBETR 65	CBETR 60	CBETR 55	CBETR 50
Avg	71.52	60.80	50.78	41.20	32.45	24.91	18.62	13.48
StD	51.66	48.58	44.96	41.25	37.23	32.73	27.91	22.93
CV	72	80	89	100	115	131	150	170
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	167.23	154.17	141.11	128.05	114.99	101.93	88.87	75.81
P(0)	0.15	0.21	0.26	0.29	0.38	0.46	0.58	0.63

Table 6 Continued

	EPENR 85	EPENR 80	EPENR 75	EPENR 70	EPENR 65	EPENR 60	EPENR 55	EPENR 50
Avg	84.00	63.74	45.82	30.64	19.76	12.49	7.15	3.33
StD	55.20	52.26	47.42	41.32	33.66	25.60	17.98	11.64
CV	66	82	104	135	170	205	252	350
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	230.93	208.50	186.07	163.64	141.21	118.78	96.35	73.92
P(0)	0.08	0.13	0.26	0.44	0.57	0.74	0.78	0.87

	EPETR 85	EPETR 80	EPETR 75	EPETR 70	EPETR 65	EPETR 60	EPETR 55	EPETR 50
Avg	50.01	35.01	23.96	16.05	10.32	5.71	2.72	1.11
StD	53.38	47.22	39.56	31.57	23.67	16.73	11.03	6.90
CV	107	135	165	197	229	293	406	622
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	209.45	187.02	164.59	142.16	119.73	97.30	74.87	52.44
P(0)	0.27	0.44	0.56	0.70	0.77	0.83	0.90	0.97

	LVENR 85	LVENR 80	LVENR 75	LVENR 70	LVENR 65	LVENR 60	LVENR 55	LVENR 50
Avg	133.24	57709.77	48799.81	40192.50	32121.40	24546.52	17640.72	12182.42
StD	49.25	24622.68	24622.68	24083.40	22803.38	21096.12	19015.32	16154.65
CV	37	43	50	60	71	86	108	133
Min	39.00	10591.96	1682.00	0.00	0.00	0.00	0.00	0.00
Max	235.54	108860.61	99950.65	91040.70	82130.74	73220.79	64310.83	55400.88
P(0)	0.00	0.00	0.00	0.06	0.12	0.18	0.29	0.48

	LVETR 85	LVETR 80	LVETR 75	LVETR 70	LVETR 65	LVETR 60	LVETR 55	LVETR 50
Avg	109.00	91.87	75.67	60.31	46.01	33.59	23.93	16.50
StD	56.28	55.05	52.54	49.28	45.35	40.44	34.21	27.51
CV	52	60	69	82	99	120	143	167
Min	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	225.91	208.09	190.27	172.45	154.63	136.81	118.99	101.17
P(0)	0.00	0.06	0.11	0.17	0.22	0.41	0.50	0.62

Table 6 Continued

	SCENR 85	SCENR 80	SCENR 75	SCENR 70	SCENR 65	SCENR 60	SCENR 55	SCENR 50
Avg	54.96	44.62	34.99	26.32	18.76	12.56	8.49	5.24
StD	47.98	43.37	38.59	33.58	28.51	23.54	18.31	13.51
CV	87	97	110	128	152	187	216	258
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	157.07	142.49	127.91	113.33	98.76	84.18	69.60	55.02
P(0)	0.26	0.31	0.38	0.44	0.53	0.63	0.75	0.81

	SCETR 85	SCETR 80	SCETR 75	SCETR 70	SCETR 65	SCETR 60	SCETR 55	SCETR 50
Avg	41.94	16501.41	12459.92	8945.44	6209.08	4311.67	2756.53	1598.61
StD	44.54	19760.70	17235.13	14725.93	12211.91	9620.10	7250.77	5133.03
CV	106	120	138	165	197	223	263	321
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	146.98	66202.57	58913.48	51624.38	44335.29	37046.20	29757.11	22468.02
P(0)	0.35	0.41	0.48	0.56	0.72	0.75	0.82	0.87

	STENR 85	STENR 80	STENR 75	STENR 70	STENR 65	STENR 60	STENR 55	STENR 50
Avg	87.66	75.06	62.77	51.15	40.55	31.08	23.59	17.07
StD	47.30	45.72	43.87	41.37	38.02	34.07	28.88	23.49
CV	54	61	70	81	94	110	122	138
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	176.66	163.16	149.65	136.15	122.65	109.14	95.64	82.13
P(0)	0.06	0.07	0.11	0.18	0.24	0.38	0.49	0.55

	STETR 85	STETR 80	STETR 75	STETR 70	STETR 65	STETR 60	STETR 55	STETR 50
Avg	58.55	48.13	38.85	31.24	24.46	18.33	12.71	8.18
StD	50.07	46.67	42.59	37.45	32.07	26.70	21.66	16.84
CV	86	97	110	120	131	146	170	206
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	163.43	149.93	136.43	122.92	109.42	95.91	82.41	68.91
P(0)	0.21	0.25	0.38	0.47	0.53	0.56	0.61	0.71

Table 6 Continued

	UCENR 85	UCENR 80	UCENR 75	UCENR 70	UCENR 65	UCENR 60	UCENR 55	UCEN R 50
Avg	49.07	40.90	33.60	27.36	22.50	18.23	14.75	12.02
StD	70.35	65.67	61.01	56.36	51.57	47.04	42.73	38.62
CV	143	161	182	206	229	258	290	321
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	259.16	243.92	228.67	213.43	198.18	182.94	167.69	152.45
P(0)	0.45	0.48	0.55	0.65	0.70	0.74	0.80	0.84

	UCETR 85	UCETR 80	UCETR 75	UCETR 70	UCETR 65	UCETR 60	UCETR 55	UCET R 50
Avg	23.66	17.31	12.09	7.86	5.26	3.21	1.75	0.58
StD	35.37	29.80	24.41	19.50	14.73	10.28	6.20	2.49
CV	149	172	202	248	280	320	354	431
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	133.11	117.86	102.62	87.37	72.13	56.88	41.64	26.40
P(0)	0.56	0.61	0.68	0.80	0.86	0.88	0.92	0.93

	NHENR 85	NHENR 80	NHENR 75	NHENR 70	NHENR 65	NHENR 60	NHENR 55	NHEN R 50
Avg	103.10	69.50	41.99	24.25	14.61	10.20	7.06	4.49
StD	76.55	72.90	65.83	55.82	45.81	36.05	26.83	18.02
CV	74	105	157	230	314	353	380	402
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	344.76	307.82	270.89	233.95	197.02	160.08	123.15	86.21
P(0)	0.03	0.14	0.40	0.65	0.86	0.90	0.93	0.93

	NHETR 85	NHETR 80	NHETR 75	NHETR 70	NHETR 65	NHETR 60	NHETR 55	NHET R 50
Avg	44.86	27.71	17.51	12.74	9.30	6.54	4.12	1.96
StD	73.89	63.79	53.80	43.91	34.56	25.57	16.94	8.75
CV	165	230	307	345	371	391	411	446
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	304.31	267.37	230.44	193.50	156.57	119.63	82.70	45.76
P(0)	0.41	0.65	0.81	0.89	0.92	0.93	0.94	0.95

Table 6 Continued

	SHENR 85	SHENR 80	SHENR 75	SHENR 70	SHENR 65	SHENR 60	SHENR 55	SHEN R 50
Avg	76.50	55.23	37.84	26.00	16.78	9.61	5.04	2.48
StD	63.22	58.32	51.32	41.76	32.21	23.63	15.84	8.92
CV	83	106	136	161	192	246	314	359
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	223.07	197.15	171.24	145.32	119.40	93.48	67.56	41.64
P(0)	0.10	0.24	0.48	0.59	0.67	0.80	0.86	0.92

	SHETR 85	SHETR 80	SHETR 75	SHETR 70	SHETR 65	SHETR 60	SHETR 55	SHETR 50
Mean	41.35	29.72	20.41	12.58	7.52	4.15	1.95	0.34
StDev	57.33	47.73	38.11	29.43	21.25	14.07	7.42	1.71
CV	139	161	187	234	283	339	381	503
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	192.00	166.08	140.16	114.24	88.32	62.40	36.48	10.56
P(0)	0.50	0.59	0.67	0.76	0.83	0.91	0.92	0.96

B = Blacklands, CB = Coastal Bend, EP = Edwards Plateau, LV = Lower Valley, SC = South Central, ST = South Texas, UC = Upper Coast, NH = Northern High Plains, SH = Southern High Plains
E = Enterprise, N = non-treated, T = treated, R = Revenue Protection

Table 6 shows that indemnities are higher for non-treated fields than treated fields. Aflatoxin contamination can be a cause of yield loss if the contamination is high enough. Table 6 shows the simulated average indemnity for non-treated revenue protection at 85% in the Blacklands (BENR85) to be $48.66/acre. Whereas the treated indemnity for the same coverage is $24.84. The difference is $23.82, meaning the non-treated scenario received $23.82 more than the treated scenario with the same coverage (Table 6). The indemnity for the Coastal Bend non-treated revenue protection with 85% coverage scenario was $16.31 higher than the treated scenario with the same coverage (Table 6). The indemnity for the Edwards Plateau non-treated revenue protection with 85% coverage scenario was $33.99 higher than the treated scenario with the same coverage level (Table 6). The indemnity for the Lower Valley non-treated revenue protection with 85% coverage scenario was $24.24 higher than the treated scenario with the same coverage level (Table 6). The indemnity for the South Central non-treated revenue protection with 85% coverage scenario was $13.02 higher than the treated scenario with the same coverage level (Table 6). The indemnity for the South Texas non-treated revenue protection with 85% coverage scenario was $29.11 higher than the treated scenario with the same coverage level (Table 6). The indemnity for the Upper Coast non-treated revenue protection with 85% coverage scenario was $25.41 higher than the treated scenario with the same coverage level (Table 6). The indemnity for the Northern High Plains non-treated revenue protection with 85% coverage scenario was $58.24 higher than the treated scenario with the same coverage level (Table 6). The indemnity for the Southern High Plains non-treated revenue protection with 85%

coverage scenario was 35.15 higher than the treated scenario with the same coverage level (Table 6). For all scenarios of every district, indemnities were higher for non-treated scenarios than for treated scenarios, meaning that federal crop insurance costs increase on non-treated fields over treated fields.

Table 7 Probability of Indemnity Occurring for RP Insurance

BENR85	BENR80	BENR75	BENR70	BENR65	BENR60	BENR55	BENR50
0.51	0.48	0.43	0.37	0.30	0.28	0.23	0.17

BETR85	BETR80	BETR75	BETR70	BETR65	BETR60	BETR55	BETR50
0.39	0.36	0.31	0.25	0.19	0.17	0.14	0.07

CBENR85	CBENR80	CBENR75	CBENR70	CBENR65	CBENR60	CBENR55	CBENR50
0.97	0.91	0.86	0.79	0.74	0.69	0.59	0.48

CBETR85	CBETR80	CBETR75	CBETR70	CBETR65	CBETR60	CBETR55	CBETR50
0.85	0.79	0.74	0.70	0.62	0.54	0.42	0.37

EPENR85	EPENR80	EPENR75	EPENR70	EPENR65	EPENR60	EPENR55	EPENR50
0.92	0.87	0.74	0.56	0.42	0.26	0.22	0.13

EPETR85	EPETR80	EPETR75	EPETR70	EPETR65	EPETR60	EPETR55	EPETR50
0.73	0.56	0.44	0.30	0.23	0.17	0.10	0.03

LVENR85	LVENR80	LVENR75	LVENR70	LVENR65	LVENR60	LVENR55	LVENR50
1.00	1.00	1.00	0.95	0.88	0.82	0.71	0.52

LVETR85	LVETR80	LVETR75	LVETR70	LVETR65	LVETR60	LVETR55	LVETR50
1.00	0.95	0.89	0.83	0.78	0.58	0.50	0.38

SCENR85	SCENR80	SCENR75	SCENR70	SCENR65	SCENR60	SCENR55	SCENR50
0.74	0.69	0.62	0.56	0.47	0.37	0.25	0.19

Table 7 Continued

SCETR85	SCETR80	SCETR75	SCETR70	SCETR65	SCETR60	SCETR55	SCETR50
0.65	0.59	0.51	0.44	0.28	0.25	0.19	0.13

STENR85	STENR80	STENR75	STENR70	STENR65	STENR60	STENR55	STENR50
0.94	0.93	0.89	0.82	0.76	0.62	0.51	0.45

STETR85	STETR80	STETR75	STETR70	STETR65	STETR60	STETR55	STETR50
0.79	0.75	0.62	0.53	0.47	0.44	0.39	0.29

UCENR85	UCENR80	UCENR75	UCENR70	UCENR65	UCENR60	UCENR55	UCENR50
0.57	0.52	0.45	0.34	0.29	0.24	0.20	0.16

UCETR85	UCETR80	UCETR75	UCETR70	UCETR65	UCETR60	UCETR55	UCETR50
0.44	0.39	0.33	0.21	0.15	0.12	0.09	0.07

NHPENR 85	NHPENR 80	NHPENR 75	NHPENR 70	NHPENR 65	NHPENR 60	NHPENR 55	NHPENR 50
0.97	0.86	0.60	0.35	0.14	0.10	0.07	0.06

NHPETR 85	NHPETR 80	NHPETR 75	NHPETR 70	NHPETR 65	NHPETR 60	NHPETR 55	NHPETR 50
0.59	0.35	0.19	0.11	0.08	0.07	0.06	0.05

SHPENR 85	SHPENR 80	SHPENR 75	SHPENR 70	SHPENR 65	SHPENR 60	SHPENR 55	SHPENR 50
0.90	0.77	0.52	0.41	0.33	0.20	0.14	0.08

SHPETR 85	SHPETR 80	SHPETR 75	SHPETR 70	SHPETR 65	SHPETR 60	SHPETR 55	SHPETR 50
0.50	0.41	0.33	0.24	0.17	0.09	0.08	0.05

B = Blacklands, CB = Coastal Bend, EP = Edwards Plateau, LV = Lower Valley, SC = South Central, ST = South Texas, UC = Upper Coast, NH = Northern High Plains, SH = Southern High Plains
E = Enterprise, N = non-treated, T = treated, R = Revenue Protection

The probability of having an indemnity is higher for non-treated scenarios than treated scenarios. Aflatoxin levels are higher in non-treated scenarios, thus increasing the probability of having losses from aflatoxin contamination. Table 7 shows the probability of having an indemnity in the Blacklands district for non-treated revenue protection with 85% coverage is 12% higher than treated scenarios with the same insurance coverage. The probability of having an indemnity in the Coastal Bend district for non-treated revenue protection with 85% coverage is 12% higher than treated scenarios with the same treated scenarios, given the same insurance coverage (Table 7). The probability of having an indemnity in the Edwards Plateau district for non-treated revenue protection with 85% coverage is 19% higher than treated scenarios with the same treated scenarios, given the same insurance coverage (Table 7). The probability of having an indemnity in the Lower Valley district for non-treated revenue protection with 85% coverage is the same as treated scenarios with the same treated scenarios, given the same insurance coverage (Table 7), however all other non-treated coverage scenarios have a higher probability of having an indemnity than treated scenarios with the same coverage levels. The probability of having an indemnity in the South Central district for non-treated revenue protection with 85% coverage is 8% higher than treated scenarios with the same treated scenarios, given the same insurance coverage (Table 7). The probability of having an indemnity in the South Texas district for non-treated revenue protection with 85% coverage is 15% higher than treated scenarios with the same treated scenarios, given the same insurance coverage (Table 7). The probability of having an indemnity in the Upper Coast district for non-treated revenue protection with 85% coverage is 13% higher than treated scenarios with the same treated scenarios, given the same insurance coverage (Table 7). The probability of having an indemnity in the Northern High Plains district for non-treated revenue protection with 85% coverage is 38% higher than treated scenarios with the same treated scenarios, given the same insurance coverage (Table 7). The probability of having an indemnity in the Southern High Plains district for non-treated revenue protection with 85% coverage is 40% higher than treated scenarios with the same treated scenarios, given the same insurance coverage (Table 7). The Edwards Plateau, Northern High Plains, and Southern High Plains have the greatest difference between probabilities of having an indemnity between non-treated and treated scenarios because those regions have higher yields.

Next, the simulated indemnities were compared to RMA premiums for crop insurance. The method compares the inflow and outflow of having crop insurance. RMA premiums listed in Table 8 are from the USDA's Quick Estimator tool, for corn in each respective district. The premiums were for one acre, the projected price for each district, and 100% price coverage. RMA subsidizes a certain percentage of the actual premium. The producer pays the remaining balance after the RMA subsidy. The amount the producer pays was used for this study.

Crop insurance uses the same premiums for both treated and non-treated scenarios. For example, RP coverage of 70% for a treated field is the same premium as a RP 70% non-treated field. For example, BENR85 and BETR85 both have a premium of $29.05/acre (Table 8) even though the probability and mean indemnity for BENR85 is higher than BETR85 (Tables 6 and 7). The results from Table 6 show the non-treated scenarios consistently receive higher indemnities than treated scenarios. Because the premiums are the same, non-treated scenarios receive considerably more money from crop insurance than do treated scenarios (Table 8). Table 8 shows the difference between RP indemnities received and premiums paid in each district.

Table 8 Differences Between Mean Indemnities and RMA Premiums for RP Insurance ($/Acre)

Non Treat	BENR 85	BENR 80	BENR 75	BENR 70	BENR 65	BENR 60	BENR 55	BETR 50
Indemnity	48.66	41.88	35.64	29.96	25.18	20.68	16.89	13.84
Premium	29.05	16.55	9.05	6.40	5.18	4.20	3.46	2.86
Difference	19.62	25.33	26.59	23.56	20.00	16.49	13.43	10.98

Treat	BETR 85	BETR 80	BETR 75	BETR 70	BETR 65	BETR 60	BETR 55	BETR 50
Indemnity	24.84	19.55	14.84	10.73	7.86	5.39	3.29	1.84
Premium	29.05	16.55	9.05	6.40	5.18	4.20	3.46	2.86
Difference	-4.21	3.00	5.79	4.33	2.68	1.19	-0.17	-1.03

Non-Treat	CBENR 85	CBENR 80	CBENR 75	CBENR 70	CBENR 65	CBENR 60	CBENR 55	CBNR 50
Indemnity	87.83	75.51	63.98	53.20	43.22	33.77	25.45	18.52
Premium	36.90	21.79	13.47	10.02	8.49	7.14	5.94	4.94
Difference	50.93	53.72	50.50	43.18	34.73	26.63	19.52	13.57

Treat	CBETR 85	CBETR 80	CBETR 75	CBETR 70	CBETR 65	CBETR 60	CBETR 55	CBER 50
Indemnity	71.52	60.80	50.78	41.20	32.45	24.91	18.62	13.48
Premium	36.90	21.79	13.47	10.02	8.49	7.14	5.94	4.94
Difference	34.62	39.01	37.31	31.18	23.95	17.78	12.68	8.54

Non-Treat	EPENR 85	EPENR 80	EPENR 75	EPENR 70	EPENR 65	EPENR 60	EPENR 55	EPENR 50
Indemnity	84.00	63.74	45.82	30.64	19.76	12.49	7.15	3.33
Premium	27.54	15.62	9.30	6.62	5.37	4.28	3.43	2.73
Difference	56.47	48.11	36.52	24.01	14.39	8.21	3.72	0.60

Treat	EPETR 85	EPETR 80	EPETR 75	EPETR 70	EPETR 65	EPETR 60	EPETR 55	EPETR50
Indemnity	50.01	35.01	23.96	16.05	10.32	5.71	2.72	1.11
Premium	27.54	15.62	9.30	6.62	5.37	4.28	3.43	2.73
Difference	22.48	19.39	14.67	9.43	4.95	1.43	-0.71	-1.62

Non-Treat	LVENR 85	LVNR80	LVENR 75	LVENR 70	LVENR 65	LVENR 60	LVENR 55	LVNR 50
Indemnity	133.2	115.4	97.60	80.39	64.24	49.09	35.28	24.36
Premium	96.48	57.18	35.55	26.56	22.59	19.05	15.91	13.15
Difference	36.76	58.24	62.05	53.82	41.65	30.05	19.37	11.22

Table 8 Continued

Treat	LVETR 85	LVETR 80	LVETR 75	LVETR 70	LVETR 65	LVETR 60	LVETR 55	LVTR 50
Indemnity	109.0	91.87	75.67	60.31	46.01	33.59	23.93	16.50
Premium	96.48	57.18	35.55	26.56	22.59	19.05	15.91	13.15
Difference	12.52	34.69	40.12	33.75	23.41	14.55	8.03	3.36

Non-Treat	SCENR 85	SCENR 80	SCENR 75	SCENR 70	SCENR 65	SCENR 60	SCENR 55	SCENR 50
Indemnity	54.96	44.62	34.99	26.32	18.76	12.56	8.49	5.24
Premium	30.61	18.01	11.14	8.25	7.00	5.87	4.88	4.15
Difference	24.35	26.61	23.85	18.07	11.76	6.69	3.61	1.09

Treat	SCETR 85	SCETR 80	SCETR 75	SCETR 70	SCETR 65	SCETR 60	SCETR 55	SCETR 50
Indemnity	41.94	33.00	24.92	17.89	12.42	8.62	5.51	3.20
Premium	30.61	18.01	11.14	8.25	7.00	5.87	4.88	4.15
Difference	11.33	14.99	13.78	9.64	5.42	2.76	0.63	-0.95

Non-Treat	STENR 85	STENR 80	STENR 75	STENR 70	STENR 65	STENR 60	STENR 55	STENR 50
Indemnity	87.66	75.06	62.77	51.15	40.55	31.08	23.59	17.07
Premium	28.02	16.25	9.88	7.24	6.09	5.08	4.32	3.68
Difference	59.64	58.81	52.88	43.90	34.46	26.00	19.27	13.40

Treat	STETR 85	STETR 80	STETR 75	STETR 70	STETR 65	STETR 60	STETR 55	STETR 50
Indemnity	58.55	48.13	38.85	31.24	24.46	18.33	12.71	8.18
Premium	28.02	16.25	9.88	7.24	6.09	5.08	4.32	3.68
Difference	30.52	31.88	28.97	24.00	18.37	13.25	8.39	4.51

Non-Treat	UCENR 85	UCEN R 80	UCEN R 75	UCENR 70	UCENR 65	UCEN R 60	UCENR 55	UCENR 50
Indemnity	49.07	40.90	33.60	27.36	22.50	18.23	14.75	12.02
Premium	27.03	15.36	8.38	5.99	4.88	4.01	3.33	2.76
Difference	22.04	25.54	25.22	21.37	17.62	14.22	11.43	9.26

Treat	UCTR85	UCTR80	UCTR75	UCTR70	UCTR65	UCTR60	UCTR55	UCTR50
Indemnity	23.66	17.31	12.09	7.86	5.26	3.21	1.75	0.58
Premium	27.03	15.36	8.38	5.99	4.88	4.01	3.33	2.76
Difference	-3.37	1.95	3.71	1.86	0.39	-0.80	-1.57	-2.18

Table 8 Continued

Non-Treat	NHNR85	NHNR80	NHNR75	NHNR70	NHNR65	NHNR60	NHNR55	NHNR50
Indemnity	103.10	69.50	41.99	24.25	14.61	10.20	7.06	4.49
Premium	20.62	11.08	6.21	3.89	2.69	1.88	1.35	0.98
Difference	82.48	58.43	35.78	20.35	11.92	8.32	5.71	3.51

Treat	NHTR85	NHTR80	NHTR75	NHTR70	NHTR65	NHTR60	NHTR55	NHTR50
Indemnity	44.86	27.71	17.51	12.74	9.30	6.54	4.12	1.96
Premium	20.62	11.08	6.21	3.89	2.69	1.88	1.35	0.98
Difference	24.24	16.63	11.30	8.85	6.62	4.66	2.77	0.99

Non-Treat	SHNR85	SHNR80	SHNR75	SHNR70	SHNR65	SHNR60	SHNR55	SHNR50
Indemnity	76.50	55.23	37.84	26.00	16.78	9.61	5.04	2.48
Premium	18.38	9.85	5.60	3.79	2.88	2.09	1.52	1.11
Difference	58.12	45.38	32.24	22.21	13.90	7.53	3.52	1.38

Treat	SHTR85	SHTR80	SHTR75	SHTR70	SHTR65	SHTR60	SHTR55	SHTR50
Indemnity	41.35	29.72	20.41	12.58	7.52	4.15	1.95	0.34
Premium	18.38	9.85	5.60	3.79	2.88	2.09	1.52	1.11
Difference	22.97	19.87	14.80	8.79	4.64	2.07	0.43	-0.77

B = Blacklands, CB = Coastal Bend, EP = Edwards Plateau, LV = Lower Valley, SC = South Central, ST = South Texas, UC = Upper Coast, NH = Northern High Plains, SH = Southern High Plains
E = Enterprise, N = non-treated, T = treated, R = Revenue Protection

Table 8 shows producers who purchase insurance and do not use atoxigenics were more likely to receive higher average net indemnities than producers who do treat with atoxigenics. Table 8 shows the difference between RP indemnities and RMA premiums for all coverage scenarios in the districts. In the Blacklands district, the difference between the non-treated average RP indemnity at 85% coverage and the RMA premium was $23.83/acre higher than the treated scenario with the same coverage (Table 8). In this coverage (BETR85), the difference between indemnity and premium is negative (-$4.21/acre). In the Coastal Bend district, the difference between the non-treated average RP indemnity at 85% coverage and the RMA premium was $16.31/acre higher than the treated scenario with the same coverage (Table 8). In the Edwards Plateau district, the difference between the non-treated average RP indemnity at 85% coverage and the RMA premium was $33.99/acre higher than the treated scenario with the same coverage (Table 8). In the Lower Valley district, the difference between the non-treated average RP indemnity at 85% coverage and the RMA premium was $24.24/acre higher than the treated scenario with the same coverage (Table 8). In the South Central district, the difference between the non-treated average RP indemnity at 85% coverage and the RMA premium was $13.02/acre higher than the treated scenario with the same coverage (Table 8). In the South Texas district, the difference between the non-treated average RP indemnity at 85% coverage and the RMA premium was $29.11/acre higher than the treated scenario with the same coverage (Table 8). In the Upper Coast district, the difference between the non-treated average RP indemnity at 85% coverage and the RMA premium was $25.41/acre higher than the treated scenario with the same coverage (Table 8). In the Northern High Plains district, the difference between the non-treated average RP indemnity at 85% coverage and the RMA premium was $58.24/acre higher than the treated scenario with the same coverage (Table 8). In the Southern High Plains district, the difference between the non-treated average RP indemnity at 85% coverage and the RMA premium was $35.15/acre higher than the treated scenario with the same coverage (Table 8). When looking at a one year budget, there is a risk that crop insurance will cover losses from aflatoxin more effectively than atoxigenics, but a partial budget simulation is needed to answer this question. However, the argument could be made that producers who apply atoxigenics to their corn should receive a lower premium than a producer who does not use atoxigenics for aflatoxin control.

6.4 Stochastic Partial Budget Analysis

Stochastic market revenue and insurance indemnities were simulated for each agricultural district using stochastic yield, market price, and aflatoxin contamination variables. Atoxigenic and aerial application costs were added for all treatment scenarios. Gross revenue consisted of total market revenue and insurance indemnities, and cost included a partial budget for cost of production, the atoxigenic and aerial costs for all treatment scenarios, and varying insurance premiums for the different insurance coverage options and coverage levels. Stochastic net incomes were simulated for each insurance option under the non-treated and treated scenarios.

The partial budget net incomes were simulated for 882 options across all districts and insurance combinations. The options included: 9 districts * 3 coverage options * 8 coverage levels * 2 (non-treated or treated) * 2 (enterprise or optional) + (2*9) (non-insured non-treated and non-insured treated for 9 districts). Table 9 shows the summary statistics of the net-incomes for non-insured options for both non-treated and treated scenarios by district.

Table 9 Net Incomes for Non-Insured Scenarios for all Districts ($/Acre)

Variable	BL NT	BL T	CB NT	CB T	EP NT	EP T
Mean	-57.92	-27.74	-109.55	-91.19	106.21	148.76
StDev	98.88	114.72	83.26	95.83	105.59	117.29
CV	-170.72	-413.49	-76.00	-105.08	99.42	78.84
Min	-259.25	-253.39	-265.70	-266.10	-135.69	-140.98
Max	245.44	322.79	129.63	238.66	447.62	514.29

	LV NT	LV T	SC NT	SC T	ST NT	ST T
Mean	26.72	53.11	-8.81	26.35	-20.10	-9.80
StDev	92.31	104.75	93.79	108.68	79.27	87.11
CV	345.54	197.22	-1064.23	412.42	-394.43	-888.58
Min	-176.59	-160.88	-213.41	-207.06	-170.36	-184.26
Max	284.88	341.25	256.53	315.10	252.35	277.00

	UP NT	UP T	NHP NT	NHP T	SHP NT	SHP T
Mean	-10.53	18.29	122.93	118.91	-181.78	-189.23
StDev	118.13	131.04	150.35	152.57	118.63	120.50
CV	-1121.51	716.34	122.30	128.31	-65.26	-63.68
Min	-222.97	-223.22	-285.91	-297.15	-472.19	-483.62
Max	473.98	507.07	532.63	539.59	142.34	148.98

The net incomes of non-insured non-treated and treated scenarios could have were positive or negative depending on the Texas A&M Agrilife Extension corn budget for the districts. For the purposes of this study, only the differences between non-treated and treated net incomes are analyzed. Table 9 shows that seven of the nine districts have higher non-insured treated average net incomes than non-insured not treated average net incomes. In the Blacklands district, the average difference between the non-insured treated and non-insured not treated scenarios was $30.18/acre (Table 9). In the Coastal Bend district, the average difference between the non-insured treated and non-insured not treated scenarios was $18.36/acre (Table 9). In the Edwards Plateau district, the average difference between the non-insured treated and non-insured not treated scenarios was $42.55/acre (Table 9). In the Lower Valley district, the average difference between the non-insured treated and non-insured not treated scenarios was $26.40/acre (Table 9). In the South Central district, the average difference between the non-insured treated and non-insured not treated scenarios was $35.17/acre (Table 9). In the South Texas district, the average difference between the non-insured treated and non-insured not treated scenarios was $10.29/acre (Table 9). In the Upper Coast district, the average difference between the non-insured treated and non-insured not treated scenarios was $28.83/acre (Table 9). In the Northern High Plains district, the average difference between the non-insured treated and non-insured not treated scenarios was -$4.02/acre (Table 9). In the Southern High Plains district, the average difference between the non-insured treated and non-insured not treated scenarios was -$7.45/acre (Table 9).

Figures 6, 7, and 8 show the StopLight analysis for the respective favorable, cautionary, and unfavorable net income results for all 500 acres, between the ranges of $0 to $25,000 for the non-insured options. The StopLight analysis charts are visual representations of probabilities. The green bar represents the favorable probability of the net income exceeding $25,000. The yellow bar represents the cautionary probability of net income between zero and $25,000. The red bar represents the unfavorable probability of the scenario net income failing to reach $0.

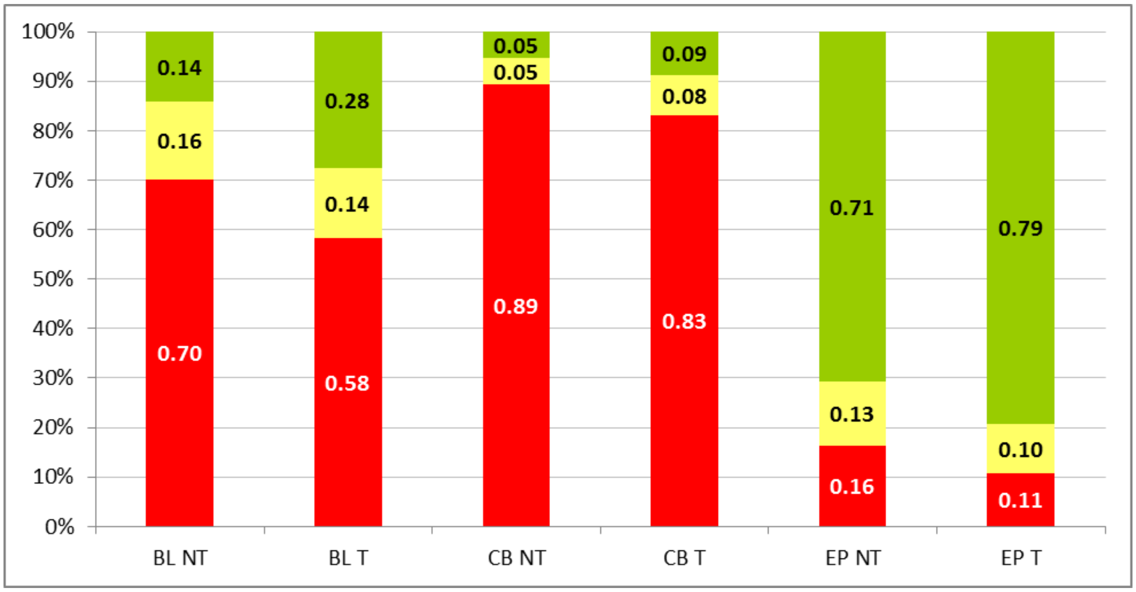


Figure 6 Stoplight Analysis of Non-Insured Net-Incomes for the Blacklands, Coastal Bend, and Edwards Plateau Districts for Probabilities Less than $0 and Greater than $25,000

BL = Blacklands, CB = Coastal Bend, EP = Edwards Plateau
NT = Not-treated, T = Treated

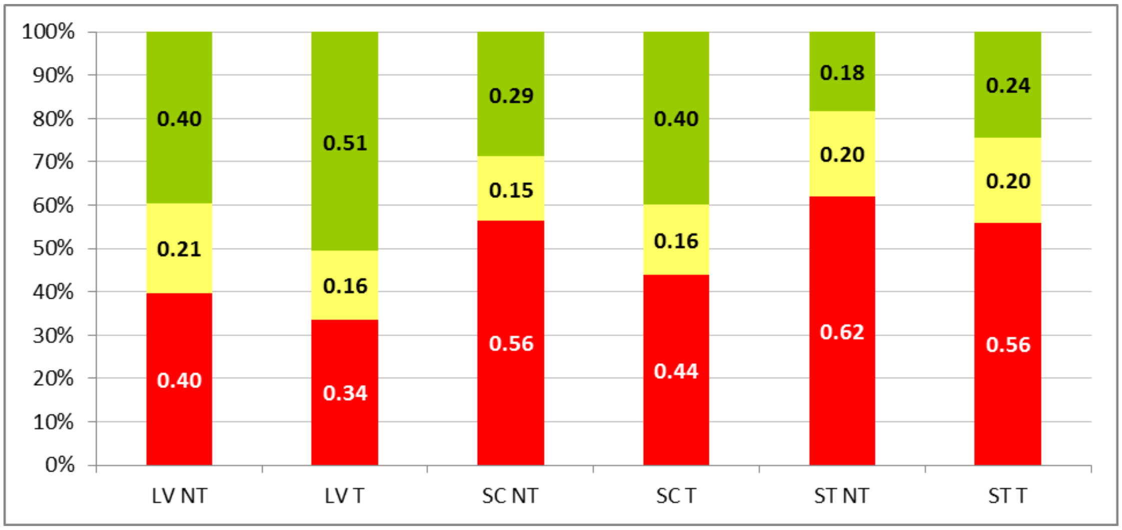


Figure 7 Analysis of Non-Insured Net-Incomes from the Lower Valley, South Central, and South Texas Districts for Probabilities Less than $0 and Greater than $25,000

LV = Lower Valley, SC = South Central, ST = South Texas

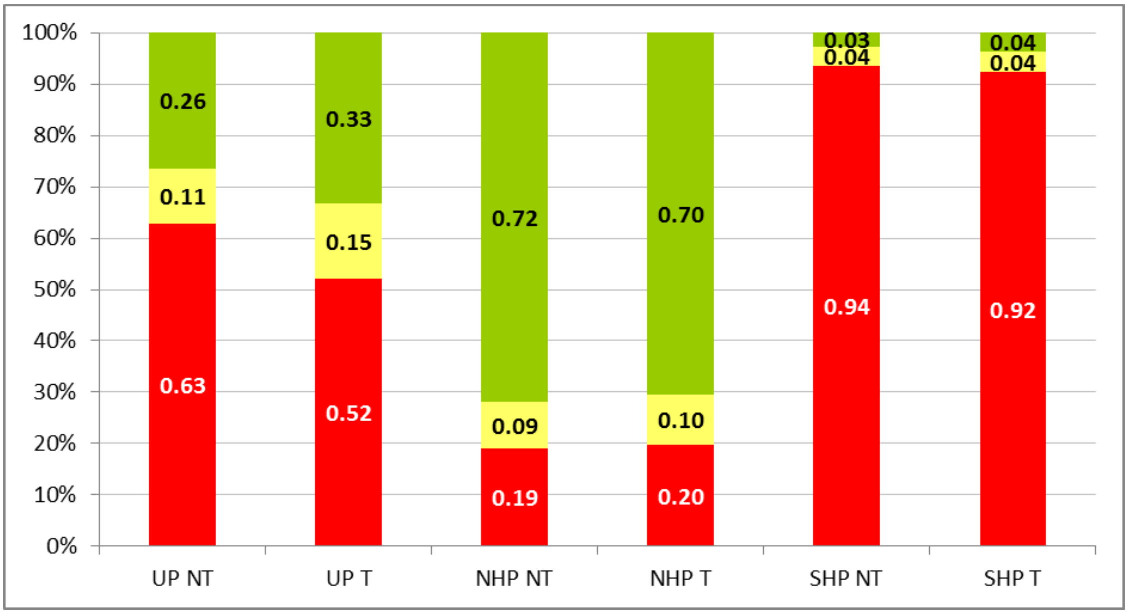


Figure 8 Stoplight Analysis of Non-Insured Net-Incomes from the Upper Coast, Northern High Plains, and Southern High Plains Districts for Probabilities Less than $0 and Greater than $25,000
UP = Upper Coast, NHP = Northern High Plains, SHP = Southern High Plains

The results of the StopLight Analysis show seven of the nine districts have a greater probability of having a positive net income and exceeding $25,000 under the treated scenarios (Figures 6, 7, 8). The Blacklands non-insured scenarios are used as an example. The Blacklands non-insured not treated scenario has a 14% favorable probability of net income exceeding $25,000, a 16% cautionary probability of net income between $0 and $25,000, and a 70% probability of failing to reach $0 (Figure 6). The non-insured treated scenario has 28% probability of net income exceeding $25,000, a 14% cautionary probability, and a 58% probability of net income failing to exceed $0 (Figure 6). The favorable probability of net income exceeding $25,000 is 14% higher for the treated scenario, and the probability of net income failing to exceed $0 is 22%

lower for the treated scenario. It can be concluded that for the Blacklands, the non-insured treated scenario is preferred over the non-insured not treated scenario.

The Blacklands, Coastal Bend, Edwards Plateau, Lower Valley, South Central, South Texas, and Upper Coast have a greater probability of having a net income, for all 500 acres, greater than $0 and exceeding $25,000 under treatment scenarios than non-treated scenarios (Figures 6, 7, 8). The Northern High Plains has a slightly greater probability of having net income greater than $0 and exceeding $25,000 under the non-treated scenario than the treated scenario due to the low probability of aflatoxin contamination in the Northern High Plains (Figure 8). The Southern High Plains is indifferent between non-treated and treated scenarios (Figure 8). This analysis was only for non-insured options for non-treated and treated scenarios. An additional analysis was performed to analyze net income of crop insurance options.

The net income results that included crop insurance coverages were compared within their respective coverage groups first. Treated YP coverage levels were compared to each other, treated RP coverage levels were compared to each other, and treated RPHE coverage levels were compared to each other. The same method was used for non-treated options. Within each district, all 98 scenarios were ranked using SDRF. Within each comparison, the top ranked options from the SDRF were ranked by SERF. In other words, the top treated YP, treated RP, treated RPHE, non-treated YP, non-treated RP, and non-treated RPHE and both non-insured treated and non-insured not treated were ranked by SERF. The upper RAC for both SDRF and SERF was calculated as four divided by 75% of market place value for 500 acres of farmland in the respective district. Farmland value was obtained from by from Texas Rural Land Value Trends (2013).

Figure 9 shows the StopLight analysis, of all 500 acres, for the eight best scenarios of the Blacklands district, which include BNINT, BENY75, BENR75, BENRH75, BNIT, BETY70, BETR75, and BETRH75. Every crop insurance and non-insured treated scenario (BNIT, BETY70, BETR75, and BETRH75) had a greater probability of net income exceeding $25,000 than the not treated scenario with the same coverage option (BNINT, BENY75, BENR75, BENRH75) (Figure 9). Figure 10 shows the SERF rankings of risky options for the Blacklands. The scenarios ranked by SERF for the Blacklands district are TYP 70%, TRP 75%, TRPHE 75%, NTYP 75%, NTRP 75%, and NTRPHE 75%. All of the coverage options are under an enterprise policy. Non-insured treated and non-treated were concluded for comparison purposes. The results suggest that all risk averse decision makers would prefer BETRH75 over the other scenarios, regardless of risk aversion level.

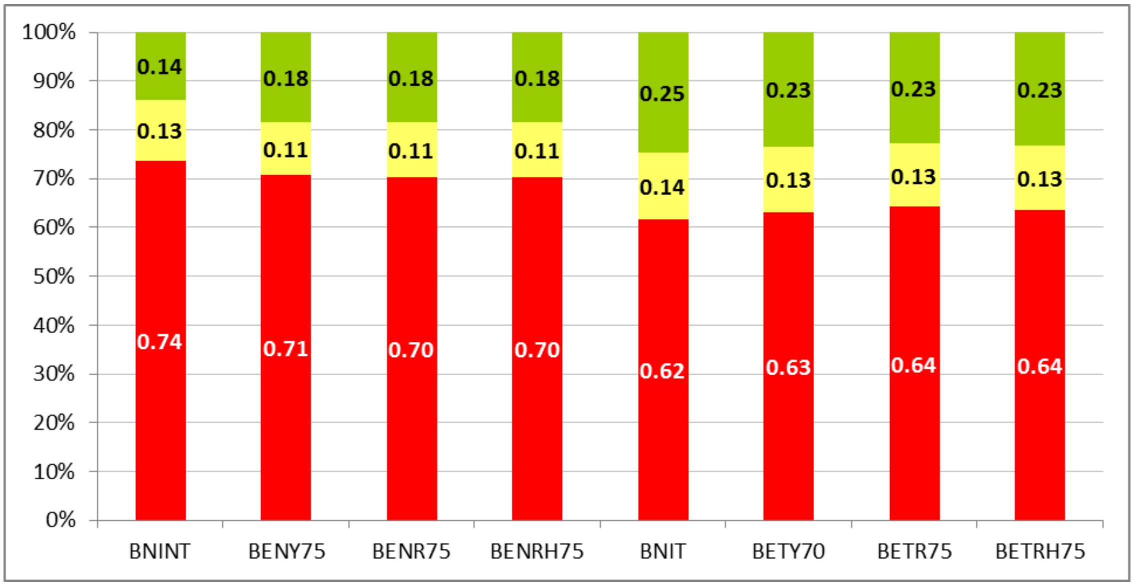


Figure 9 Stoplight Analysis of Net-Incomes for Blacklands for Probabilities Less than $0 and Greater than $25,000

BNINT = Blacklands non-insured not treated
BENY75 = Blacklands enterprise not treated yield protection 75%
BENR75 = Blacklands enterprise not treated revenue protection 75%
BENRH75 = Blacklands enterprise revenue protection with harvest price exclusion 75%
BNIT = Blacklands non-insured treated
BETY70 = Blacklands enterprise treated yield protection 70%
BETR75 = Blacklands enterprise revenue protection 75%
BETRH75 = Blacklands enterprise revenue protection with harvest exclusion 75%

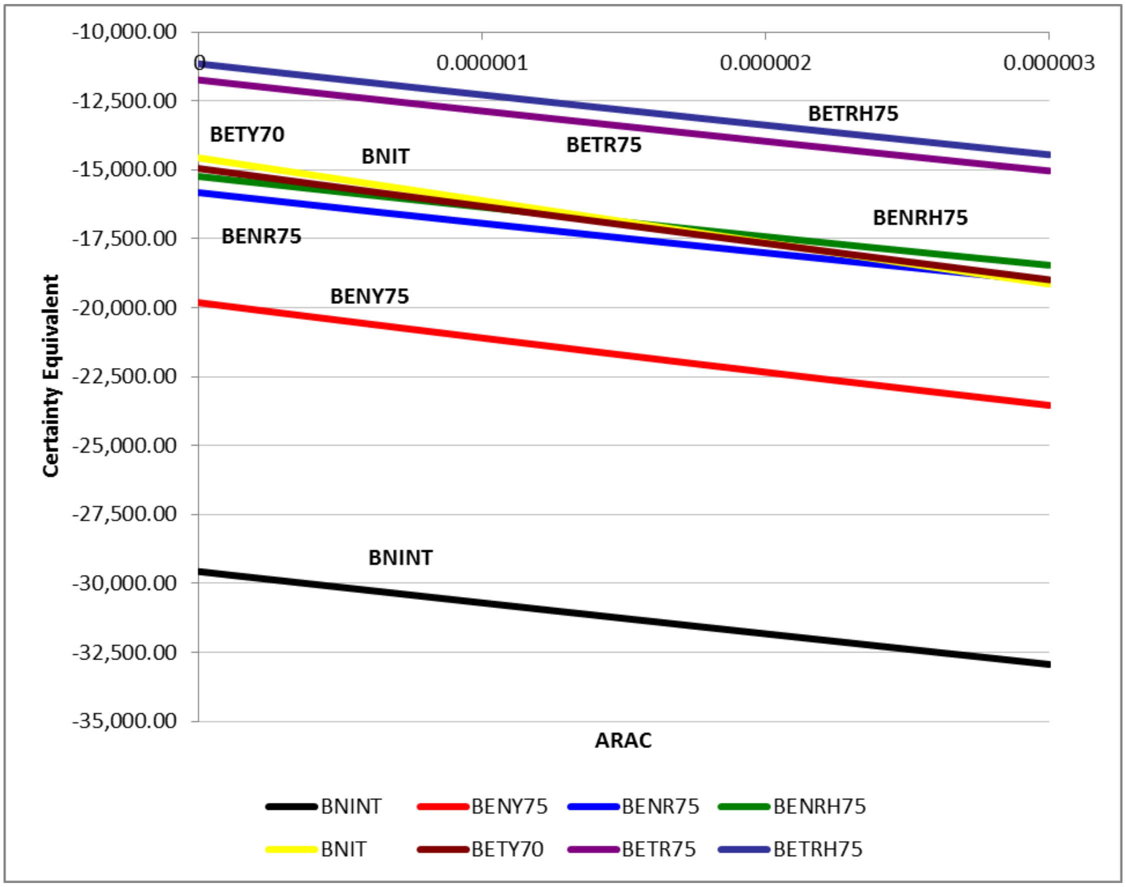


Figure 10 SERF Analysis of Net-Incomes for Blacklands

BNINT = Blacklands non-insured not treated
BENY75 = Blacklands enterprise not treated yield protection 75%
BENR75 = Blacklands enterprise not treated revenue protection 75%
BENRH75 = Blacklands enterprise revenue protection with harvest price exclusion 75%
BNIT = Blacklands non-insured treated
BETY70 = Blacklands enterprise treated yield protection 70%
BETR75 = Blacklands enterprise revenue protection 75%
BETRH75 = Blacklands enterprise revenue protection with harvest exclusion 75%

The top rated risky scenarios for the Coastal Bend district that were ranked first by SDRF and then by SERF include CBENRH80, CBENR85, CBENY80, CBNIN, CBETRH80, CBETR80, CBETY75, and CBNIT. Figure 11 shows the StopLight analysis of net incomes for the Coastal Bend, and Figure 12 shows the SERF analysis for the Coastal Bend district. The StopLight analysis in Figure 11 shows the treated scenarios (CBETRH80, CBETR80, CBETY75, and CBNIT) had a greater probability of having a positive net income and exceeding $25,000 (Figure 11). For example, the best-treated scenario CBETRH80 had a 7% greater probability of exceeding $0 than the best non-treated scenario CBENRH80. The top ranked treated scenarios (CBETRH80, CBETR80, CBETY75, and CBNIT) were approximately 4% higher than their top ranked non-treated counterparts (CBENRH80, CBENR85, CBENY80, CBNIN) (Figure 11). The SERF analysis in Figure 12 shows a slight preference for the treated RP and RHPE coverage options. Although the results show that growing corn in the Coastal Bend is not a profitable practice at current prices, using atoxigenics for aflatoxin control offers financial incentives. The results indicate that enterprise RPHE insurance option at 80% will return the highest net income (Figure 12). The least favorable scenario, according to Figure 12, is the non-insured, non-treated scenario.

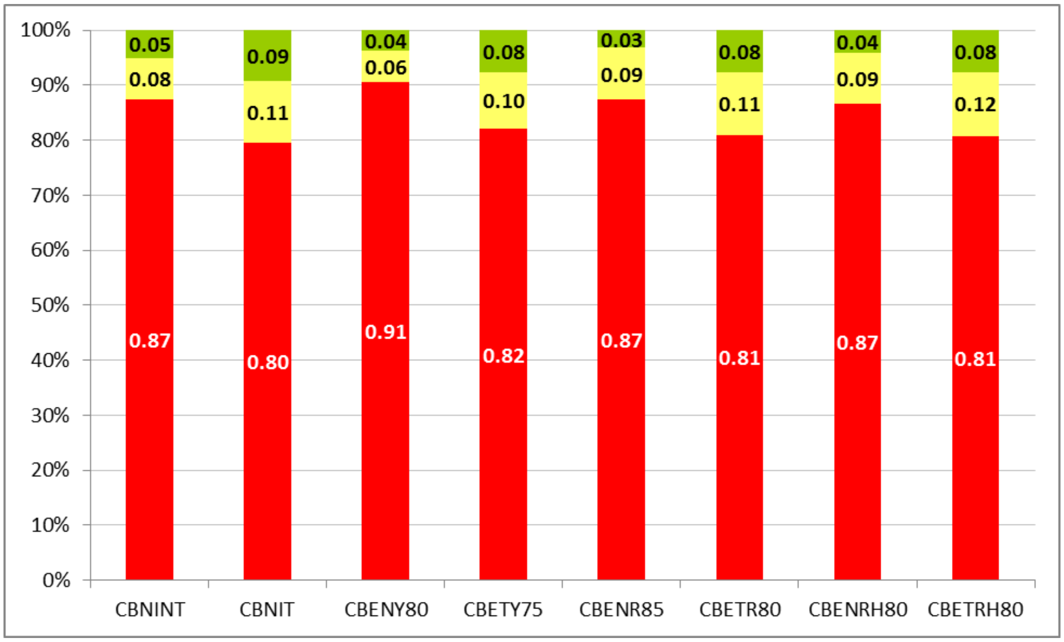


Figure 11 Stoplight Analysis for Net Incomes of Coastal Bend for Probabilities Less than $0 and Greater than $25,000

CBNINT = Coastal Bend non-insured not treated
CBNIT = Coastal Bend non-insured treated
CBENY80 = Coastal Bend enterprise non treated yield protection 80%
CBETY75 = Coastal Bend enterprise treated yield protection 75%
CBENR85 = Coastal Bend enterprise non treated revenue protection 85%
CBETR80 = Coastal Bend enterprise treated revenue protection 80%
CBENRH80 = Coastal Bend enterprise non treated revenue protection with harvest price exclusion 80%
CBETRH80 = Coastal Bend enterprise treated revenue protection with harvest price exclusion 80%

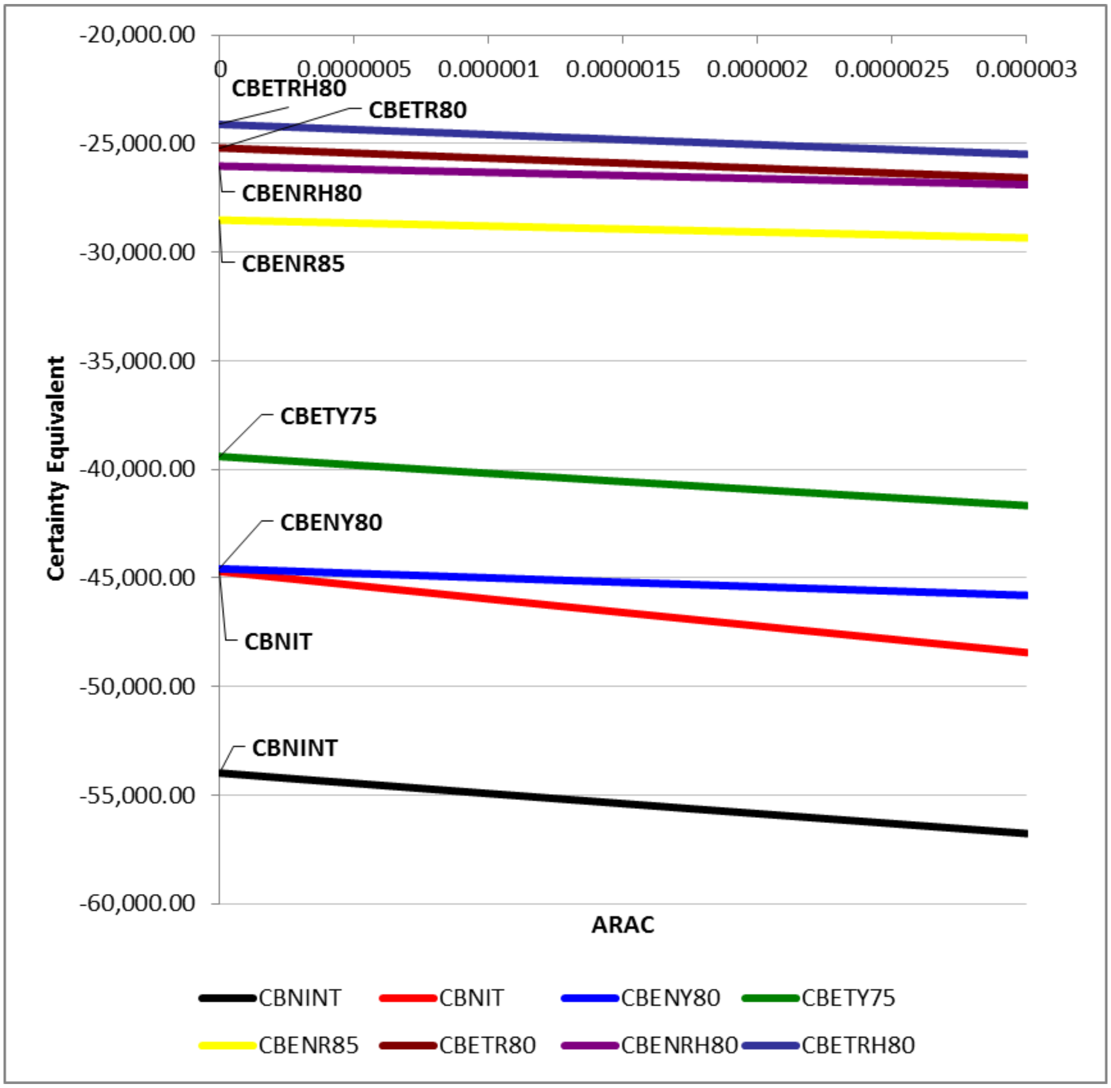


Figure 12 SERF Analysis of Net-Incomes for Coastal Bend

CBNINT = Coastal Bend non-insured not treated
CBNIT = Coastal Bend non-insured treated
CBENY80 = Coastal Bend enterprise non treated yield protection 80%
CBETY75 = Coastal Bend enterprise treated yield protection 75%
CBENR85 = Coastal Bend enterprise non treated revenue protection 85%
CBETR80 = Coastal Bend enterprise treated revenue protection 80%
CBENRH80 = Coastal Bend enterprise non treated revenue protection with harvest price exclusion 80%
CBETRH80 = Coastal Bend enterprise treated revenue protection with harvest price exclusion 80%

The top rated risky scenarios for the Edwards Plateau district that were ranked first by SDRF and then by SERF include EPNIN, EPENY75, EPENR85, EPENRH85, EPNIT, EPETY85, EPETR85, and EPETRH85. Figure 13 shows the StopLight analysis of net incomes for Edward Plateau, and Figure 14 shows the SERF analysis for the Edwards Plateau. The StopLight analysis in Figure 13 shows the treated scenarios (EPNIT, EPETY85, EPETR85, and EPETRH85) had a greater probability of having a positive net income and exceeding $100,000 (Figure 13). The treated non-insured scenario (EPNIT) had 5% higher probability of having a positive net income than the non-insured not treated scenario (EPNINT), the treated scenario also had a 14% greater probability of reaching or exceeding $100,000 than the non-treated scenario (Figure 13). The SERF analysis in Figure 14 shows a preference for the treated RP and RHPE options. The results indicate that using atoxigenics for aflatoxin control in corn is cost effective in the Edwards Plateau. The results indicate that enterprise RPHE insurance option at 85% is the most preferred. Similar to the previous region, the least favorable scenario is non-insured, non-treated (Figure 14).

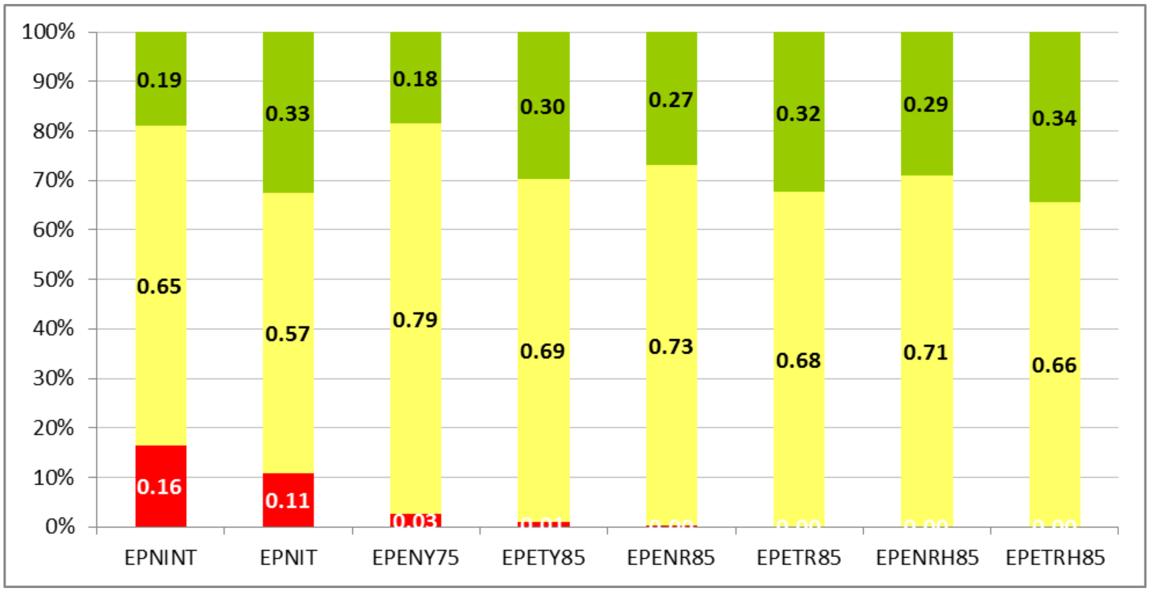


Figure 13 Stoplight Analysis for Net-Incomes of Edwards Plateau for Probabilities Less than $0 and Greater than $25,000

EPNINT = Edwards Plateau non-insured not treated
EPNIT = Edwards Plateau non-insured treated
EPENY75 = Edwards Plateau enterprise not treated yield protection 75%
EPETY85 = Edwards Plateau enterprise treated yield protection 85%
EPENR85 = Edwards Plateau enterprise not treated revenue protection 85%
EPETR85 = Edwards Plateau enterprise treated revenue protection 85%
EPENRH85 = Edwards Plateau enterprise not treated revenue protection with harvest price exclusion 85%
EPETRH85 = Edwards Plateau enterprise treated revenue protection with harvest price exclusion 85%

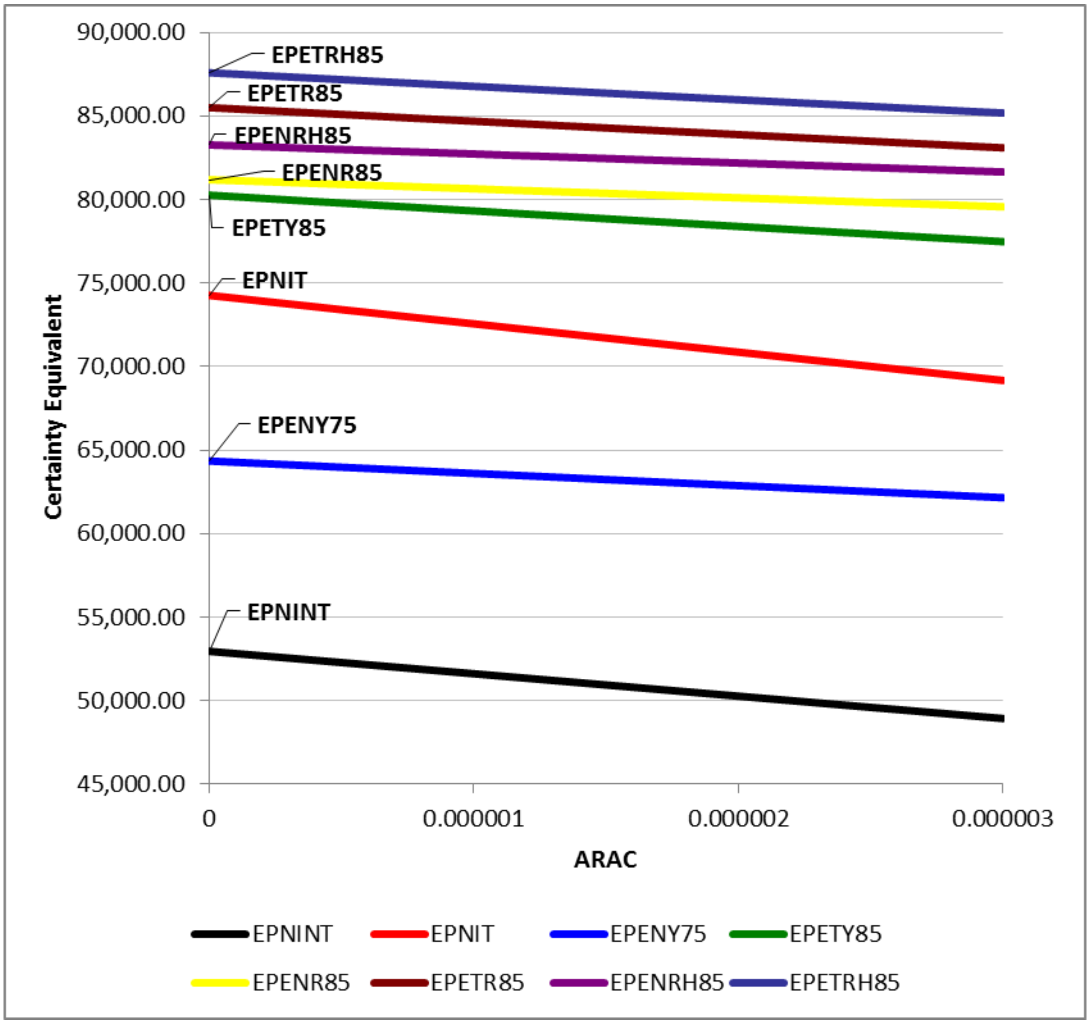


Figure 14 SERF Analysis of Net Incomes for the Edwards Plateau

EPNINT = Edwards Plateau non-insured not treated
EPNIT = Edwards Plateau non-insured treated
EPENY75 = Edwards Plateau enterprise not treated yield protection 75%
EPETY85 = Edwards Plateau enterprise treated yield protection 85%
EPENR85 = Edwards Plateau enterprise not treated revenue protection 85%
EPETR85 = Edwards Plateau enterprise treated revenue protection 85%
EPENRH85 = Edwards Plateau enterprise not treated revenue protection with harvest price exclusion 85%
EPETRH85 = Edwards Plateau enterprise treated revenue protection with harvest price exclusion 85%

The top rated risky scenarios for the Lower Valley that were ranked first by SDRF and then by SERF include LVNIN, LVENY70, LVENR75, LVENRH75, LVNIT, LVETY70, LVETR75, and LVETRH75. Figure 15 shows the StopLight analysis of net incomes for the Lower Valley district, and Figure 16 shows the SERF analysis for the Lower Valley. The StopLight analysis in Figure 15 shows the treated scenarios (LVNIT, LVETY70, LVETR75, and LVETRH75) had a greater probability of having a positive net income and exceeding $50,000. The treated non-insured scenario (LVNIT) had a 7% higher probability of having a positive net income than the non-insured, not treated scenario (LVNINT), the treated scenario also had an 11% greater probability of reaching or exceeding $50,000 than the non-treated scenario (Figure 15). The SERF analysis in Figure 16 shows a preference to the treated RP and RHPE coverage options. The results indicate that using atoxigenics for aflatoxin control in corn is cost effective in the Lower Valley district. The results indicate that the enterprise RPHE insurance option at 75% (LVETRH75) is preferred by all risk averse decision makers. Similar to the previous region, the least favorable scenario is non-insured, non-treated (Figure 16). If the producer decided not to treat or treatments were unavailable, using revenue protection with harvest price exclusion would be the best scenario.

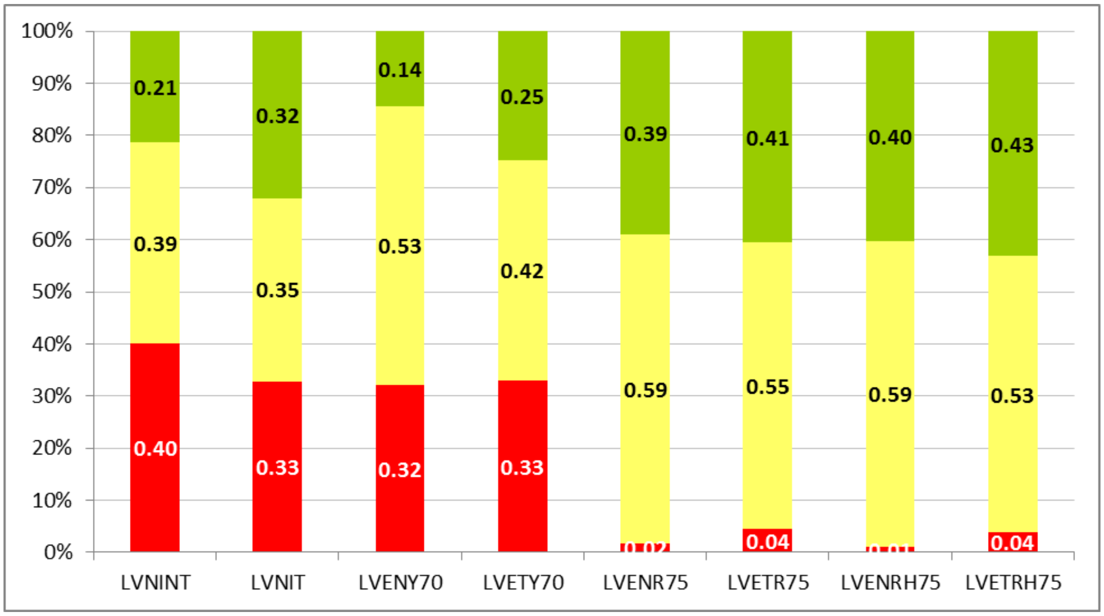


Figure 15 Stoplight Analysis of Net-Incomes for the Lower Valley for Probabilities Less than $0 and Greater than $25,000

LVNINT = Lower Valley non-insured not treated
LVNIT = Lower Valley non-insured treated
LVENY70 = Lower Valley enterprise not treated yield protection 70%
LVETY70 = Lower Valley enterprise treated yield protection 70%
LVENR75 =Lower Valley enterprise not treated revenue protection 75%
LVETR75 = Lower Valley enterprise treated revenue protection 75%
LVENRH75 = Lower Valley enterprise not treated revenue protection with harvest price exclusion 75%
LVETRH75 = Lower Valley enterprise treated revenue protection with harvest price exclusion 75%

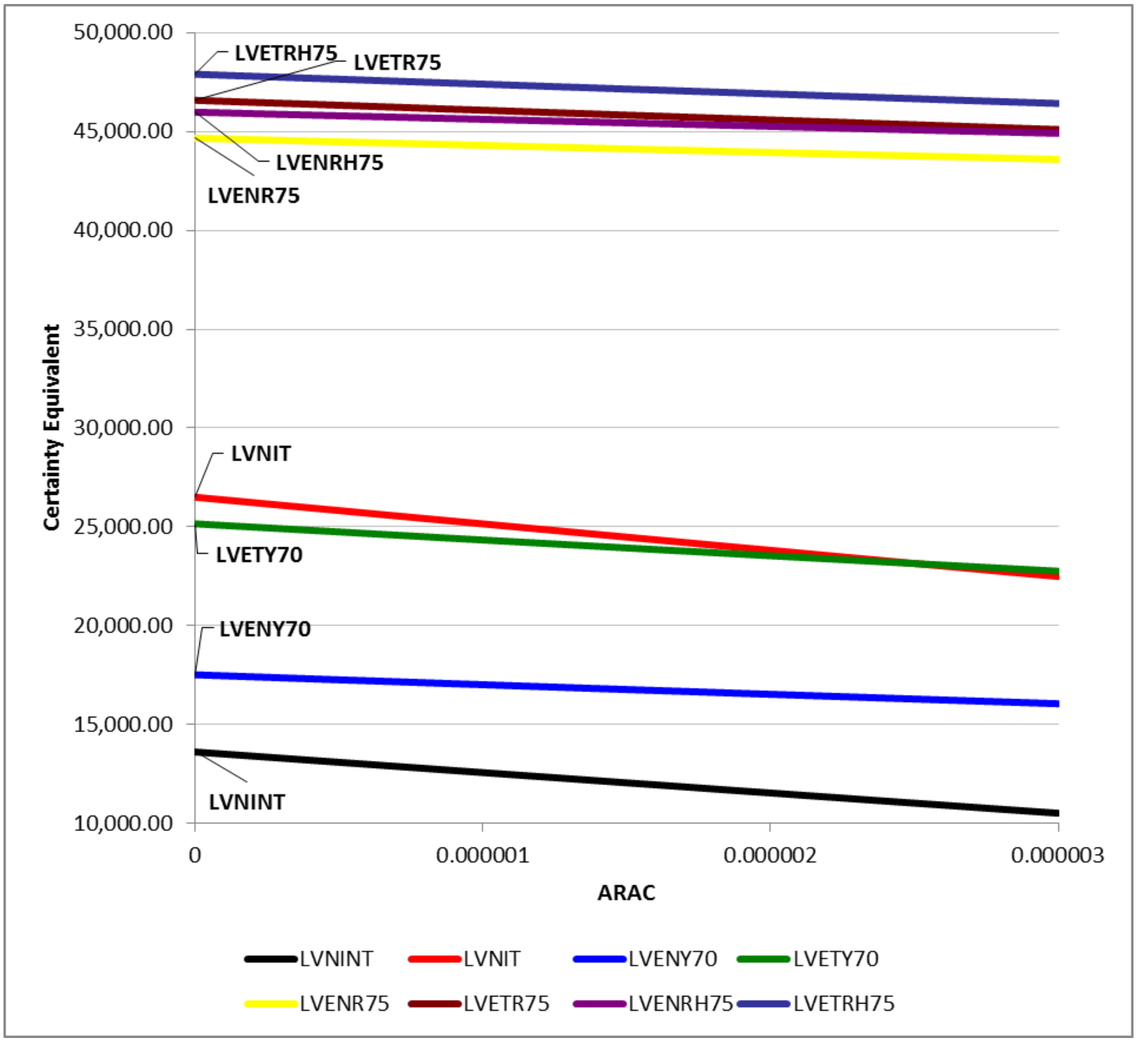


Figure 16 SERF Analysis for Net-Incomes for the Lower Valley
LVNINT = Lower Valley non-insured not treated
LVNIT = Lower Valley non-insured treated
LVENY70 = Lower Valley enterprise not treated yield protection 70%
LVETY70 = Lower Valley enterprise treated yield protection 70%
LVENR75 =Lower Valley enterprise not treated revenue protection 75%
LVETR75 = Lower Valley enterprise treated revenue protection 75%
LVENRH75 = Lower Valley enterprise not treated revenue protection with harvest price exclusion 75%
LVETRH75 = Lower Valley enterprise treated revenue protection with harvest price exclusion 75%

The top rated risky scenarios for the South Central district that were ranked first by SDRF and then by SERF include SCENIN, SCENIT, SCENY75, SCETY70, SCENR80, SCETR80, SCENRH80, and SCETRH80. Figure 17 shows the StopLight analysis of net incomes for the South Central, and Figure 18 shows the SERF analysis. The StopLight analysis in Figure 17 shows the treated scenarios (SCNIT, SCETR80, SCENRH80, and SCETRH80) had a greater probability of having a positive net income and exceeding $25,000. The treated non-insured scenario (SCNIT) had 13% greater probability of having a positive net income than the non-insured not treated scenario (SCENIN), the treated scenario also had a 12% higher probability of exceeding $25,000 than the non-treated scenario (Figure 17). The SERF analysis in Figure 18 shows a preference to the treated RP and RHPE coverage options. The results indicate that using atoxigenics for aflatoxin control in corn is cost effective in the South Central district. The results indicate that enterprise RPHE insurance option at 80% (SCETRH80) was the most preferred scenario. Similar to other regions, the least favorable scenario is non-insured, non-treated (Figure 18). A risk neutral producer would view the non-treated yield protection scenario as equally or close to as unfavorable as non-insured untreated, however as the producer becomes more risk averse, the non-insured untreated scenario is the least favorable.

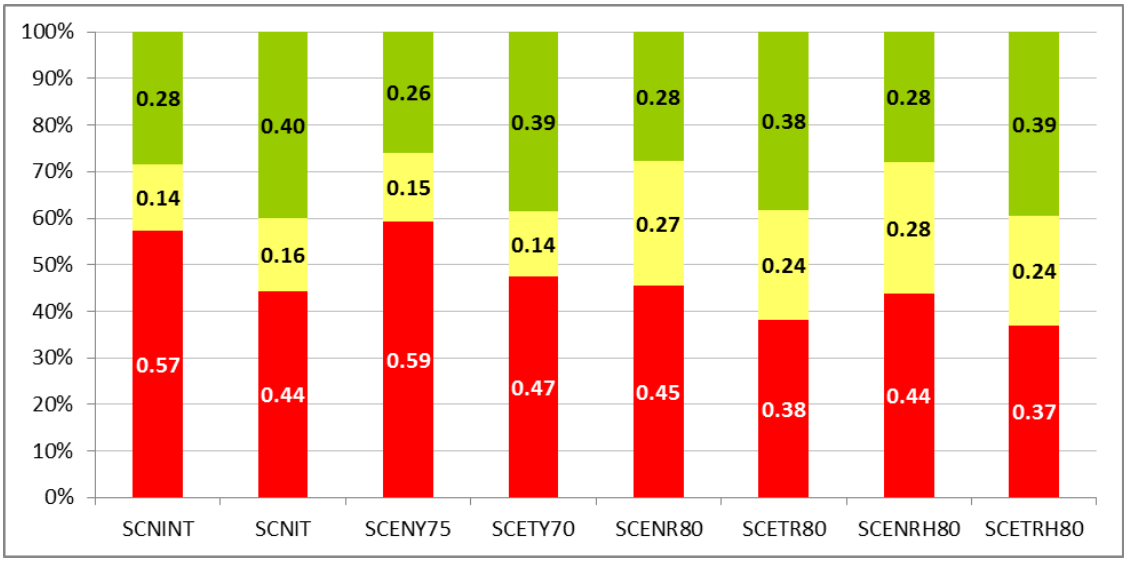


Figure 17 Stoplight Analysis of Net-Incomes for South Central for Probabilities Less than $0 and Greater than $25,000

SCNINT = South Central non-insured not treated
SCNIT = South Central non-insured treated
SCENY75 = South Central enterprise not treated yield protection 75%
SCETY70 = South Central enterprise treated yield protection 70%
SCENR80 = South Central enterprise not treated revenue protection 80%
SCETR80 = South Central enterprise treated revenue protection 80%
SCENRH80 = South Central enterprise not treated revenue protection with harvest price exclusion 80%
SCETRH80 = South Central enterprise treated revenue protection with harvest price exclusion 80%

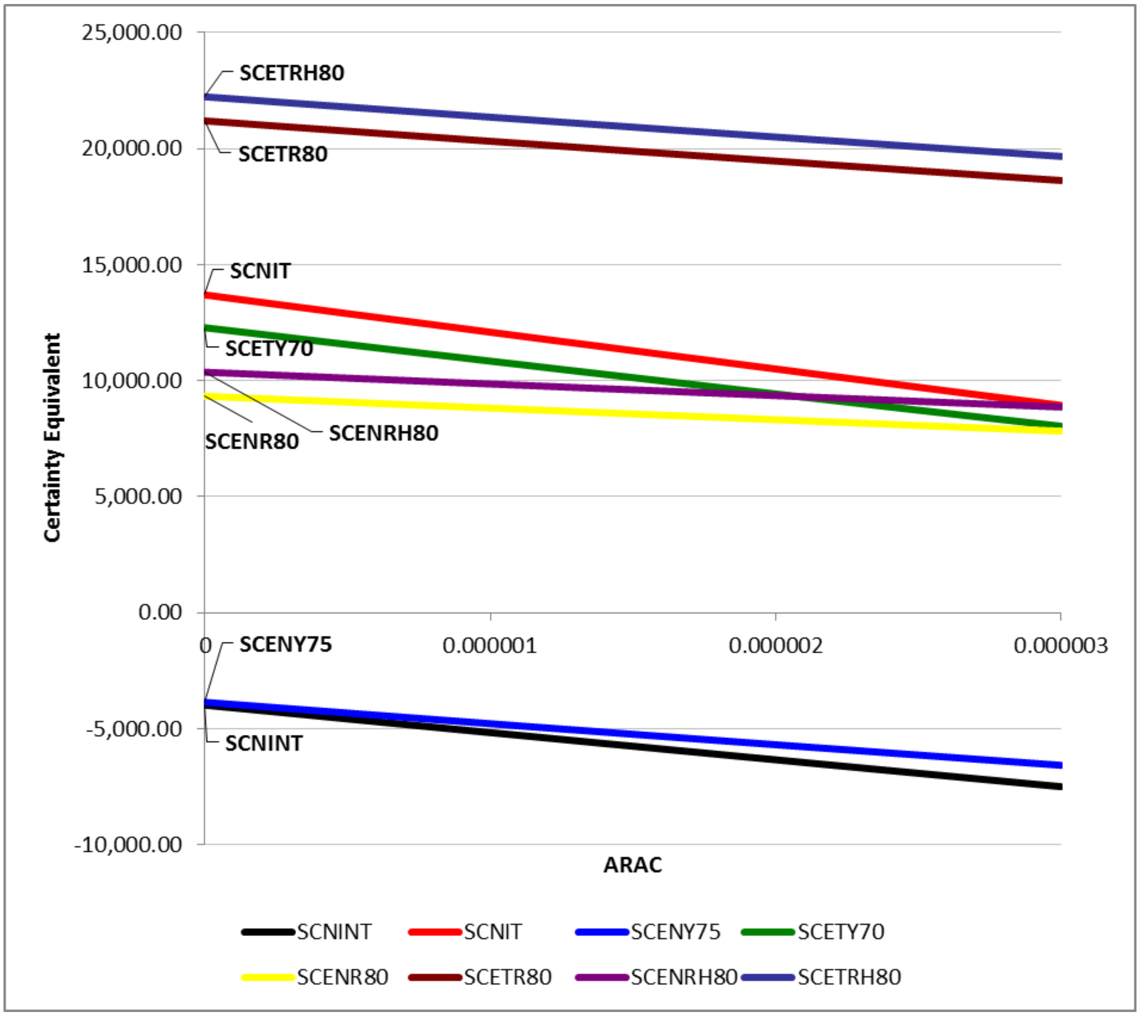


Figure 18 SERF Analysis for Net-Incomes for South Central

SCNINT = South Central non-insured not treated
SCNIT = South Central non-insured treated
SCENY75 = South Central enterprise not treated yield protection 75%
SCETY70 = South Central enterprise treated yield protection 70%
SCENR80 = South Central enterprise not treated revenue protection 80%
SCETR80 = South Central enterprise treated revenue protection 80%
SCENRH80 = South Central enterprise not treated revenue protection with harvest price exclusion 80%
SCETRH80 = South Central enterprise treated revenue protection with harvest price exclusion 80%

The top rated risky scenarios for South Texas that were ranked first by SDRF and then by SERF include STNIN, STNIT, STENY75, STETY75, STENR85, STETR80, STENRH85, and STETRH80. Figure 19 shows the StopLight analysis of net incomes for South Texas, and Figure 20 shows the SERF analysis for South Texas. The StopLight analysis in Figure 19 shows mixed results. Treated non-insured (STNIT) and treated YP (STETY75) both had greater probabilities of having a positive net income and a 5% higher probability of exceeding $25,000 than their non-treated counterparts (STNINT and STENY75). However, treated STETR80 and treated STETRH80 both have a lower probabilities of having a positive net income and have a 10% to 11% lower probability of exceeding $25,000 than their non-treated counterparts (STENR85 and STENRH85) (Figure 19). The SERF analysis in Figure 20 shows preference to the non-treated RPHE and non-treated RP scenarios. The certainty equivalent of STENTR85 and STENTR85 is approximately 8,000 higher than that of STETRH80 and STETR80, respectively. The most preferred scenario for the South Texas district is non-treated revenue protection with harvest price exclusion 85 % (STENRH85). Using atoxigenics in the South Texas district is not as cost effective as not treating and purchasing either RP or RPHE crop insurance.

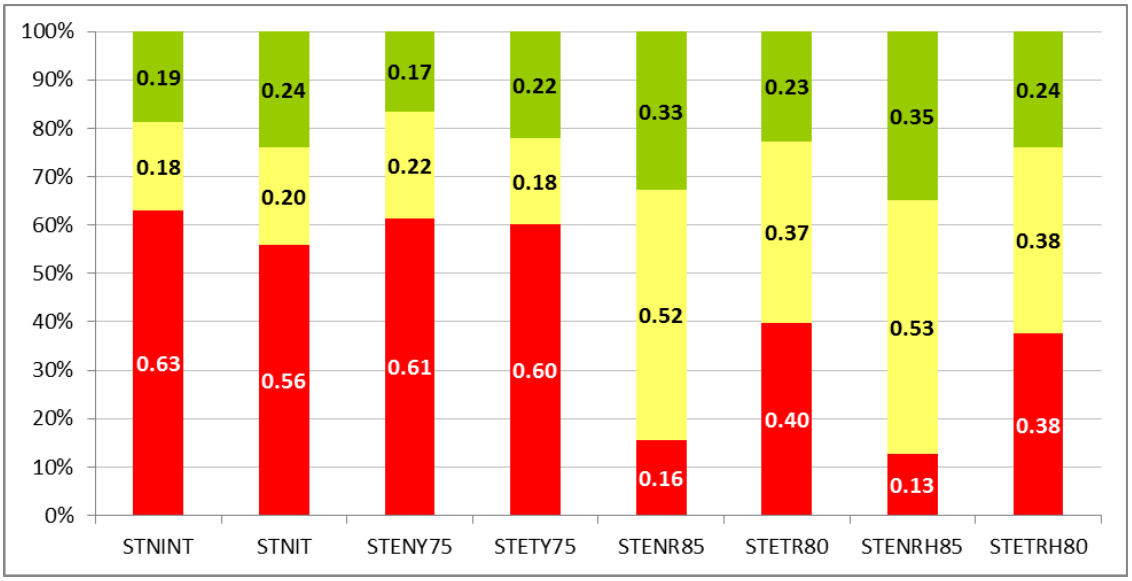


Figure 19 Stoplight Analysis of Net-Incomes for South Texas for Probabilities Less than $0 and Greater than $25,000

STNINT = South Texas non-insured not treated
STNIT = South Texas non-insured treated
STENY75 = South Texas enterprise not treated yield protection 75%
STETY75 = South Texas enterprise treated yield protection 75%
STENR85 = South Texas enterprise not treated revenue protection 85%
STETR80 = South Texas enterprise treated revenue protection 80%
STENRH85 = South Texas enterprise not treated revenue protection with harvest price exclusion 85%
STETRH80 = South Texas enterprise treated revenue protection with harvest price exclusion 80%

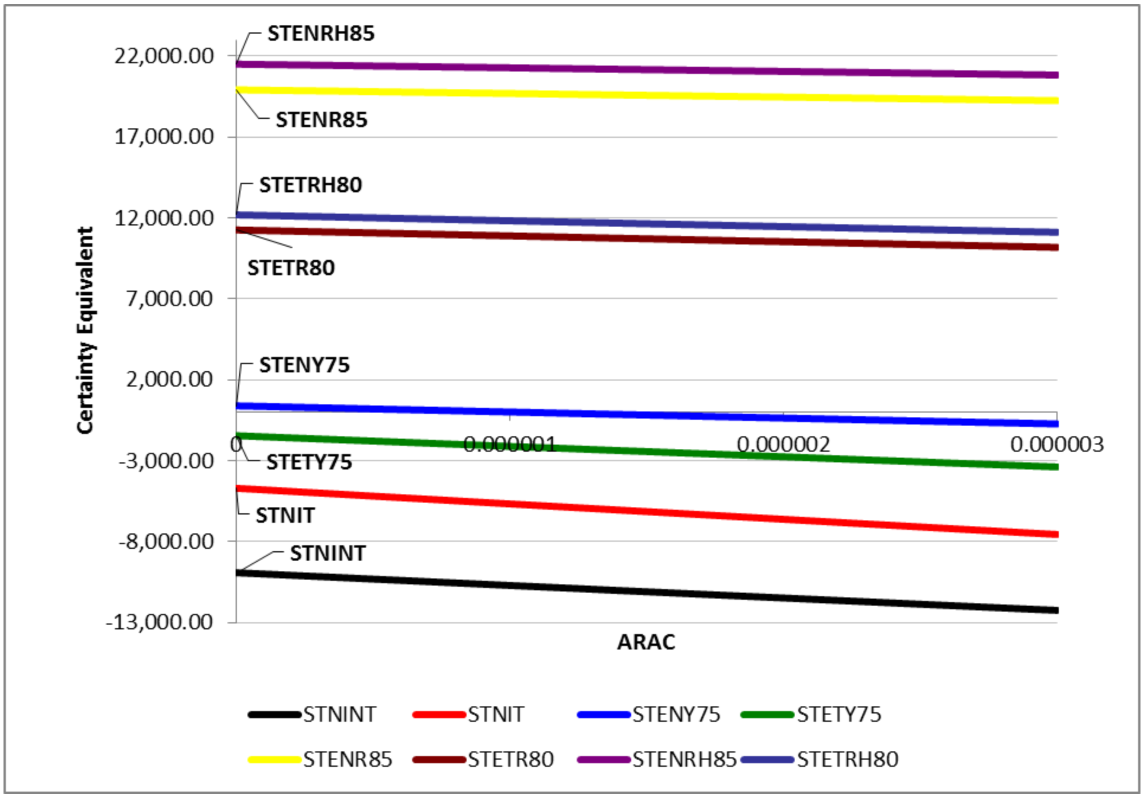


Figure 20 SERF Analysis for Net-Incomes for South Texas

STNINT = South Texas non-insured not treated
STNIT = South Texas non-insured treated
STENY75 = South Texas enterprise not treated yield protection 75%
STETY75 = South Texas enterprise treated yield protection 75%
STENR85 = South Texas enterprise not treated revenue protection 85%
STETR80 = South Texas enterprise treated revenue protection 80%
STENRH85 = South Texas enterprise not treated revenue protection with harvest price exclusion 85%
STETRH80 = South Texas enterprise treated revenue protection with harvest price exclusion 80%

The top rated risky scenarios for the Upper Coast that were ranked first by SDRF and then by SERF include UCNINT, UCENY75, UCENR80, UCENRH80, UCNIT, UCETY70, UCETR75, and UCETRH75. Figure 21 shows the StopLight analysis of net incomes for the Upper Coast, and Figure 22 shows the SERF analysis for the Upper Coast. The StopLight analysis in Figure 21 shows the treated scenarios (UCNIT, UCETY70, UCETR75, and UCETRH75) had a greater probability of having a positive net income and exceeding $25,000. The top ranked treated scenarios (UCNIT, UCETY70, UCETR75, and UCETRH75) had a 4% to 10% higher probability of exceeding $25,000 than their top ranked non-treated counterparts (UPENINT, UPENY75, UPENR80, UPENRH80, UPNIT) (Figure 21). The SERF analysis in Figure 22 shows a preference to the treated RP and RHPE coverage options. In the Upper Coast district, using atoxigenics for aflatoxin control is cost effective. The results indicate that enterprise RPHE insurance option at 75% (UCETRH75) was the most preferred scenario.

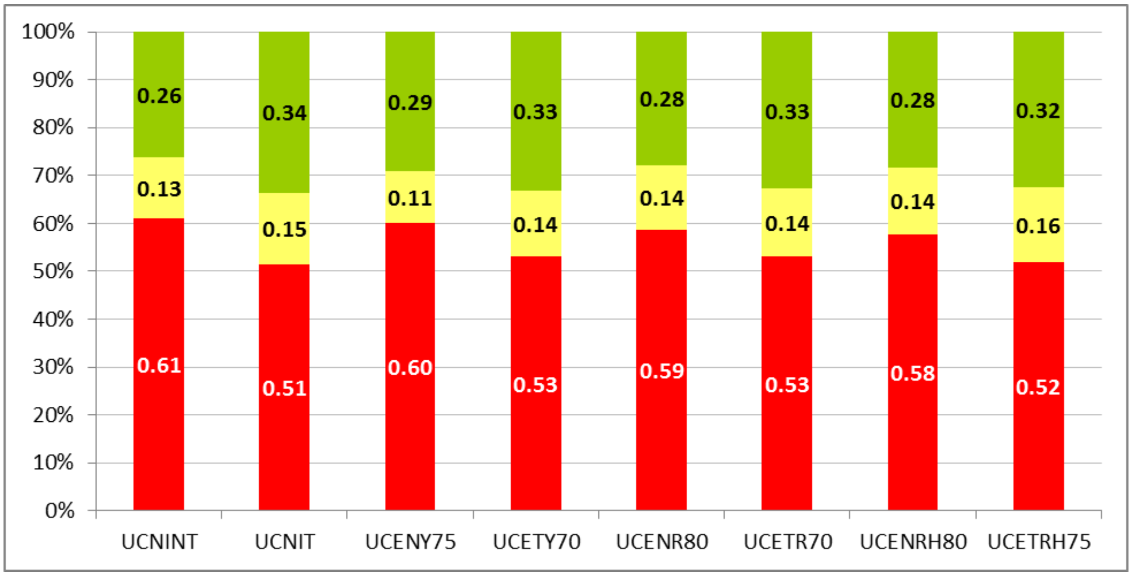


Figure 21 Stoplight Analysis of Net-Incomes for the Upper Coast for Probabilities Less than $0 and Greater than $25,000

UCNINT = Upper Coast non-insured not treated
UCNIT = Upper Coast non-insured treated
UCENY75 = Upper Coast enterprise not treated yield protection 75%
UCETY70 = Upper Coast enterprise treated yield protection 70%
UCENR80 = Upper Coast enterprise not treated revenue protection 80%
UCETR70 = Upper Coast enterprise treated revenue protection 70%
UCENRH80 = Upper Coast enterprise not treated revenue protection with harvest price exclusion 80%
UCETRH75 = Upper Coast enterprise treated revenue protection with harvest price exclusion 75%

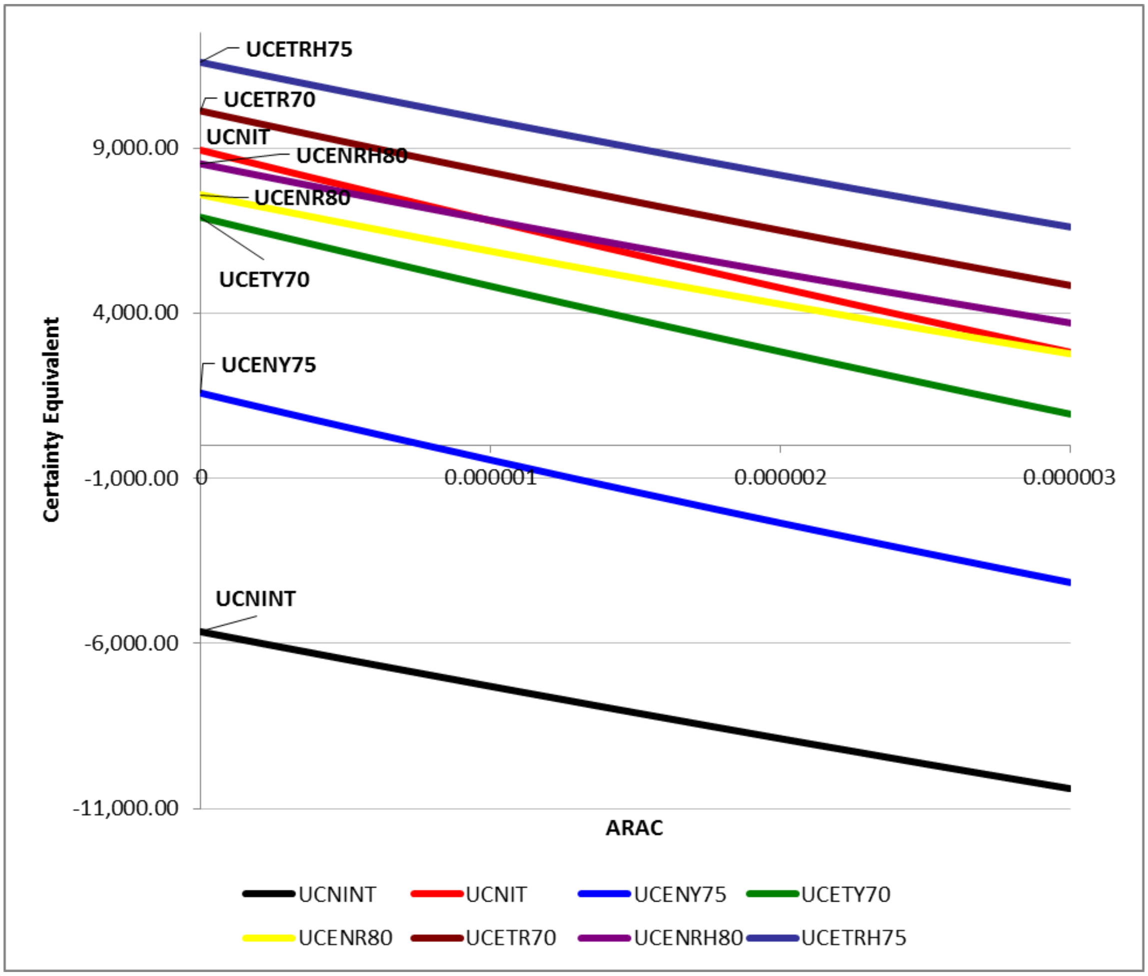


Figure 22 SERF Analysis for Net-Incomes for the Upper Coast

UCNINT = Upper Coast non-insured not treated
UCNIT = Upper Coast non-insured treated
UCENY75 = Upper Coast enterprise not treated yield protection 75%
UCETY70 = Upper Coast enterprise treated yield protection 70%
UCENR80 = Upper Coast enterprise not treated revenue protection 80%
UCETR70 = Upper Coast enterprise treated revenue protection 70%
UCENRH80 = Upper Coast enterprise not treated revenue protection with harvest price exclusion 80%
UCETRH75 = Upper Coast enterprise treated revenue protection with harvest price exclusion 75%

The top rated risky scenarios for the Northern High Plains that were ranked first by SDRF and then by SERF include NHPNIN, NHPENY85, NHPETY85, NHPENR85, NHPETR85, NHPENRH85, NHPETRH85, and NHPNIT. Figure 23 shows the StopLight analysis of net incomes for the Northern High Plains, and Figure 24 shows the

SERF analysis for the Northern High Plains. The StopLight analysis in Figure 23 shows that non-treated crop insurance scenarios (NHPNIN, NHPENY85, NHPETY85, NHPENR85) have a 5% to 6% higher probability of having a positive net income and had a 15% to 22% higher probability of net income exceeding $100,000 than their treated counterparts (NHPETR85, NHPENRH85, NHPETRH85, and NHPNIT). The not treated, non-insured scenario (NHPNIN) had a 1% higher probability on both ends than the non-insured, treated scenario (NHPNIT) (Figure 23). The SERF analysis in Figure 24 shows preference to non-treated RP (NHPENR85) and non-treated RPHE (NHPENRH85) scenarios. Due to a lack of aflatoxin contamination in the Northern High Plains, the use of atoxigenics for aflatoxin control is not cost effective. The reduction of aflatoxin results in fewer and less severe RIVs. The less frequent and lower RIVs translate to increased market revenue for treated fields. The Northern High Plains do not have enough aflatoxin to validate the use of atoxigenics.

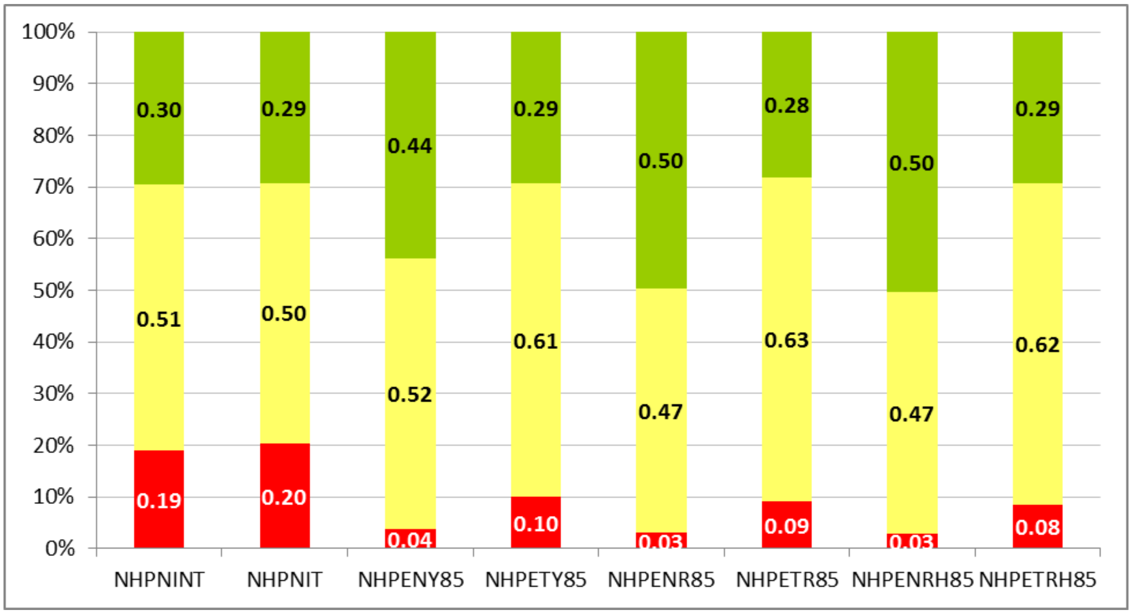


Figure 23 Stoplight Analysis of Net-Incomes for the Northern High Plains for Probabilities Less than $0 and Greater than $25,000

NHPNINT = Northern High Plains non-insured not treated
NHPNIT = Northern High Plains non-insured treated
NHPENY85 = Northern High Plains enterprise not treated yield protection 85%
NHPETY85 = Northern High Plains enterprise treated yield protection 85%
NHPENR85 = Northern High Plains enterprise not treated revenue protection 85%
NHPETR85 = Northern High Plains enterprise treated revenue protection 85%
NHPENRH85 = Northern High Plains enterprise not treated revenue protection with harvest price exclusion 85%
NHPETRH85 = Northern High Plains enterprise treated revenue protection with harvest price exclusion 85%

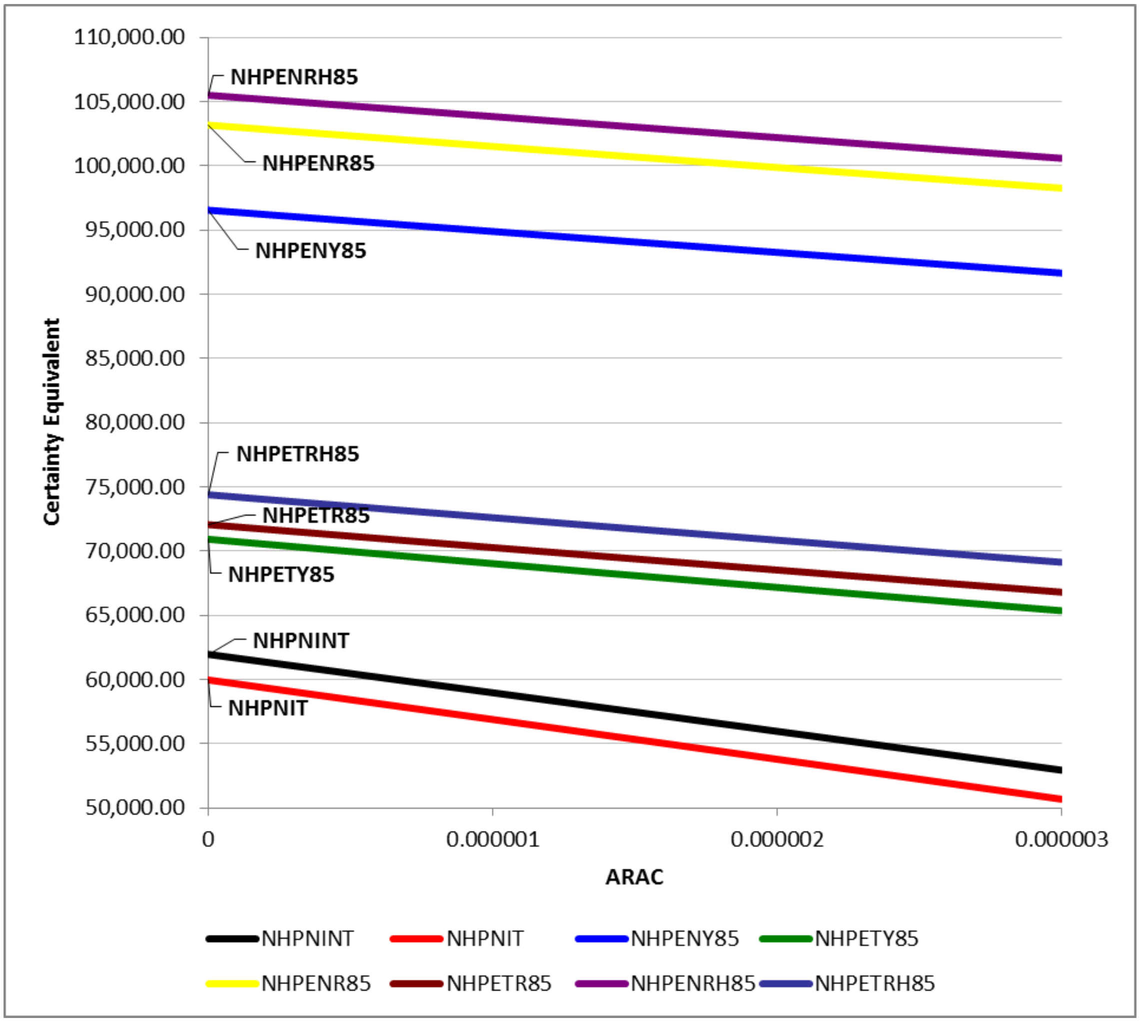


Figure 24 SERF Analysis for Net-Incomes for the Northern High Plains

NHPNINT = Northern High Plains non-insured not treated
NHPNIT = Northern High Plains non-insured treated
NHPENY85 = Northern High Plains enterprise not treated yield protection 85%
NHPETY85 = Northern High Plains enterprise treated yield protection 85%
NHPENR85 = Northern High Plains enterprise not treated revenue protection 85%
NHPETR85 = Northern High Plains enterprise treated revenue protection 85%
NHPENRH85 = Northern High Plains enterprise not treated revenue protection with harvest price exclusion 85%
NHPETRH85 = Northern High Plains enterprise treated revenue protection with harvest price exclusion 85%

The top rated risky scenarios for the Southern High Plains that were ranked first by SDRF and then by SERF include SHPNIN, SHPENY85, SHPETY85, SHPENR85, SHPETR85, SHPENRH85, SHPETRH85, and SHPNIT. Figure 25 shows the StopLight analysis of net incomes for the Southern High Plains, and Figure 26 shows the SERF analysis for the Southern High Plains. The StopLight analysis in Figure 25 shows that non-treated crop insurance scenarios (SHPENY85, SHPETY85, SHPENR85) had a 4% to 5% higher probability of having a positive net income and had a 1% to 2% higher probability of net income exceeding $25,000 than their treated counterparts (SHPETR85, SHPENRH85, SHPETRH85). The not treated, non-insured scenario (SHPNINT) has the same probability as the non-insured, treated scenario (SHPNIT) of net income exceeding $25,000 (Figure 25). The SERF analysis in Figure 26 shows preference to non-treated RP (SHPENR85) and non-treated RPHE (SHPETRH85) scenarios. The analysis shows that producing corn in the Southern High Plains is very unprofitable at the current price and the use of atoxigenics is not cost effective in the Southern High Plains. Although the analysis shows producing corn in this region is not profitable, the scope of this study looks at the cost-effectiveness of applying atoxigenics.

Figure 25 Stoplight Analysis of Net-Incomes for the Southern High Plains for Probabilities Less than $0 and Greater than $25,000

SHPNINT = Southern High Plains non-insured not treated
SHPNIT = Southern High Plains non-insured treated
SHPENY85 = Southern High Plains enterprise not treated yield protection 85%
SHPETY85 = Southern High Plains enterprise treated yield protection 85%
SHPENR85 = Southern High Plains enterprise not treated revenue protection 85%
SHPETR85 = Southern High Plains enterprise treated revenue protection 85%
SHPENRH85 = Southern High Plains enterprise not treated revenue protection with harvest price exclusion 85%
SHPETRH85 = Southern High Plains enterprise treated revenue protection with harvest price exclusion 85%

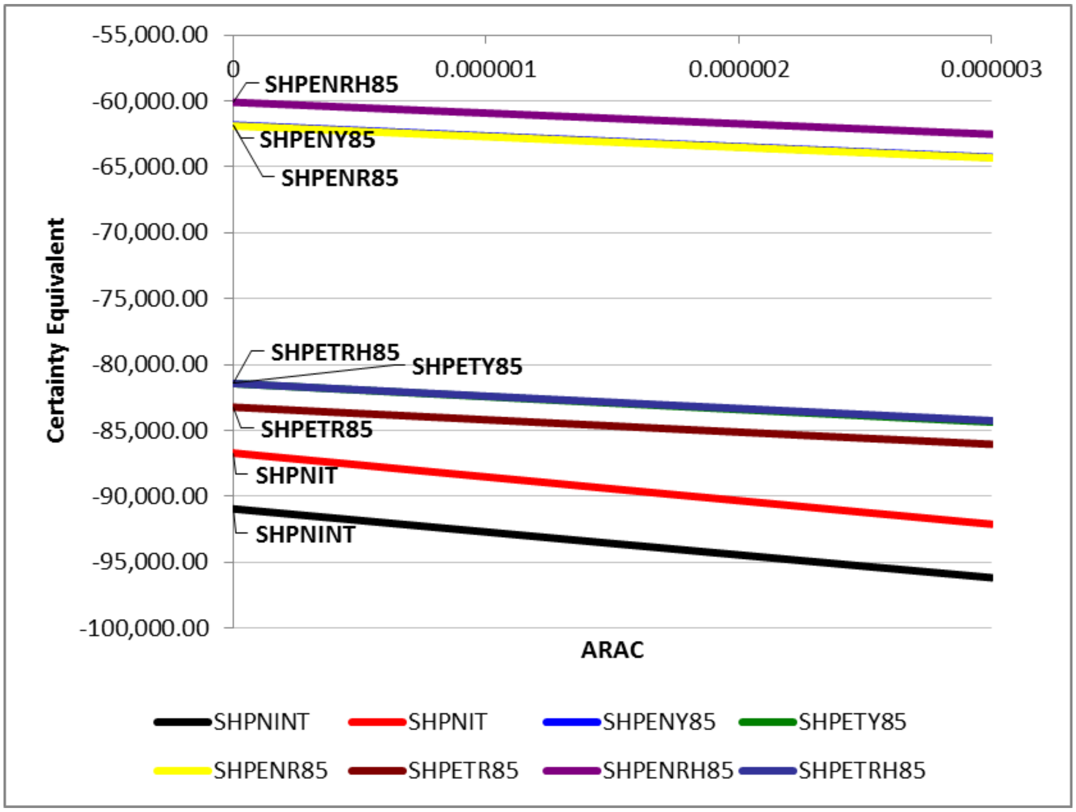


Figure 26 SERF Analysis for Net-Incomes for the Southern High Plains

SHPNINT = Southern High Plains non-insured not treated
SHPNIT = Southern High Plains non-insured treated
SHPENY85 = Southern High Plains enterprise not treated yield protection 85%
SHPETY85 = Southern High Plains enterprise treated yield protection 85%
SHPENR85 = Southern High Plains enterprise not treated revenue protection 85%
SHPETR85 = Southern High Plains enterprise treated revenue protection 85%
SHPENRH85 = Southern High Plains enterprise not treated revenue protection with harvest price exclusion 85%
SHPETRH85 = Southern High Plains enterprise treated revenue protection with harvest price exclusion 85%

6.5 Summary of Results

Ignoring crop insurance, the results show seven of the nine agricultural districts realized financial benefits for using atoxigenics for aflatoxin control. The Blacklands, Coastal Bend, Edwards Plateau, South Central, South Texas, Lower Valley, and Upper Coast districts had financial benefits of $10/acre to $40/acre when using atoxigenics for aflatoxin control. The Northern High Plains and Southern High Plains did not have financial benefits for using atoxigenics due to low probabilities of aflatoxin contamination. The Northern High Plains and Southern High Plains saw losses of $4.07 and $7.43, respectively, for treated scenarios.

The fact that crop insurance premiums are the same for non-treated and treated scenarios complicates the decision to use atoxigenics. Producers who treat pay the same premium, but receive lower indemnities than producers who do not treat. Net income simulations for crop insurance scenarios show producers in some districts have financial incentives to use atoxigenics while producers in other districts do not. The results show producers in the Blacklands, Coastal Bend, Edwards Plateau, Lower Valley, South Central, and Upper Coast districts have financial incentives to use atoxigenics for every insurance scenario, whether insured or not. Producers in the Northern High Plains and Southern High Plains have financial incentives not to use atoxigenics. All scenarios in the Northern High Plains and Southern High Plains, whether insured or not have higher net returns from not treating. The results of the South Texas district show the cost effectiveness of atoxigenics depends on the type of insurance coverage the producer chooses. In the South Texas district, there are financial incentives to use atoxigenics under YP coverage and non-insured scenarios. However, in the South Texas district, there are financial incentives not to use atoxigenics under RP and RPHE coverage options. The scenarios of treated non-insured, treated YP, not treated RP, and not treated RPHE return the highest net incomes in their respective categories. However, not treated RP and not treated RPHE are ranked best for all risk averse decision makers by the SERF ranking analysis. The most cost effective scenario for the South Texas district is not treating and having RPHE coverage.

7. SUMMARY AND CONCLUSIONS

Atoxigenics and crop insurance are tools producers can use to guard against losses from aflatoxin. There are several studies measuring the cost effectiveness of using atoxigenics for aflatoxin control in corn. This study expands a previous study on aflatoxin in Bell County to the rest of Texas. In addition to expanding the reach of the earlier study to the rest of the state, the current study used the One Sample Strategy for aflatoxin testing. The current study performs an economic analysis of using atoxigenics for aflatoxin control in Texas.

The study uses Simetar©, an Excel add-in, to simulate a risk based partial budget model combined with an aflatoxin contamination model. Stochastic net incomes are simulated to assist with the decision to use atoxigenics for aflatoxin control. SERF was used to estimate risk ranking for risk averse DMs, based on simulated net incomes for all crop insurance coverages available under non-treated and treated scenarios. Net incomes are simulated for nine agricultural districts in Texas. Field data for aflatoxin contamination is from Bell County, Texas. Isakiet, a plant pathologist at Texas A&M Agrilife Extension, rated the remaining district's aflatoxin contamination levels relative to Bell County. The aflatoxin probability distributions for the Blacklands were adjusted to reflect the relative mean and variance indicated by Isakeit's ranking of aflatoxin incidence. The current study should assist the farmers by considering the risk of aflatoxin contamination, contamination level, aflatoxin test inaccuracies, cost of atoxigenic, cost of insurance premiums, crop insurance indemnity payments, and stochastic local yields and market prices. The objective of this study is to perform an economic analysis on the decision to use atoxigenic treatments on corn crops for aflatoxin control, and to evaluate the economic outcome of different crop insurance levels for corn producers in Texas.

Ignore crop insurance results shows atoxigenics provide financial benefits for seven of the nine Texas agricultural districts in the study. The treated non-insured net incomes of the Blacklands, Coastal Bend, Edwards Plateau, Lower Valley, South Central, South Texas, and Upper Coast districts were \$10/acre to \$40/acre higher than the not treated, non-insured net incomes for the same districts. The Northern High Plains and Southern High Plains district's non-insured results show that it is not cost effective to use atoxigenics. The treated non-insured net incomes from the Northern High Plains and Southern High Plains were \$4.07 and \$7.43 lower, respectively, than the not treated, non-insured net incomes.

Crop insurance premiums for 2015, set by RMA, and simulated indemnity payments were incorporated into the model for all crop insurance options available to corn producers in their respective districts under non-treated and treated scenarios. The results showed using atoxigenics for aflatoxin control in corn was cost effective in six of the nine agricultural districts. Net incomes for treated scenarios for the Blacklands, Coastal Bend, Edwards Plateau, Lower Valley, South Central, and Upper Coast districts were higher than non-treated scenarios. The net incomes of treatment scenarios for Northern High Plains and Southern High Plains were lower than the net incomes of non-treated scenarios. The South Texas results were mixed. Net incomes for non-insured and YP coverage treated scenarios were higher than the net incomes for non-insured and

YP coverage non-treated scenarios. However, net incomes for non-treated RP and non-treated RPHE scenarios were higher than the net incomes for treated RP and RPHE scenarios. The most preferred scenario ranked by SERF for the South Texas district was non-treated RPHE coverage for all risk averse decision makers.

As of April 2014, 29 grain elevators in Texas use the One Sample Strategy for aflatoxin testing. The aflatoxin simulation in this study assumed one test for both the grain elevator and crop insurance purposes. Although this method of testing is becoming more common across grain elevators in Texas, elevators that do not participate with the One Sample Strategy could have different testing results than the crop insurance companies. For future studies in this area, one might factor in the producer rejecting the first grain elevator and driving to another elevator that does not use testing equipment required for the One Sample Method Strategy qualifications. The less efficient testing equipment typically results in a lower RIV (Park et al., 2007).

This study could also be applicable to other regions of the United States. Local prices and yields and aflatoxin information can be provided for other areas for an economic analysis. The most important factor that could be added to this study is the effect that yield reductions from aflatoxin contamination have on the decision to buy insurance over time as lower yields reduce farmers' approved production history (APH). This study simulated data for a one year analysis. An additional study that measures the reduction of yield over time due to losses from aflatoxin contamination could account for longer-term impacts on APH. For example, in 10 years the yield history of a farm that did not used atoxigenics could be a considerably lower than the yield history of a farm that did use atoxigenics. The lower yield history reduces the farm’s APH and thus the amount of indemnities the farm can potentially receive. This study showed that higher indemnities for non-treated fields are a critical factor when determining aflatoxin cost effectiveness.

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